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THE ELLENBURGER GROUP OF CENTRAL TEXAS

By

PRESTON E. CLOUD, JR.

and

VIRGIL E. BARNES

Bureau of Economic Geology

John T. Lonsdale, Director

Prepared in co-operation with the United States Geological Survey

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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THE ELLENBURGER GROUP OF CENTRAL TEXAS

PRESTON E. CLOUD, JR.,[1] AND VIRGIL E. BARNES[2]

PART I

GENERAL DISCUSSION

ABSTRACT

The incomplete sequence of Lower Ordovician carbonate rocks known as the Ellenburger group consists of the Tanyard, Gorman, and Honeycut formations, named in ascending order. It is essentially equivalent to the lower half of the Lower Ordovician of the Ozark uplift of Missouri and Arkansas. Outcropping Ellenburger rocks younger than the Jefferson City group of the Ozark uplift are unknown. The Ellenburger has its maximum development at the surface in the southeastern corner of the Llano uplift (1820 feet). It thins to only 830 feet in the northwestern corner, mainly by pre-Devonian truncation, but in part by westward thinning of the Tanyard formation. The rocks of the Ellenburger group are essentially nonglauconitic, and, at most places, are sparingly fossiliferous. Its limestones are dominantly sublithographic and very light gray, the purer ones commonly being in the upper part of the section. Its dolomites range from microgranular to coarse grained; the coarser grained, paler ones ordinarily being in the lower part of the section, with the finer grained, more brightly colored ones above. The carbonate rocks that overlie the Ellenburger are nondolomitic, typically dark in color, commonly granular, and are apt to contain organic remains in relative abundance. The limestones of the Upper Cambrian in central Texas are ordinarily granular, glauconitic, and darker in color than those of the Ellenburger; and the dolomites are apt to be darker in color and finer in grain than the immediately superjacent dolomites of the Ellenburger.

The basal third of the complete Ellenburger sequence constitutes the Tanyard formation, correlative with the Gasconade dolomite (including Van Buren formation) of Missouri. It averages 590 feet thick, thinning westward. The Threadgill member constitutes its lower part, with the Staendebach member above. The dolomites of the Threadgill member are medium to coarse grained, and the distribution of limestone and dolomite is irregular. Dolomite predominates, except in the western part of the region where the member is wholly limestone. The dolomites of the Staendebach member are dominantly fine to medium grained. The member is wholly dolomite at places in the western part of the Llano uplift; but, to the east, erratically occurring limestone is conspicuous and locally dominant. Chert is rare in the Threadgill member, or consists of principally drusy and dolomoldic types. The Staendebach member, especially toward the east, differs from the Threadgill in containing compact cherts that weather smooth and shiny white. Much of this chert in the Staendebach is oölitic. With rare and inconspicuous exceptions, grains of quartz-sand are absent from the Tanyard formation. The Tanyard fauna is dominated by gastropods and cephalopods.

The Gorman formation, correlative with the Roubidoux formation of Missouri, comprises the middle third of the Ellenburger group. It averages 470 feet thick. Dominantly microgranular to very fine grained dolomite constitutes a lower dolomitic facies; except in the northwestern corner of the uplift, where the grain size of the dolomite is coarser, and where

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erratic lateral transition to calcitic rocks occurs. The upper half of the formation is principally limestone, with a median parvafacies of dolomite coming in eastward, and with the uppermost limestones unusually pure and thickly bedded. The chert of the Gorman formation is apt to be chalcedonic to porcelaneous. Sand is a characteristic feature of the Gorman formation, not as well-defined beds, but as scattered to abundant grains in dolomite, limestone, or chert. Where sand occurs in Ellenburger rocks it constitutes presumptive evidence, but not positive proof, that the strata are younger than the Tanyard formation. Moreover, it suggests that they are older than the lower 50 feet of the Honeycut formation. Relatively large low-spired gastropods are the most conspicuous fossils in the Gorman formation. *Archaeoscyphia* has been found in the Gorman formation only near its middle, essentially dividing the calcitic facies above from the dolomitic facies below.

The upper third of the Ellenburger sequence, essentially correlative with the Jefferson City group of the Ozark uplift, is called the Honeycut formation. It is known to be present only in the eastern part of the Llano region, and there attains a thickness of about 680 feet. It disappears by truncation west of 98° 55′ longitude in western San Saba County. Where fully represented it is divisible into three facies, a lower one of alternating limestone and dolomite, a middle dolomitic facies, and an upper calcitic facies. Lithically, individual samples of limestone, dolomite, or chert are very like those of the Gorman formation. Sand grains are much less common than in the Gorman formation, and are rare at most places above the lower 50 feet. *Ceratopea* and *Archaeoscyphia* are locally common and some beds containing them are useful local datum-markers. The fauna of the Honeycut formation is dominated by gastropods of many sizes and shapes, and the sponge *Archaeoscyphia.* Trilobites are commoner than in lower Ellenburger strata except in the upper 100 feet of the Tanyard formation.

As the standard section of the Ellenburger group, the authors have selected the Lower Ordovician part of the composite Riley Mountain section, for reasons given on page 252. This section is described on pages 260–283 and is section number 6 of Plate 14. The type section of the Ellenburger is the composite Tanyard-Gorman section (p. 224), described on pages 230–249 and diagrammed as section number 5 on Plate 14, but it is too inaccessible and widely spread for convenient standard usage.

Evidence is advanced in favor of the hypothesis that the limestones of the Ellenburger group probably originated as chemically precipitated aragonite muds, under sedimental conditions similar to those found today in the Bahama Bank region, southeast of Florida. Much if not all of the dolomite, it is suggested, resulted from alteration at or near the sea floor of the original calcium carbonate muds, through interaction with magnesium salts in the basal layer of sea water or in percolating magnesium solutions. The finer the grain, the more nearly penecontemporaneous with original sedimentation are the dolomites thought to be. Coarser grain sizes suggest slower alteration by percolating waters below the sea floor at some deferred stage in diagenesis. Although there is no direct evidence that the more finely granular, laterally extensive dolomites are not primary, published information on the relative solubilities of the various salts of calcium and magnesium in sea waters at present appears to favor the deduction that penecontemporaneous alteration is a more important dolomitization process than primary precipitation. Lateral transition between limestones and diagenetic dolomites (including penecontemporaneous dolomites) may be related in part to the distribution of the minerals calcite and aragonite in the sediments being altered, and in part to variations in original permeability. Metasomatism is thought to take place according to the law of equal volumes. It is held that porosity of the diagenetic dolomites probably results from the slow leaching by meteoric waters of incompletely dolomitized rocks, resulting in removal of calcite particles and inclusions as well as some corrosion of the marginal dolomite. Surface leaching of

the dolomites of the Staendebach member of the Tanyard formation, as suggested by the concentration of springs on its outcrop, probably offers maximum opportunity for the development of continuous porosity in Ellenburger rocks.

Optimum conditions for the accumulation of petroleum in Ellenburger rocks below ground, therefore, may be expected where dolomites of the Tanyard formation, and especially the Staendebach member, are unconformably overlain by impermeable beds; assuming favorable structural conditions, a source of oil, and a development of the rocks similar to that known at the surface. The ultimate source of petroleum might be extraneous or autochthonous. Traces of petroleum have been detected in some of the finer grained Ellenburger and Cambrian dolomites at the surface.

The typically microgranular to very fine grained dolomites of the Gorman formation could form a seal to upward migrating petroleum in the dolomites of the Staendebach member of the Tanyard formation, if subsurface leaching, like surface leaching, were able to develop permeability in the Staendebach without making the Gorman permeable. Supplementary accumulations of petroleum could also be related to caverns, channels, or brecciation in limestones at the unconformable zone; or to lateral irregularities in granularity and mineral composition.

Plate 14 serves as a graphic summary of Ellenburger stratigraphy and correlation in the Llano region and Plate 15 summarizes its regional correlation. The other maps, charts, and figures graphically present much of the factual data on which the report is based, as well as some of the interpretations made. Twenty-seven fulltone plates illustrate some of the fossils, characteristics of the terrane and vegetation, and gross lithic features.

The body of the report is divided into three parts, in order to separate general descriptions and conclusions from purely documentary detail. In Part 1 is presented information related to the Ellenburger group of central Texas as a whole. The writers here discuss the stratigraphy of the Ellenburger group and pertinent details of the beds that overlie and underlie these rocks; consider some Ellenburger correlatives from other regions; investigate the probable lithogeny of the Ellenburger rocks and ecography of the Ellenburger sea; and summarize the geologic history, paleontography, geologic structure, petrography, and economic resources of the Ellenburger group. Here also the basis of correlation is summarized, selected technical terms are defined, and other features of general interest are briefly noted. Part 2 comprises the local stratigraphic detail and descriptions of sections, and Part 3 includes supplementary data of various sorts.

INTRODUCTION

Critical work on the Lower Paleozoic rocks of central Texas began with that of Dake and Bridge (1932), and subsequent studies by Bridge and later by Barnes served to delineate the larger features of the Ellenburger problem. A preliminary report by the present authors and Josiah Bridge (1945) summarized what was then known of the outcropping Ellenburger rocks, and Barnes and Cloud (1945) described a representative sequence of Ellenburger strata. The present report gives the final results of continuous cooperative work by geologists of the Texas Bureau of Economic Geology and the U.S. Geological Survey between December, 1943, and June, 1946. It is intended to be a basic study of Ellenburger rocks, with emphasis on features of possible significance to the search for new sources of petroleum. In order that it may be complete, many of the data given in the preliminary reports are repeated here, and some portions are taken bodily from those papers, with appropriate revision.

The present report summarizes the stratigraphy of the Ellenburger group and correlates it with other strata on the basis of detailed local observations in various parts of the Llano uplift of central Texas. The areas worked in detail were selected on the basis of reconnaissance studies at many localities, and are thought to be representative of the part of the Llano uplift in which they occur. It was considered better for the purposes of this report to coördinate by reconnaissance a

large amount of detail from strategically spaced local areas than to cover a wide area diffusely. Primarily it is desired to tell what subdivisions may be made of the rocks studied, how to recognize these subdivisions and correlate them from place to place, and how the information obtained may be applied. To accomplish this the report first gives definitions of some of the descriptive terms used, then states the methods followed and the sorts of evidence on which subdivision and correlation were based, and finally provides descriptions of the units themselves and a discussion of the cultural and economic applications of information derived from their study. This is accomplished in Part 1, whereas Part 2 presents the descriptive details of local areas, and Part 3 comprises supplementary data of various sorts.

The index map (Pl. 1) shows the general region involved, and the various other illustrations serve as a graphic summary of the report.

A generalized diagram (Pl. 45) to aid the reader in visualizing the various units and facies being discussed is reprinted from a National Research Council publication (Cloud and Barnes, 1946, p. 88a). This plate, as well as Plates 1 through 16, is in the pocket accompanying this publication.

The immediately ensuing remarks outline the more general features of the Llano uplift. A fuller account is given by Sidney Paige (1912) in the Llano-Burnet folio, and the bibliography lists many papers that deal with various aspects of the region. The geologic map of Texas by Darton, Stephenson, and Gardner (1937) shows the general geologic setting, but a recent map of the Llano region by F. B. Plummer (1945) presents considerably more detail for the Carboniferous rocks and the local geography than does the State map.

Rocks of the Ellenburger group are known to crop out only in the Llano region, a basinlike structural uplift at the geographic center of Texas, between latitudes of 30° 10′ to 31° 20′ north and longitudes of 98° 05′ to 99° 40′. It is rimmed by the Edwards Plateau on the west, south, and east, and adjoins the Carboniferous rocks of the Osage Plains at the north. Primarily it is a region of pre-Cambrian and early Paleozoic rocks that have been exposed by gentle doming and erosion of the overlying Cretaceous and late Paleozoic strata. In this sense it is essentially oval; about 80 miles long in a northwest-southeast direction, 55 miles wide, and about 4400 square miles in area. This is the region referred to in the present report as the Llano uplift, the Llano region, or simply as central Texas. It is the same as the Central Mineral region of some reports. The general area affected by doming and faulting, however, is probably more than 100 miles in diameter and extends into the adjacent subsurface.

The Llano region is historically a positive one, being similar to such other isolated positive regions as the Black Hills, the Ozark uplift, and the Adirondack Mountains. From it extend such subsurface structures as the Bend arch to the north and the Concho arch to the northwest. The pre-Cambrian rocks were intensively folded, faulted, and injected with igneous intrusions before Upper Cambrian time, and late Paleozoic faulting affected all rocks of pre-Canyon age. Presumably other significant movements that affected the Llano uplift during Paleozoic time were epeirogenic, and the epeirogenic history of the region is reflected in the succession and character of the sedimentary rocks preserved upon it. Post-Paleozoic faulting within the Llano region is not known, although the Edwards Plateau within which it lies was raised by the arcuate line of Balcones and associated faulting that borders it to the east and south. The important late Paleozoic faults strike mostly in the northeast and southwest quadrants, and the block-faulted ridges which they make are elongated in the same direction. These faults are steep to vertical, commonly braided and branching, locally *en echelon*, and subject to abrupt changes in strike. Dips of beds are mostly gentle in the Paleozoic rocks where they are not collapsed or adjacent to faults, and the best places to measure sections are in high hills or adjacent to major faults that have

steepened dips without sending branch faults into the section.

By far the greater part of the Llano region is underlain by pre-Cambrian rocks, the Paleozoic strata being preserved either as marginal deposits, or as outlying block-faulted peninsulas or monadnocks in the pre-Cambrian terrane. Schistose and granitic rocks that are poorly resistant to weathering comprise the larger part of the pre-Cambrian, expressing themselves topographically as shallow basins and low domes. The gneissic and finer grained igneous rocks, however, are commonly resistant to erosion, forming rugged hills and peaks, and the granite locally forms imposing exfoliation domes. These and the steep-sided, block-faulted Paleozoic ridges give the region a rugged and mountainous appearance when viewed from some places, but relief seldom exceeds 400 to 600 feet and the basinlike Llano "uplift" is entirely below the level of the adjacent Edwards Plateau.

Drainage of the Llano uplift is accomplished almost entirely by Colorado River and its tributaries. The most important tributaries are Llano River in the southern half and San Saba River in the northern half of the region, but many other perennial streams of considerable volume belong to the same drainage system. Rainfall averages about 20 inches a year and is largely seasonal, so that streams are subject to wide fluctuations in volume and those that are perennial owe their tenure to springs. Streams in the pre-Cambrian areas ordinarily have broad valleys, are of low gradient, and commonly are choked with waste, but the more actively degrading streams that transect the Paleozoic rocks commonly occupy deeper, narrower valleys or steep-walled gorges.

The Llano region and adjacent parts of the Edwards Plateau are for the most part more thickly wooded than the plains-country to the north, west, or south, and central Texas seems truly verdant when approached from these directions. Juniper, locally called cedar, the usage followed in this paper, abounds in areas of limestone, especially in the eastern part of the region. Scrubby deciduous oaks thrive on sandstone and granite. Mesquite and various spiny bushes choke the ground underlain by argillaceous and schistose rocks and will grow in any area of low relief that develops even a moderate soil cover. Dolomitic rocks are apt to be the most sparsely wooded, ordinarily expressing themselves as rolling hills or uplands that support clumpy growths of live oak and occasional cedar or mesquite. In rugged and well watered sections, however, even the dolomites may be thickly overgrown with cedar, and in the western part of the uplift the vegetation is apt to be relatively sparse and to contain a preponderance of semiarid types of plants. Many kinds of cacti abound in the region, as do several sorts of yucca and various spiny bushes of semiarid types. The better stream valleys, however, support a good growth of deciduous trees such as pecan and varieties of oak, elm, gum, and poplar.

The Llano region embraces parts of ten counties. Its principal industry is ranching and the ranches range in size from under 1000 to about 80,000 acres, with the average ranch comprising perhaps 2000 acres. It is reasonably well watered and, although there is not enough soil at most places for farming, it makes good pastureland where properly cared for. In general it is thinly populated. The principal towns of the region, with average populations of 2000 to 6000, are Llano, Mason, Brady, San Saba, Lampasas, Burnet, Marble Falls, Johnson City, and Fredericksburg, and all of these except Marble Falls are county seats.

Good roads serve much of the region, and the more important of these are paved. Those that are not paved may be difficult after heavy rains but are generally passable. Where public roads are not available pasture roads make most parts of the country accessible by automobile to those who have the good will of the ranchers. Rail service is available to the northeastern half of the region.

Close collaboration was maintained between the authors at all stages of the field work and in the preparation of the final report. Responsibility for the doc-

umentary data is indicated at appropriate places, but general conclusions suggested were jointly considered and are a matter of joint responsibility. In the matter of the actual writing, Barnes is the author of sections on "Geologic structure," "Petrography," and "Economic resources" in Part 1; the descriptions of the Lange's Mill, Tanyard, Gorman Falls, Backbone Mountain, and Johnson City areas, and the notes on the Sudduth section and the well called Rowntree No. 1 Kott in Part 2; and the sections on "Chemical data" and "Representative thin sections of Ellenburger rocks" in Part 3. Cloud is responsible for the actual writing of the remainder of the report and for most of the paleontologic work. The aerial photographs on Plates 31 to 37 are reproduced through the courtesy of the U.S. Department of Agriculture; other photographs are by Cloud unless otherwise credited.

As one may see by reference to the ensuing section, this report is, in a very real sense, the product of collaboration between members of the coöperating organizations, the petroleum geologists of the southern mid-Continent, colleagues from other institutions and regions, and the people of central Texas. If, upon critical examination, it be found to have merit, there will be many to share it with. For the faults that are sure to be found, the writers wish no indulgence. They have themselves nowhere hesitated to criticize where they judge facts inaccurate, procedure misleading, or inference unwarranted, and they expect their own work to receive the same objective treatment.

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Mr. L. E. Warren helped with the field work from the beginning and drafted all geologic maps that are not in color (Pls. 4–13). He also compiled or helped with the compilation of most of these maps from field data. Without his meticulous and cheerful coöperation, the completion of this report would have been indefinitely deferred.

The work done by the geologists of the U.S. Geological Survey was for the Fuels Section and was under the direct administrative supervision of Messrs. H. D. Miser and A. A. Baker. Each gave the project his full support from the beginning, and Mr. Miser consulted with the authors in the field on two occasions and critically reviewed the report in typescript. His continued understanding interest in the work and the objectives of the writers will be largely responsible for any merit their paper may be found to have.

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Mr. R. L. Heller assisted with the mapping in parts of the Cherokee area and independently mapped a large area near its center. His call to service with the armed forces in August 1944 deprived the Ellenburger surface project of a valued associate. Mrs. Mildred Cloud helped faithfully with many of the mechanical details of field work and did most of the typing. Drs. R. S. Bassler and G. A. Cooper made the facilities of the U.S. National Museum available to Cloud during the spring of 1946. Dr. S. S. Goldich and Mr. E. B. Parmelee, of the Argicultural and Mechanical College of Texas, made

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Members of the Committee on Geologic Names of the U.S. Geological Survey efficiently performed the chore of clearing the report for publication, and Dr. J. B. Reeside, Jr., critically reviewed the final typescript.

Particular sections of the report were read and criticized at the authors' request by Josiah Bridge, G. A. Cooper, C. E. Decker, W. H. Hass, P. B. King, J. B. Knight, Mrs. E. B. Knopf, H. S. Ladd, A. K. Miller, John Rodgers, H. C. Stetson, and James Steele Williams. The authors are deeply grateful to all of these for the time they so generously gave to the improvement of this report.

Dr. G. A. Cooper identified or checked the identification of the Mississippian macrofossils cited in this report, and Dr. W. H. Hass reported on the conodonts obtained. Dr. J. B. Knight advised on the generic identification of some of the gastropods, Dr. Edwin Kirk identified some Mississippian Pelmatozoa, and Dr. A. K. Miller contributed suggestions about the goniatites.

Some additional acknowledgments are made at appropriate places in the report, but a very great debt must be satisfied by a general expression of thanks to the many ranchers and other local residents of central Texas who befriended the authors with unfailing courtesy in ways too numerous to mention in a report of this nature.

LOCAL PRONUNCIATION OF PLACE-NAMES

The following list gives the accepted local pronunciations of geologically important place-names in the Llano region where pronunciation is not evident from spelling

Barnett	(bärn′ ĕt)
Burnet	(bûrn′ ĕt)
Chappel	(chăp′ ĕl)
Lampasas	(lăm - păs′ ăs)
Llano	(lăn′ ō)
Pedernales	(pĕd′ ĕn - ăl′ ĕs)
San Saba	(săn să′ bă)
Staendebach	(stīn′ dē băk)
Sudduth	(sŭd′ ŭth)
Tanyard	(tăn′ yärd)
Welge	(wĕl′ gē)

GLOSSARY OF SELECTED TECHNICAL TERMS

It has been the aim of the writers to reduce their observations to approximate systematic categories, recognizable in the field and expressed consistently by unambiguous terms in such a manner as to be most usable in comparative work. Within the limits of existing terminology they have chosen descriptive rather than genetic terms, and they have preferred obvious combinations of familiar words to the coining of new terminology.

Published terms and symbols are adapted to present purposes without reference to etymology, history, or original authorship except in special instances. This is not an oversight, but an implication that the terms or symbols are so

well established or so obvious that they may be considered a part of the English language, or of geologic symbolism, and thus common property. In the instance of words of classical origin the authors accept miscegenous words whose meaning is clear in preference to coining new words. The prefixes *sub* and *semi*, although of Latin derivation and classically to be used only in combination with Latin roots, are here used indiscriminately as accepted prefixes in the English language—*sub* to mean *almost* or *nearly; semi* to mean *half*, denoting a median position in a gradational series of any sort.

For definitions of terms other than those here noted, the reader is referred to Grabau (1924), to Twenhofel *et al.* (1932), to Hatch, Rastall, and Black (1938), or to Rice (1945). It is hoped that clarity of presentation will be improved by definition of the meanings attributed to the following terms:

Aphanitic—*see* sublithographic.

Bedding—in the Johnson City and Lange's Mill sections the bedding is mostly described in generalized terms. The expression "thinly bedded" indicates beds roughly less than 3 inches thick, "medium bedded" 3 to 10 inches thick, and "thickly bedded" more than 10 inches thick. The word "massive" has been used chiefly to describe the indistinctly bedded, microgranular to very fine grained, sphenoidally jointed dolomites.

Benthos or benthon—bottom dwellers; benthonic—bottom dwelling.

Bioherm—"moundlike, lenslike, or otherwise circumscribed structures of strictly *organic origin*, embedded in rocks of different lithology" (Cummings, 1932, p. 333). *See* Plate 18; Plate 19, figure A. Term proposed by Cummings and Shrock (1928, p. 599). Whether bioherms were also reefs must be judged on the basis of information commonly not available to the geologist. Biohermal structures may coalesce to form biostromes (Pl. 33, fig. B).

Biostrome—laterally extensive *bedded* structures consisting of or built mainly by or through the life activities of sedentary organisms, and not swelling into moundlike or lenslike forms (Cummings, 1932, p. 334). Not properly applied to shell breccias, limesand banks, or other deposits of detrital origin. (Pl. 25, fig. B.)

Calcarenite—a rock resulting from the lithification of detrital calcium carbonate wherein the calcitic particles exceed 0.05 mm. in diameter. Not used in the present report. *See* lime-sandstone and limesand.

Calcilutite—a rock resulting from the lithification of calcium carbonate muds, of detrital origin (Grabau, 1913, p. 290). The sublithographic limestones of the present report are not calcilutites, being of dominantly chemical origin. *See* lime-mudstone and sub-lithographic limestone.

Calcitic dolomite—a carbonate rock that effervesces slightly under dilute hydrochloric acid.

Caliche—a variously defined term here used to refer either to precipitated calcareous crusts of water-soluble minerals in the zone of soil formation or to the precipitated calcareous bonding material in certain detrital accumulations. In central Texas the mineral composition of caliche is essentially calcium carbonate, with minor impurities. *See* travertine.

Cannonball—a term here used to indicate subspheroidal to ellipsoidal balls of chert and partially chertified limestone; varying in texture from solid granular to porous and chalklike chert, through chert with inclusions of limestone, to siliceous limestone. Generally with a fragmental structure, commonly containing fossils or fragments of them, and not uncommonly with scattered to abundant ovoid bodies or cloudy indistinct markings such as characterize pellet limestones, they are strikingly different from other types of chert and from the rock containing them. They are suggestive of lime-mud balls (pp. 95–96) in various stages of chertification and are commonly associated with chert of similar character that is spread out in irregularly lobate forms as though accumulated in minor local depressions or squashed out to that form while yet plastic. This type of chert has not been unequivocally recorded below the *Archaeoscyphia* zone of the Gorman formation and is generally uncommon below the base of the Honeycut formation. The term, cannonball, is not here used to designate concretionary chert that is concentrically banded or chalcedonic to porcelaneous in texture.

Chalcedonic—*see* texture (chert).

Chert—a collective term used to include all varieties of cryptocrystalline to subcrystalline quartz aggregates ordinarily occurring in sedimentary rocks.

Chert-matrix sand—chert containing varying but relatively large amounts of ordinary quartz-sand grains.

Clastic—produced by mechanical processes. *See* detrital.

Coarse grained—*see* texture (bulk rock).

Color—pending the preparation and adoption of usable standard rock-color charts, rock-colors are described subjectively, using ordinary color-terms in general usage. In their original studies of samples from the Cherokee and Johnson City areas, Barnes and Cloud followed Cullison and Ellison (1944) in deriving specific color-terms by actual comparison of rock-samples with the charts in the Maerz and Paul color dictionary (1930) and found

the comprehensiveness and general plan of this "dictionary" an aid to systematization. Due to the fact that its cost ($12.00) is prohibitive to general usage by geologists and to the unusual nature of many of the names applied to common rock-colors, its use was finally abandoned, but the conceptions of many of the color-names given are traceable to this book.

Compact—constituent particles closely united or packed. It is to be assumed that all rocks here described are compact unless stated to be otherwise. *See* dense.

Crypto-oölitic—applied to oölitic chert where the character of the oöids and of the matrix is so similar that the oölitic structure is not readily detectable with the naked eye previous to examination with a hand lens. Crypto-oölitic chert is commonly pseudospicular, and some may represent the results of chert replacement of pellet limestones.

Dense—same as compact; or refers to ratio of mass to bulk or volume. Inaccurately used by some authors in a restricted sense to denote smooth-fracturing rocks which are not visibly granular. *See* calcilutite, compact, chalcedonic, porcelaneous, sublithographic, lithographic, vaughanitic.

Detrital or clastic limestone—refers to limestone that is composed of fragments worn from calcareous skeletons or pre-existing rocks by mechanical processes.

Dolocastic[23]—applied to previously dolomitic or dolomoldic chert wherein the dolomite rhombs have been replaced or their molds refilled with some mineral other than dolomite. Such chert, with pseudomorphs of quartz, was collected near the middle of the Staendebach member of the Tanyard formation on the east side of State highway 16 and about 9.65 miles by speedometer south of San Saba and has been seen but not collected at a few other localities. *See* dolomoldic.

Dolomite—a calcium-magnesium carbonate rock that effervesces very slightly or not at all under dilute hydrochloric acid. Van Tuyl (1914, p. 257) shows that the name dolomite was originally and is properly a *rock term.*

Dolomitic limestone—a carbonate rock that effervesces moderately under dilute hydrochloric acid.

Dolomoldic—applied to previously dolomitic or interstitial chert from which the dolomite has been removed, leaving rhombic holes or molds where the dolomite was. Dolomitic and interstitial chert become artificially dolomoldic in the preparation of insoluble residues in the laboratory. Dolomoldic chert is commonly but erroneously referred to as dolocastic. *See* dolocastic.

Eustatic—refers to changes in the volume of the oceans, or to movements of the oceanic basins, affecting the total volume of water on the continents and raising or lowering the entire surfaces of epicontinental seas.

Fine grained—*see* texture (bulk rock).

Glauconite—a complex hydrous silicate of potassium and ferric iron typically occurring in sedimentary rocks of marine origin as small ovoid pellets or globules of a shiny dark green to yew green color. According to Hatch and Rastall (1938, pp. 141–142), glauconite may behave as a mobile mineral and may be taken into solution or redeposited. Inasmuch as the determinations of glauconite here noted are based almost entirely on visual inspection, the term glauconite, with or without the modifying word "globular," is used only to denote the ordinary type composed of small ovoid pellets. The words "interstitial glauconite" are here used to denote other occurrences resembling or thought to be glauconite. Most of the flaky green minerals seen in the carbonate rocks of central Texas are argillaceous, rather than glauconitic.

Granular—composed of grains or closely packed crystals.

Granularity—*see* texture (bulk rock and chert).

Interstitial—used in this paper to refer to chert or glauconite that occurs between the grains of a crystalline rock and has its form determined or strongly modified by the crystallinity of the host rock.

Lime-mud and lime-mudstone—calcium carbonate mud and the rock resulting from its lithification. *See* sublithographic limestone.

Limesand and lime-sandstone—here used in rather loose interchange to refer to conspicuously detrital and commonly friable limestones. The limesands and lime-sandstones of this report could properly be called calcarenites, and the names are not here extended in ordinary description to very finely detrital and well indurated lime-sandstones, or to the shell-breccias and granular limestones of the Cambrian.

Limesilt and lime-siltstone—detrital calcium carbonate wherein the calcitic particles are less than 0.05 mm. in diameter, and the rock resulting from its lithification.

Limestone—a carbonate rock that effervesces strongly under dilute hydrochloric acid.

Lithographic—*see* texture (bulk form).

Littoral—between tides. May be taken as the upper part of the neritic zone. Sometimes confused with neritic, which *see.*

Medium grained—*see* texture (bulk rock).

Microgranular—*see* texture (bulk rock).

Nektos or nekton—free swimmers; nektonic—free swimming.

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[23]The writers accept the recommendation of Ireland and others (Bull. Amer. Assoc. Petr. Geol., vol. 31, pp. 1482, 1483, 1947) that *dolomorphic* is preferable to *dolocastic* as an adjective descriptive of the type chert here noted. No change is made in the text because of the rarity of this type of chert and a wish to emphasize the incongruity of the use of the word dolocastic for a chert containing rhomboidal *molds.*

Neritic—between low tide and depths exceeding 100 fathoms, that is, less than 100 fathoms deep but not ordinarily exposed to the atmosphere. *See* littoral.

Oöcastic—if used should be applied to previously oölitic substances wherein the individual oöids have been replaced or their molds refilled with some substance other than that originally composing the oöids. The use of this term for chert involves the question of whether most if not all oölitic chert is not really oöcastic; and, if not, how an oöcastic chert is to be recognized.

Oöid—the individual tiny spheroid in an oölitic rock. Here used in preference to the term oölith of some authors to avoid confusion with oölite and oölitic. The suffixes *lith* and *lite* are both derived from the Greek root *lithos*, meaning a stone, and therefore properly denote the öolite rock itself. The combining form, oö, from the Greek for egg, becomes oöid, meaning like an egg, and logically refers to the original roe-like particles. *See* also oölite.

Oölith—*see* oöid and oölite.

Oölite—a rock with a considerable proportion of tiny spheroidal bodies varying as to microstructure but commonly comprised of concentric shells, or with a radial structure, and known as oöids from their resemblance to fish roe. The common usage of this term is followed for chert as well as bed rock, even though it may be reasonable to argue that most oöids were primarily calcitic and that the chert is therefore oöcastic. Likewise it is probable that some of the cherts the writers call oölitic really represent chert replacement of pellet limestones wherein the included pellets were largely spheroidal. Such pellets commonly form the nuclei of true oöids. *See* also oöid.

Oömoldic—applied to previously oölitic or oöcastic chert from which the original oöids or their replacements have been removed, leaving subspherical holes or molds where the oöids were.

Pellet limestone—described by Hatch, Rastall, and Black (*in* Hatch and Rastall, 1938) as a limestone consisting of "small ovoid bodies, aggregated to form a rock superficially resembling an oolitic limestone or an oolite sand. The constituent grains show no original concentric structure, although in some cases they have acted as nuclei for ooliths." H. B. Moore (1933) shows that modern muds are pelleted by various mud-feeding invertebrates, which pass the sediment through their bodies and leave the rejected material in the form of smooth or longitudinally groved ellipsoidal grains and rod-shaped pellets. In recent marine sediments these may form "up to 30 per cent and in rarer cases as much as 100 per cent of the deposit" (Moore, 1933, p. 19). Although more than one type is found, the commonest is a simple ovoid type whose nature suggests that it is that of either a polychaete worm or a mollusc (Moore, 1933, p. 25).

Porcelaneous—*see* texture (chert).

Pseudospicular—applied to crypto-oölitic cherts wherein the outlines of the oöids are discontinuous; resulting in a pattern resembling the spicular meshwork of certain lithistid sponges.

Quartzose—containing inclusions or comprised of visibly crystalline quartz. Used especially in describing chert to contrast with types composed entirely of cryptocrystalline to subgranular varieties of quartz.

Reticulate weathering—applied to limestones having an internal meshwork of dolomite that weathers to dark, rough, interlacing welts on the lighter, smoother, relatively depressed surface of the limestone.

Sand—aggregated detrital particles larger than 0.05 mm. in diameter. Where chemically bonded or otherwise lithified the resulting rock is called sandstone. Mineralogic composition is varied, but unless otherwise specified is understood to be quartz.

Semichalcedonic—*see* texture (chert).

Semiporcelaneous—*see* texture (chert).

Silt—aggregated detrital particles smaller than 0.05 mm. in diameter.

Smooth-fracturing—considered to be an inherent character of certain textural types (*see* texture, chert, and bed rock), just as a rough fracture is of others, and ordinarily not specifically mentioned.

Sphenoidally jointed—irregularly "jointed" in blocks of roughly sphenoidal shape with slightly curved smooth surfaces. The surfaces follow no detectable pattern and are characteristically a weathering feature of the microgranular to very fine grained dolomites.

Spiculite—a rock in which sponge spicules are volumetrically important.

Stromatolite—a laminated but otherwise structureless object; commonly of some particular shape, ordinarily with a surface of attachment in the larger forms, and probably of algal origin, but not biologically classifiable (*see* Cloud, 1942).

Stromatolitic—of the nature of or pertaining to stromatolites.

Structural sink—a collapse or subsidence feature having the structure but not the topographic expression of a sink.

Subchalcedonic—*see* texture (chert).

Subgranular—*see* texture (chert).

Sublithographic—*see* texture (bulk rock).

Subporcelaneous—*see* texture (chert).

Texture (bulk rock)—the previously published grain size scales differ widely and are not satisfactory for the sedimentary carbonate rocks here considered. The following scale is used by the authors:

lithographic; smooth-fracturing, with no granularity detectable except at very high enlargements, and of sufficiently uniform

character to be potential lithographic stone.

sublithographic; smooth-fracturing, with no granularity detectable except at very high enlargements, but not of sufficiently uniform character to be used commercially as lithographic stone. A compromise term meaning the same thing as aphanitic does for igneous rocks. Many of the limestones described as sublithographic in the present report are in part pellet limestones, which locally results in a granular appearance; but the pellets themselves are mostly of sublithographic texture. The sublithographic limestones of this report are lime-mudstones of probable chemical origin (that is, calcipulverties or hydrocalcilutites; Grabau, 1913, pp. 283, 297).

microgranular; visibly granular, but individual grains mostly not resolvable with the aid of an ordinary 10-power hand lens and commonly requiring better than 25-power magnification for resolution. Dimensions of grains mostly less than 0.05 mm.

very fine grained; individual grains mostly not resolvable to the naked eye but distinct under an ordinary 10-power hand lens. Dimensions of grains averaging 0.05 to 0.20 mm.

fine grained; individual grains mostly resolvable with the naked eye, and with dimensions of most grains from 0.2 to 0.6 mm.

medium grained; dimensions of individual grains, averaging between 0.6 and 1.2 mm.

coarse grained; dimensions of individual grains mostly exceeding 1.2 mm.

The last five terms are used principally to classify dolomites, most limestones being referred to simply as either sublithographic or granular. Weather conditions may affect grain size determinations of dolomites in the field. Bright sunlight reflected from cleavage surfaces not uncommonly results in grain size determinations a grade coarser than might be made on a cloudy day. Although not practicable in the field, exact measurements with a microscope and ocular grid should be made in laboratory studies of samples and well cuttings.

Texture (chert)—the various cryptocrystalline to subcrystalline varieties of quartz collectively known as chert show a variation in their luster and manner of fracture that probably reflects their state of granularity. Although a loose usage of the three terms chalcedonic, porcelaneous, and granular suffices for general discussion, in detailed descriptions and more specific discussion the following terminology is used:

chalcedonic; translucent, smooth-fracturing chert with a shiny luster. The cherts here called chalcedonic are commonly variegated like agate and have a luster more like that variety of chalcedony than the waxy luster commonly associated with the term chalcedony when used in a restricted sense.

subchalcedonic; not quite chalcedonic, grading toward semichalcedonic.

semichalcedonic; subtranslucent to opaque, smooth-fracturing chert with a rather dull luster and ordinarily of some dull color.

porcelaneous; opaque to subtranslucent, smooth-fracturing chert with a dull luster; typically china white and with the faintest suggestion of granularity on the fractured surface. The texture is that of the finest porcelain or chinaware.

subporcelaneous; not quite porcelaneous, grading toward semiporcelaneous.

semiporcelaneous; opaque, dull-lustered chert that feels rough on a fractured surface but is not visibly granular.

subgranular; opaque, uneven-fracturing, dull-lustered chert that feels and looks rough but is not visibly granular.

granular; visibly granular chert but ordinarily without the individual grains resolvable to the naked eye.

Travertine—"a concretionary calcium carbonate formed by deposit" (Webster). Here applied to banded or laminated deposits of fresh-water limestone precipitated from moving water. *See* caliche.

Vaughnitic—*see* sublithographic; *see* Kindle, 1923, p. 370.

Very fine grained—*see* texture (bulk rock).

METHODS AND TECHNIQUES

The whole effort of the authors and their assistants in the field was geared to obtaining measurements of representative sections, to describing and marking them in such a manner that they could be followed by others, and to recording lateral variations away from the lines of section. In spite of the large number of variables dealt with in any one area, their fluctuations from area to area, and the necessity of recording them in the field without bulky equipment, the authors strove for the greatest feasible accuracy in all significant details. To what degree the various details are significant from place to place is, of course, a matter of judgment, but a judgment that had to be exercised if the work was to be brought to a conclusion.

The degree of reliability that may be attributed to the data presented is directly proportional to the accuracy of the techniques used and the methods followed in obtaining and recording them. These are briefly outlined in order that the reader may better judge the limitations of the work.

The work done went through three phases: (1) detailed study of particular areas to establish key faunal and lithic sequences, accompanied by office studies of aerial photographs in an effort to recognize photographic similarities and select promising areas for further study; (2) reconnaissance study on the ground of areas judged to be promising, and selection of certain of these areas for detailed study; (3) detailed studies and measurement of sections in selected areas. The second phase of the work was the shortest of the three. It was followed by a progress report (Cloud, Barnes, and Bridge, 1945), whereas the present report comprises the results of all the work and cites the detailed documentary evidence for these results.

Measurement of each of the sections of Ellenburger and related rocks described in Part 2 was preceded by detailed mapping of a sufficiently large area to establish measurable and structurally uncomplicated areas of section, as well as to work out lateral variations in the mapable characters of the rocks. Both geology and base data were plotted in the field on aerial photographs. All contacts and faults were walked out except where so evident on the photographs that there was no chance of misinterpretation, and the patterns so obtained were checked by closely spaced cross-section traverses. All cultural data and all places where the drainage pattern was in question were checked on the ground, and a car has been driven over all roads shown on the maps. It is probable that the authors or their assistants have been within 500 feet of every point in the areas mapped, and, in most instances, closer.

Most mapping was done on vertical aerial photographs of the U.S. Department of Agriculture enlarged to the approximate scale of 1:7920, except in the Cherokee and Bald Ridge areas where contact prints at the approximate scale of 1:20,000 were used. In the Bald Ridge area, and locally in other areas, data were mapped on the contact prints and later transferred to the enlargements. All maps were plotted planimetrically from the enlarged aerial photographs except that of the Cherokee area (Pl. 2) which was plotted from the contact prints. The geologic map of a part of the Cherokee area (Pl. 7) was prepared from photostatic enlargements of Plate 2. The 10 maps of small areas in the vicinity of measured sections (Pls. 4–13) are here reproduced at the approximate scale of 1:10,000. The colored maps of the two larger demonstration areas (Pls. 2 and 3) are given at the approximate scale of 1:31,680. That of the Johnson City area was pantographically reduced to the drafted scale of 1:20,000 from the enlarged aerial photographs. Many of the maps deviate slightly from the intended scales, due to irregularities in reproduction, but the graphic scale should be accurate within the limits of the system and data used in compilation.

All maps were compiled by the admittedly crude method of center-point control, and errors were distributed as evenly as possible. The amount and kind of ground control varies from place to place and is given under the individual areas. Because of the relatively slight topographic relief at most places it is believed that the center-point compilations make about as satisfactory planimetric maps as could be compiled short of resorting to the multiplex machine or similar complicated and expensive processes. They are better than the average plane-table map available to geologists, because linear features can be traced out for their full length in relatively true perspective to the geologic boundaries. The average user of these maps, while warned of general cartographic inaccuracy, will probably not notice inaccuracies in detail unless he runs fairly close instrumental surveys. There is, of course, no doubt that good topographic base maps would have enhanced the usefulness of the geologic maps.

In descriptions of particular localities all distances given are airline unless stated to be by speedometer or by road. Airline distances and directions were obtained by measurements from aerial photographs, or by pace and compass traverses. The approximate scales of aerial photographs in the several areas were checked or determined by random meas-

urements between recognizable points on several photographs; the measurements being made by alidade, by taping, or by comparison with instrumental traverses of the Texas State Highway Department.

Sections were measured directly in the field and adjusted to computations based on vertical and horizontal measurements along the lines of traverse. The described sections follow routes that give the best combinations of continuity and exposures in minimum horizontal distances. Lateral shifts are made to avoid faults, to obtain better exposures, or to secure a topographic advantage. The horizontal length of traverse may be reduced by increased topographic relief or by steeper dips of bedding. Where topography is the major factor, the accuracy in direct measurement or graphic computation is inversely proportional to the length of traverse for any given thickness of rocks, and it is the experience of the authors that essentially the same is true where length of traverse is related to dips up to about 15 degrees. The personal error in direct measurements, however, tends to increase rapidly as the dip steepens from about 15 degrees and probably just about offsets the advantage gained by shortening of traverse at 20 degrees. Low dips result in other disadvantages, and the optimum dip is thought to be between 6 and 15 degrees. Effort was made to find the most continuous sections, but only two are not composite (Cherokee and Highway 87) and one of these (Highway 87) is unsatisfactory because of low relief, low dips, and poor exposures. The composite sections are joined on the basis of detailed mapping, and their joinings probably involve no greater error than is involved in many of the lateral shifts.

Neither direct measurements nor computations are any better than the data on which they are based. Avoidance of structural complications in measured sections of Ellenburger rocks in the Llano region depends on detailed mapping. In the non-dolomitic Cambrian and post-Ellenburger rocks, bedding alignments are generally much better defined than in the Ellenburger, permitting more ready determination of faults from study of aerial photographs. In these rocks favorable areas for measuring sections may be suggested from study of the aerial photographs alone and checked by means of less detailed mapping than is called for in selecting measurable sections of the Ellenburger strata at most places.

Once assured of a structurally uncomplicated line of section, attitude of the beds is the most important item. Dips lower than 6 degrees are commonly difficult to read accurately, and unless exposures are very good, minor undulations may escape notice. Most dips were measured in whichever combination of the following three ways seemed the more feasible: (1) contact measurement with a Brunton compass on a flat object of the maximum convenient length laid on a good bedding surface, (2) sighting normal to the dip with a Brunton compass, (3) sighting parallel to the dip with a Brunton compass. Ordinarily the dip finally accepted was the average of a number of readings, and dips used in measurement were averaged continuously from data along and adjacent to the line of section. At a few places dips were instrumentally determined by the three-point method with an alidade and plane table.

It is considered likely that the inaccuracies in reading dips and tracing out lateral shifts are largely compensatory, and that the limit of error in measurements is probably within 10 per cent. The unavoidable inaccuracy, however, is such that extreme care in obtaining computative data or applying small local corrections did not seem warranted. Instrumental traverses were made of some sections, but computations of others were based on horizontal distances scaled from aerial photographs and elevations determined with a Paulin precision altimeter. Where computations checked direct measurements within reasonably close limits no correction was applied.

The general system of measurement and description of detailed sections found preferable is as follows: (1) the general line of section having been worked out by mapping, the best actual route for it to follow, including necessary lateral shifts, it scouted out and marked; (2) attitudes of beds are determined as

frequently as practicable along and near the line of section and averaged at appropriate intervals; (3) traverses are made of the line of section to determine elevations and, in some instances, distances between points, and thicknesses between recognizable data are computed; (4) the section is directly measured and marked on the ground and checked at appropriate intervals with the computed thicknesses; (5) the section is finally described in detail. The general system suggested resulted from trial and error in the measurement and description of early sections. It was found impracticable to perform all the steps suggested at once. Even though the work was done by teams its coördination was difficult, things were forgotten, and confusion and inaccuracy resulted. It is better that the whole job be done by two people as a set of separate operations, except that the actual composition of the description should be a single continuous operation by one person. However, it is advantageous to dictate the description to an assistant, because of the many operations involved in composing a detailed description.

Direct measurements of strata were made with a Brunton compass set at the proper angle of inclination and used on a measured and graduated staff. In order to facilitate sampling, the sections are marked at approximately 5-foot intervals with paint-spots of some conspicuous color. Yellow or orange were found to be more conspicuous than other colors, and the Sherwin-Williams trimbrite paint No. 19604 called "fiesta yellow" proved to be the brightest and most durable of the paints tried.

In addition to the usual equipment and techniques employed in study and description of outcrops and sections, it was found helpful to carry a dropper-bottle of dilute hydrochloric acid, and it was found very useful to develop the technique of seeing properly paired aerial photographs as a stereoscopic unit without optical aids. As in other areas, familiarity with the local rocks permitted ready visual differentiation between limestone and dolomite in most instances, and the dolomite was so habitually crystalline and dull weathering that chemical testing was mostly a confirmatory matter. The searches for sand grains in the sparsely arenaceous rocks of the Ellenburger group were greatly expedited and facilitated by the simple procedure of dragging a hammer blade across the outcrops. Disseminated silica of any sort draws instant protest from the hammer, and many sparsely arenaceous intervals were located in this manner.

Without vertical aerial photographs the work would have been vastly more difficult, but it must not be supposed that the aerial photographs are a panacea for all the difficulties of areal geology. They are perhaps at their maximum usefulness in regions such as the Llano uplift where topographic distinctions are well expressed but not extreme, where vegetation is mostly neither dense nor very sparse, and where soil cover is not great. They furnish many useful clues in the way of topographic and vegetal patterns, and in stratigraphic and structural alignments of various sorts. They show, in most instances clearly, the cultural features in existence at the time they were taken. They guide one to the outcrops and show him where outcrops are unlikely to be found. But all these things must be checked on the ground, and it is not uncommon for such checking to yield negative results. Their use can best be learned by practice, but even one skilled in their interpretation will not always find it easy to keep himself located in very thick woods, in formerly wooded areas that have been cut over, or in very sparsely vegetated areas of gentle topography. Unaided stereoscopic vision should be cultivated by anyone who contemplates using aerial photographs for geologic work, and he should have access to a good book on their interpretation, such as that of H. T. U. Smith (1943).

BASIS OF CORRELATION

Correlation of the various rock units mapped within the Llano region is based on fossils, lithic character of the dominant rock, macroscopically visible accessory lithic constituents, topographic expression, and vegetation. Regional corre-

lation, on the other hand, is based wholly on fossils. For correlation on physical evidence in and near the Llano uplift the distribution of quartz-sand and glauconite and the grain sizes of the dolomites are particularly helpful. Topographic expression and vegetal patterns are most helpful in mapping on aerial photographs.

Approximate ranges in the Ellenburger group and Wilberns formation of 36 genera other than *Ceratopea*, of 6 "species" of that gastropod operculum, and of the trilobite subfamily Saukiinae are graphically shown on Plate 14. Inasmuch as most of the genera here listed are short ranged, specific determinations are given for few of them. Some of the index fossils from the Ellenburger group and associated rocks are figured on Plates 38 to 44, and faunal differentiation is discussed under "Paleontography."[2b]

Physical criteria applied to the subdivision of the Lower Ordovician and Upper Cambrian carbonate rocks of central Texas and the correlation of their various units are as follows:

1. *Distribution of glauconite.*—Within the experience of the authors in the mid-Continent region, the presence of glauconite as a common accessory mineral is presumptive evidence of a Cambrian age for the rock in which it occurs. Such glauconite is likely to be globular if from limestone and interstitial if from dolomite. The occasional occurrence of glauconite in rocks of known Lower Ordovician age is not regarded as a refutation of this general principle, nor does the mere absence of glauconite necessarily suggest a Lower Ordovician age. Glauconite is locally common near the base of the Tanyard formation in the western part of the Llano uplift, has been seen at other levels in the Ellenburger group, and occurs in parts of the Lower Ordovician of west Texas. It is abundant in the Bliss sandstone of the Franklin Mountains, which is provisionally considered to be Lower Ordovician but may be Upper Cambrian in age. The sedimentational implications of glauconite are discussed on pages 97–98.

2. *Distribution of quartz-sand.*—The relative local abundance of quartz-sand other than detrital chert, the frequency in vertical distribution of arenaceous zones, and the character of the sand are of critical importance in the stratigraphy of the Ellenburger and associated Upper Cambrian rocks in the Llano uplift. In their field examinations of surface exposures, as well as their examinations in the office with a binocular microscope of chip-samples and uncontaminated hydrochloric acid residues from surface sections, the writers nowhere observed sand from the Tanyard formation and at only a few places above the basal 50 feet of the Honeycut formation. However, detailed petrographic examination by Dr. S. S. Goldich and Mr. E. B. Parmelee of the hydrochloric acid residues from samples from the composite Riley Mountain section revealed sand grains positively at 180 feet above the base of the Tanyard formation and possibly at 7, 113, 513, and 548 feet above its base. Thus sand does occur rarely in the Tanyard formation, at least toward the south side of the Llano uplift. The simple presence of sand grains in Ellenburger rocks, therefore, suggests, although it does not prove, a post-Tanyard age; and sand in relative abundance indicates the Gorman formation or the lower 50 feet of the Honeycut. As a rule, sand grains from the Ellenburger are scattered, clean (unstained), very smoothly frosted, well rounded, and small but poorly sorted within their relatively narrow size-limits. Where sand occurs in the Cambrian rocks of the Llano region, it is ordinarily more abundant, more coarsely frosted or pitted, less well rounded, and generally composed of larger and relatively better sorted grains than are normally found in the Ellenburger. The Cambrian sand grains are locally subangular to angular, locally have recomposed crystal faces, and commonly are stained with iron oxides. Such sand grains with ferruginous stains as occur in the Ellenburger suggest derivation from zones of exceptional permeability, or relatively thick arenaceous in-

[2b]New names for some of the fossils here listed and illustrated will be found in papers by Bridge and Cloud (gastropods and trilobites, 1947; species of *Ceratopea*, in press) and by Cloud (brachiopods, in press). It is suggested that the interested reader consult these papers for appropriate systematic changes.

tervals such as occur locally at the Tanyard-Gorman boundary or within the Gorman formation. In other areas of outcropping Lower Ordovician rocks that rim the Permian basin region the distribution of sand does not follow the rules outlined above, and at some intermediate parts of the subsurface they must cease to be applicable.

3. *Grain size of dolomites.*—Except in the northwestern corner of the Llano uplift (Bald Ridge area), grain size of the dolomites is an important clue to correlation of the Ellenburger and associated carbonate rocks of the Upper Cambrian. The applications of this clue will be evident from Plate 14, table 2, the "Explanations" on the various geologic maps, and the descriptions in the text.

Microgranular dolomite is excessively rare in the Tanyard formation, and, except in the lower part of the Staendebach member, very fine grained dolomite is uncommon in the Tanyard. Conspicuous zones of microgranular to very fine grained dolomite feature the lower part of the Gorman formation, the middle of the Honeycut formation, and locally the upper or lower parts of the Pedernales dolomite member of the Wilberns formation. The dolomites of the Threadgill member of the Tanyard formation are characteristically medium to coarse grained, and those of the Staendebach member are mostly fine to medium grained. Except in the northwestern corner of the Llano region there is a conspicuous break in grain size of the dolomites at or near the Tanyard-Gorman boundary, from coarser below to finer above. Except in the southeastern corner of the region the Cambrian-Ordovician boundary displays a similar though reversed break where it is in dolomite. A less conspicuous break from coarser grained dolomites below to finer grained dolomites above is a common feature of the contact between the Threadgill and Staendebach members of the Tanyard formation where it is in dolomite.

4. *Granularity of the limestones.*—Whereas essentially nondolomitic, granular limestones characterize the Upper Cambrian; sublithographic limestones, if not from Cambrian bioherms, suggest the Ellenburger.

5. *Types of chert.*—The several significant varieties of chert are here briefly discussed and listed in the approximate order that they affect the selection of boundaries from bottom to top of the section, note being made of relative abundance or absence.

Except in the Pedernales dolomite member of the Wilberns formation chert is very rare in the Upper Cambrian of the Llano uplift.

Finely vesicular, dolomoldic or oömoldic, platy-looking chert in tones of yellowish to olive or greenish brown, tan, and beige is characteristic of the upper part of the Pedernales dolomite member of the Wilberns formation at some places.

Oölitic and oömoldic chert is rare in the lower 90 to 300 feet of the Ellenburger group (Threadgill member of the Tanyard formation), but such chert is locally common at higher and lower levels. The upper one-fourth to one-half of the Tanyard formation in the northern and western parts of the Llano uplift is featured by dull, russet-weathering, laminated, oölitic to oömoldic chert (oölitic laminar chert), and at places by free siliceous oöids. Semichalcedonic to subchalcedonic cherts are commonly oölitic and chalcedonic cherts are occasionally so.

Conspicuously dolomoldic chert and interstitial chert such as would appear in hydrochloric residues as a highly cellular or "lacy" dolomoldic chert is much more common in the lower 520 to 660 feet of the Ellenburger strata (Tanyard formation) than above.

Quartz druse and conspicuously quartzose chert are abundant in the Tanyard formation and locally abundant in the underlying Pedernales dolomite member of the Wilberns formation. They are much less common in the Gorman and Honeycut formations, although they may be found throughout the Ellenburger group. The insoluble elements of this type are best displayed on weathered surfaces and may be represented only by highly disseminated silica in samples from below ground.

Sparingly dolomoldic porcelaneous and chalcedonic chert is rare in the lower 90 to 300 feet of the Ellenburger group (Threadgill member of the Tanyard formation) at most places, and may be uncommon in the lower 500 feet. The several varieties and grades of chalcedonic chert are normally common in the Gorman and Honeycut formations, and, except in the western part of the region, in the Staendebach member of the Tanyard formation. Porcelaneous chert is normally common in the lower part of the Gorman formation, and, again excepting the western part of the region, in the Staendebach member of the Tanyard formation. In the eastern areas the rather abrupt appearance, in the Ellenburger group, of porcelaneous and chalcedonic chert marks the base of the Staendebach member of the Tanyard formation, but in the Bear Spring and Bald Ridge areas the lowest occurrence of such chert in abundance is in the vicinity of the Tanyard-Gorman contact. In general the occurrence of truly chalcedonic cherts in abundance suggests a post-Tanyard age and of truly porcelaneous cherts a lower Gorman age. The duller varieties of both, such as would be modified by the prefixes *sub* and *semi*, preponderate in the Staendebach member of the Tanyard formation where it is cherty, and are locally abundant in the Pedernales dolomite member of the Wilberns formation. There seems to be a general tendency for the porcelaneous cherts of the Gorman formation to be less quartzose, less abundantly dolomoldic, and ordinarily to have finer dolomolds than those from lower strata. Semichalcedonic and subchalcedonic cherts are very likely to be at least partly oölitic to crypto-oölitic and pseudospicular. Truly chalcedonic chert is seldom more than slightly oölitic, for oöids tend to dull the luster and impede the smoothness of fracture of the chert which they partially comprise. The chalcedonic varieties of chert that occur as larger masses tend to be semichalcedonic to subchalcedonic; but where nodular or concretionary, or where occurring as thin lenticles or plates, they are most apt to be truly chalcedonic to subchalcedonic. All varieties of chalcedonic and porcelaneous chert tend to weather white, bluish white, or light tan, with a shiny luster.

The lithistid sponge *Archaeoscyphia* is so habitually preserved as chert, that it is, in a sense, a distinct type of chert and is here so treated. Its knotty spicular meshwork is recognizable even in small pieces of chert and it is a valuable guide to stratigraphic position. It is abundant in and normally characteristic of the Honeycut formation, occurring below the Honeycut only near the middle of the Gorman formation. Its occurrence at the latter position furnishes a biostratigraphic datum of considerable local significance.

Cannonball chert (*see* "Glossary") is uncommon below the Honeycut formation, lower occurrences being characteristically near the zone of *Archaeoscyphia* in the Gorman formation.

Chert that occurs in beds that may rest upon the Ellenburger group should be briefly noted. The Stribling formation of Devonian age is featured by chalcedonic to subchalcedonic bluish to brownish and grayish chert in irregular lenses and lenticles. The chert of the Bear Spring formation of Devonian age is mostly subporcelaneous to subgranular, dull white to tan or speckled tan and white, and partly banded. The basal Mississippian Ives breccia is composed of locally derived detrital chert similar to that in the beds it rests upon. The chert that occurs locally in the Barnett formation of the Bear Spring area is semiporcelaneous to subporcelaneous or granular, locally crinoidal, light gray, and occurs as nodules, lenses, and concretions. The chert of the Marble Falls limestone is commonly black or speckled black and light gray, giving an oxford gray effect. It locally contains numerous Foraminifera. In the Bear Spring area the lower several inches to 2 feet of the Marble Falls limestone contain subangular pebbles and granules of varicolored chert.

6. *Color of the fresh rock.*—Colors of the freshly fractured surfaces of dolomites examined show a general tendency to range from lighter to darker as the size of grain ranges from coarser to finer, and the darker colored dolomites vary in vividness of tone in rough relationship to their position in the section. Colors

such as beige, yellow beige, rose beige, rose, and cinnamon pink are uncommon except in dolomites of the Gorman formation and locally in the Honeycut formation. Tones of olive gray, brownish gray, grayish brown, and nutria are more common in the fine grained portions of the Pedernales dolomite member of the Wilberns formation than elsewhere, but locally they feature the Gorman and Honeycut formations. The very fine grained to microgranular dolomites of the Honeycut formation, except at the east side of the Llano uplift, tend to be lighter in color than dolomites of similar grain size in the Gorman formation and the Pedernales dolomite member of the Wilberns formation, and are apt to be light gray to yellowish gray, pale beige, flax, and old ivory. At the east side of the uplift, however, these dolomites of the Honeycut formation tend to be darker, except in the upper calcitic facies, than are those of the Gorman; with tones of brown, nutria, and beige dominating, and lighter colors less common. Most of the medium to coarse grained dolomites are very light gray to almost white in color, and the coarse grained dolomites are the lightest colored of the Ellenburger and Upper Cambrian rocks.

Among the rocks considered, light gray to white limestone is likely to be sublithographic, and hence to belong to the Ellenburger group. On the other hand, brown or greenish to yellowish brown limestones are likely to be granular, and hence to be Cambrian. Nondolomitic granular limestones are also likely to be marked by scattered to abundant green specks of glauconite, and the sublithographic to microgranular biohermal limestones of the Wilberns formation commonly have a greenish or pinkish cast.

7. *Major lithic features.*—Whether the rock is limestone or dolomite, and what the relative proportions, purity, and vertical frequency of the two may be, is commonly useful contributory evidence in stratigraphic studies of the Ellenburger and uppermost Cambrian carbonate rocks. Below, as well as above, the sequence of carbonate rocks here primarily considered, simpler stratigraphic division into sandstone, shale, and limestone units can commonly be made.

Among the carbonate rocks here considered differentiation between limestone and dolomite can ordinarily be made on sight. The freshly fractured surfaces of the dolomites sparkle from their crystallinity whereas those of the limestones, whether sublithographic or granular, tend to be dull of luster. The dolomites weather to dark or medium tones of gray, commonly with a brownish or yellowish cast, whereas the limestones weather light to medium gray with a typically bluish cast. The granular limestones generally weather darker than the sublithographic limestones. Weathered surfaces of the Ellenburger and Upper Cambrian limestones are typically smooth or smoothly pitted and fluted by solution; but the weathered surfaces of the fine to coarse grained dolomites are apt to be rough or roughly pitted, and even the more smoothly weathered surfaces of the microgranular to very fine grained dolomites tend to develop a chamois-like dullness and weather to sphenoidally jointed blocks.

Mixtures of dolomite and limestone can readily be determined on either fresh or weathered surfaces by the fact that the dolomitic portions normally show a marked crystallinity and weather in dark relief against the adjacent depressed portions of light-weathering limestone. The dolomite of intergrading series is seldom very fine grained or microgranular, and the distinctions noted hold good whether the dolomite occurs as scattered individual rhombs, as local patches, as rings in stromatolitic structures, as an internal meshwork in the limestone, or as the matrix in which minor inclusions of limestone occur. Limestones with an internal meshwork of dolomite, or dolomites with a similar meshwork of limestone weather to a characteristically reticulate pattern referred to at many places in the ensuing pages of this report.

Limestone as opposed to dolomite expresses a difference of no apparent general importance, for either may grade

abruptly to the other. In general, however, the microgranular to very fine grained dolomites are fairly persistent, not being subject to the abrupt and repeated lateral transitions undergone by the coarser grained dolomites.

The limestones of the Ellenburger group above the Tanyard formation, except in the northwestern part of the Llano region, and in the Kott well in Gillespie County, tend to hold their level better and to be purer in mineralogic composition than those of the Tanyard formation. In fact, reticulate weathering, meshwork limestone suggests the Tanyard formation and probable near-by gradation to dolomite.

GENERAL STRATIGRAPHY

INTRODUCTORY NOTES

The ensuing paragraphs consider the general stratigraphic features of the Paleozoic rocks of the Llano uplift, insofar as they are related to the Ellenburger problem. Summary discussion only is given of the Cambrian, Devonian, and Pennsylvanian strata. For further detail of the Cambrian formations the reader is referred to a paper by Bridge, Barnes, and Cloud (1947); for the Devonian formations to papers by Barnes, Cloud, and Warren (1945, 1947); and for the Pennsylvanian strata to reports by Plummer (1945), by Sellards (1932), and by Moore and others (1944).

The geologic column for the Llano uplift, with emphasis on the Paleozoic strata of pre-Pennsylvanian age, is as follows:

Cenozoic era
  Represented by surficial deposits of Quaternary or Recent origin
Mesozoic era
  Cretaceous system
    Lower Cretaceous
      Fredericksburg group
        Edwards limestone
        Comanche Peak limestone
        Walnut clay
      Trinity group
        Glen Rose limestone
        Travis Peak formation
Paleozoic era
  Carboniferous system
    Pennsylvanian series
      Canyon group
      Strawn formation
      Smithwick shale
      Marble Falls limestone
    Mississippian series
      Barnett formation
      Chappel limestone
      Unnamed shale and phosphatic limestone of local occurrence in Blanco County
      Ives breccia
      Unnamed limestone, in part below and perhaps laterally equivalent to the Ives breccia (p. 316).
  Devonian system
    Upper (?) Devonian
      Zesch formation
    Middle Devonian
      Bear Spring formation
    Middle or Lower Devonian
      Stribling formation
    Lower Devonian
      Pillar Bluff limestone
  Ordovician system
    Lower Ordovician
      Ellenburger group
        Honeycut formation
        Gorman formation
        Tanyard formation
          Staendebach member
          Threadgill member
  Cambrian system
    Upper Cambrian
      Wilberns formation
        Pedernales dolomite member
        San Saba limestone member
        Point Peak shale member
        Morgan Creek limestone member
        Welge sandstone member
      Riley formation
        Lion Mountain sandstone member
        Cap Mountain limestone member
        Hickory sandstone member
Pre-Cambrian eras
  Varied metasedimentary and igneous rocks of the basement complex

Table 1 constitutes a summary of the measured thicknesses of the various units of the Ellenburger group and such Upper Cambrian carbonate rocks as have in the past been included with the "Ellenburger limestone" of reports. The distance of *Plectotrophia* below the Cambrian-Ordovician boundary is also given, as indicative of disconformable relationships at that boundary in the southeastern part of the Llano uplift.

As the writers checked the galley proof, it became evident that some generalized diagram should be included as a reference for the reader to aid him in visualizing the various units and facies being discussed. Such a figure has been published previously (Cloud and Barnes, 1946, p. 88a) and is included as Plate 45 of the present report (in pocket).

Table 1. Thicknesses of units of the Ellenburger group (Lower Ordovician) and contiguous Upper Cambrian carbonate rocks, as measured in various parts of the Llano uplift.

	Bald Ridge area	Bear Spring area	Lange's Mill area	Cherokee area	Gorman and Tanyard areas	Riley Mountains	Backbone Mountain area	Johnson City area
Ellenburger group (total)	830	973	———	1128	1457	1512	1457+*	1826
Honeycut formation (total)	———	———	———	142	325	453	402	679
Gorman formation (total)	295	450	———	426	474	456	483	490
Calcitic facies	90+	237	———	275	383	242	263	246
Dolomitic facies	205—	213	———	151	91	214	220	244
Tanyard formation (total)	535	523	———	560	658	603	572*	657
Staendebach member (total)	280	229	———	300	456	353	481*	415
Calcitic facies	———	———	———	176	137	121	———	33
Dolomitic facies	280	229	———	124	319	232	481*	382
Threadgill member (total)	255	294	280+	260	202	250	91	242
Dolomitic facies	———	———	———	260	64	174	91	59
Calcitic facies	255	294	280+	———	138	76	———	183
Cambrian: Distance of *Plectotrophia* zone below top of Cambrian	300	315	335	270	338	239	275	37 (?)
Cambrian: Pedernales dolomite member of the Wilberns formation	———	———	———	90	277	73	224	195
Cambrian: San Saba limestone member of the Wilberns formation	200	260	307	140	47	145	48	———

*Includes 100 feet allowed for a fault between the Gorman formation and the dolomitic facies of the Staendebach member of the Tanyard formation.

PRE-ELLENBURGER BEDS

Riley Formation

As defined by Cloud, Barnes, and Bridge (1945, p. 154), the Riley formation includes all known Cambrian strata in central Texas beneath the Wilberns formation. It is thus the basal formation of Paleozoic age in the Llano uplift. In its type area, in the Riley Mountains of southeastern Llano County, it is about 780 feet thick, and it normally averages about 680 feet thick.

At most places the Riley formation is subequally divided between the noncalcareous, nonglauconitic, Hickory sandstone member below and the calcareous sandstones and glauconitic, gray to brown, granular limestones of the Cap Mountain limestone member above. The 20- to 50-foot thick glauconitic and calcareous Lion Mountain sandstone member caps the sequence. Some of the fossils from the Riley formation are described and illustrated by Lochman (1938), and its rocks are correlated with the Upper Cambrian Dresbach sandstone of the upper Mississippi Valley by Bridge (1937) and by Bridge, Lochman, and Barnes (*in* Howell *et al.*, 1944). Its rocks are described and columnar sections of them diagrammatically illustrated by Bridge, Barnes, and Cloud (1947).

The topographic and vegetal patterns of the units of the Riley formation are illustrated on Plate 33 (fig. 8).

Wilberns Formation

The Wilberns formation was named by Sidney Paige in 1911 (p. 23) and described in more detail by the same author a year later (Paige, 1912, pp. 6–7). Five member names are now in use for the rocks of this formation (*see* Bridge, Barnes, and Cloud, 1947), and its original upper limit has been revised to coincide with the Cambrian-Ordovician boundary (Cloud, Barnes, and Bridge, 1945). Through most of the Llano uplift the Wilberns formation ranges from 540 to 610 feet thick, but in the southeastern corner of the region (Johnson City area) it is only about 360 feet thick, because of truncation and disconformity at the top. Its average thickness is about 550 feet if the thin Johnson City section is considered, and about 580 feet if that section is discounted. The members of the Wilberns formation are briefly summarized below, discounting, for purposes of generalization, the aberrant Johnson City section.

At the base of the sequence is the yellowish brown, sparingly glauconitic to nonglauconitic Welge sandstone member, averaging 18 feet thick.

The Morgan Creek limestone member consists of granular, glauconitic limestones that are gray or greenish gray above and reddish to pinkish in the lower part. It is commonly arenaceous at the base, grading to the Welge sandstone member below. It averages about 130 feet thick.

The Point Peak shale member consists of green calcareous shales interbedded with subordinate amounts of limestone, intraformational limestone conglomerate, and occasional dolomite. Stromatolitic limestones locally feature its upper beds, forming bioherms (Pl. 18; Pl. 19, fig. A) that at places coalesce to become biostromes (Pl. 33, fig. B). The Point Peak shale member tends to be gradational to the San Saba limestone member above and the Morgan Creek limestone member below, and at some places it is difficult to draw precise boundaries between them. Including adjacent biohermal limestones, where they occur, the Point Peak shale member averages about 150 feet thick.

The San Saba limestone and Pedernales dolomite members are essentially equivalent facies of the upper Wilberns strata, with limestone predominating in the western part of the Llano uplift and dolomite in the east. They are gradational both vertically and laterally. Where both facies are present the dolomite is normally above the limestone, but the sequence is reversed in the Calf Creek area of northwestern Mason County. As long as the relationships are understood no particular advantage is accomplished by revising the nomenclature of this part of the section. If it were to be consistent with the simplified terminology in use

for the Ellenburger group the two so-called members would be unnamed calcitic and dolomitic facies of a single named member; but the dolomitic facies of this member would extend downward in the southeastern part of the Llano uplift to occupy the normal stratigraphic position of part or all of the Point Peak shale member. The average thickness of the San Saba limestone and Pedernales dolomite members, taken as a unit, is about 280 feet. Both members have been included with the Ellenburger group by earlier workers. However, the fine to very fine grained or microgranular, brownish gray to grayish brown dolomites that feature the upper Pedernales in much of its outcrop area differ clearly from the coarse to medium grained dolomites of the lower Tanyard formation, and difficulty in boundary placement occurs only where the upper Pedernales is coarse to medium grained. Inasmuch as the latter circumstance probably results from disconformity, it is scarcely a valid objection to nomenclatural differentiation. The granular and intermittently glauconitic limestones of the San Saba limestone member are likewise distinct from the sublithographic, essentially nonglauconitic limestones of the Ellenburger group. The small subspherical stromatolites known as girvanellas are locally abundant in the San Saba limestone member east from the Bald Ridge area, and appear in equivalent beds of the Pedernales dolomite member as "eyes" of limestone or as siliceous replacements. Similar objects are uncommon in other Upper Cambrian strata of the Llano uplift and have not been seen in rocks of the Ellenburger group. At the extreme western margin of the outcropping Paleozoic rocks, intervals of sandstone appear in the San Saba limestone member.

A few Wilberns fossils were described and illustrated by Roemer (1852) and by Bridge (1936), but splendid faunas remain to be described, especially from the Morgan Creek limestone member. The Wilberns formation is correlated with the Upper Cambrian Franconia sandstone and Trempealeau formation of the upper Mississippi Valley by Bridge (1937) and by Bridge, Lochman, and Barnes (*in* Howell *et al.*, 1944).

The topographic and vegetal patterns of the several units of the Wilberns formation are generally similar to those illustrated on Plate 33 (fig. B).

ELLENBURGER GROUP

Summary Statement

The "Ellenburger limestone" of early reports was revised to group status, restricted to rocks of Lower Ordovician age, and divided into three formations by the writers and Josiah Bridge in 1945. In upward succession the named divisions of the Ellenburger group are the Tanyard formation, comprising the Threadgill and Staendebach members; the Gorman formation; and the Honeycut formation. Although the three formations of the Ellenburger group are essentially equivalent to previously named stratigraphic units in Missouri (*see* Pl. 15), new stratigraphic names were introduced for the Llano region because of lithic differences and geographic isolation.

Local and regional correlation of the Ellenburger group and related rocks of Upper Cambrian age is indicated on Plates 14 and 15; and Plate 14 presents a graphic summary of Ellenburger stratigraphy in the Llano uplift. It will be apparent from Plate 14 that a complex system of nomenclature could have been devised to accommodate the conditions there indicated. The writers chose the simplest practicable nomenclatural expression of the group, using subordinated general statements of rock types for differing facies within inconspicuously gradational units called members and essentially chronologic, faunal and lithic units called formations.

As the standard section of the Ellenburger group, the authors have selected the Lower Ordovician part of the composite Riley Mountain section, for reasons given on page 252. This section is described on pages 260–283 and is section number 6 of Plate 14. The type section of the Ellenburger is the composite Tanyard-Gorman section (p. 224), described on pages 230–249 and diagrammed as section number 5 on Plate 14, but it is

too inaccessible and widely spaced for standard usage.

General Features of the Group

History and basis of revision.—Nomenclaturally the Ellenburger group is derived by revision from the so-called Ellenburger limestone, named by Paige (1911, 1912) for the Ellenburger Hills in the northwestern corner of the Burnet quadrangle, southeastern San Saba County, Texas. Reconnaissance study of the rocks comprising the Ellenburger Hills (Pl. 21, fig. B) indicates them to belong principally if not wholly to the Tanyard formation; yet by definition and subsequent usage the "Ellenburger limestone" had come to include not only all Lower Ordovician dolomites and limestones in the Llano region and the adjacent subsurface, but the immediately subjacent carbonate rocks of the Upper Cambrian as well.

Although the evidence from the principally calcitic lower sequence in the western part of the Llano uplift suggests essentially continuous sedimentation across the Cambrian-Ordovician faunal boundary there (Pl. 19, fig. D), the same boundary is at least locally and perhaps widely disconformable in the principally dolomitic sequence of the eastern part of the uplift (Pl. 20, figs. A and B). There is, moreover, a marked faunal break at this boundary; a break from glauconitic rocks below to essentially nonglauconitic rocks above; and, except in the southeastern corner of the region, differences in texture and color of the dominant rock and chert between the Cambrian and Ordovician carbonate rocks. All things considered, the carbonate rocks of the Llano region that were formerly lumped as the "Ellenburger limestone" are divisible at most places along a boundary set up on conventional faunal evidence into two clearly different sets of rock units—one Upper Cambrian and the other Lower Ordovician. Where they are not so divisible, in the southeastern corner of the uplift, evidence from mapping suggests that this is due to maximum disconformity for the region that brought like strata into contact by removal or nondeposition of the uppermost Wilberns strata.

As revision was necessary, the choice lay between restricting the term Ellenburger as a group term to include the Lower Ordovician rocks, or restricting it even further to include only the dolomites and limestones here called the Tanyard formation. The first alternative was adopted because it required the least revision of previous concepts.

Areal distribution.—The only known outcrops that are properly assignable to the Ellenburger group are in the Llano uplift of central Texas. The Lower Ordovician outcrops of other regions differ sufficiently from those of the Llano region that they are better designated by different names. The writers think of the name Ellenburger as applying properly to Lower Ordovician rocks of the pure lime-mudstone or calcilutite facies—that is, to those in which relatively pure, light colored, sublithographic limestones are a conspicuous lithic element. In this sense it is likely that much of the so-called Ellenburger of the subsurface would go by other names, such as Arbuckle group, El Paso formation (perhaps eventually a group), or possibly Marathon limestone. The extent of rocks of the Ellenburger facies within the Permian basin region is unknown to the writers, but this facies may be expected wherever shoal-water sedimentation poor in terrigenous debris occurred. Shoaling related to persistent structural highs may be reflected by the occurrence of rocks of the Ellenburger facies on and adjacent to known structural highs in the subsurface, such as the Central Basin Platform and similar features. Where such rocks grade to shore-derived sediments the facies changes may result in stratigraphic petroleum traps, and it may thus be of practical value to recognize the differing facies of the Lower Ordovician carbonate rocks in the subsurface.

Within the Llano region the occurrence of Ellenburger rocks is determined by structure and topography. They occur either at the margins of the basin-like structural uplift or in block-faulted outliers of Paleozoic rocks that are largely

or entirely surrounded by pre-Cambrian rocks. The general pattern of the outcropping Ellenburger rocks is shown on the geologic map of Texas (Darton, Stephenson, and Gardner, 1937).

Thickness.—The Ellenburger group of the Llano uplift attains its maximum known thickness of approximately 1820 feet in the vicinity of Johnson City, in the southeastern corner of the uplift. From there it thins west and north, mainly by truncation of the upper beds but in part by westward thinning of the Tanyard formation. It is only 970 feet thick in the Bear Spring area of western Mason County and about 830 feet thick in the Bald Ridge area of McCulloch County. The effective truncation of the Ellenburger strata was essentially a pre-Devonian event (pp. 109–110), although they were subsequently overlapped at various times by younger sediments. This pre-Devonian truncation appears to have completely removed the Honeycut formation west of western San Saba County, and it is at its visible maximum in the northwestern part of the Llano region. Its progressive development is indicated by the ideal line of section on Plate 14. The Ellenburger group of the subsurface probably contains at some places stratigraphically higher beds than any known at the surface in the Llano region, and at other places it may be entirely absent.

No evidence known at the surface indicates significant wedging or truncation of essentially isochronous rock units within the Ellenburger group. However, some of the facies shifts mapped could be mistaken for wedging or truncation. There is, moreover, clearly some variation in thickness of the formations, probably due to local variation in the rate of deposition as well as to temporary nondeposition along the Tanyard-Wilberns, Tanyard-Gorman, and Gorman-Honeycut contacts.

Lithic character.—The limestones of the Ellenburger group are predominately sublithographic and pearl gray to wood-ash gray and old ivory, varying to ordinary brownish grays and light browns. They are commonly although not generally stromatolitic, indicating an at least partial algal origin and generally a shallow water environment. Deposition in shallow waters is also indicated by ripple marks and intraformational breccias; and local, temporary subaerial exposure is suggested by the presence of contraction polygons in some of the more thinly bedded limestones. Pellet limestones occur locally throughout the Ellenburger group, denoting the activity of mud-ingesting invertebrates. The limestones tend to weather smooth to solution pitted or grooved and medium to light bluish gray. Locally they weather almost white.

The dolomites vary from microgranular to coarse grained. The more vividly colored microgranular to very fine grained dolomites occur in the Gorman and less commonly in the Honeycut formation, and they show greater lateral persistence than the generally coarser grained and light colored dolomites of the Tanyard formation. The latter are apt to grade laterally to limestone with great abruptness. The fine to coarse grained dolomites weather rough to pitted and medium gray to iron-gray; and the microgranular to very fine grained dolomite weathers sphenoidally jointed to hackly surfaced, smooth, and medium gray to light yellowish gray. Stratigraphic applications of the various grain sizes of dolomites are discussed on page 24.

As a general rule the limestones of the Ellenburger group are lighter colored and finer grained than the Carboniferous limestones above, or those of the Cambrian below. The dolomites tend to be coarser grained and lighter colored, or finer grained and more vividly colored than the dolomite of the Cambrian (Pedernales dolomite member of the Wilberns formation), whereas dolomite is rare in the Carboniferous strata. Chert is more abundant in the post-Threadgill rocks of the Ellenburger group than in subjacent strata other than the Pedernales dolomite member of the Wilberns formation and superjacent Paleozoic rocks other than the Marble Falls limestone and local patches of Devonian rocks. The stratigraphic applications of several kinds of chert are discussed on pages 24–25.

Porosity and potential petroliferous zones.—The obvious place to expect oil

in the Ellenburger group is in the beds immediately below the post-Ellenburger unconformity, where shales or other impervious rocks in the capping strata are potential sealing beds below which petroleum may accumulate in either stratigraphic or structural traps. Chances for unconformity-production from the top of the Ellenburger should be optimum where overlying impervious beds rest on permeable dolomites, and chances for secondarily induced permeability in the dolomites are at their best below an unconformity representing prolonged subaerial exposure of the coarser grained incompletely dolomitized rocks (pp. 93–94). Structural highs, therefore, may serve the double purpose of facilitating truncation to the coarser grained lower dolomites of the Ellenburger group and of furnishing structural traps. Of course, cavern, channel, or brecciation production from the limestones of the Ellenburger, especially those of the upper Gorman formation is always a possibility in the unconformable zone. Unfortunately such production, however rich to begin with, is likely to be local and short lived; and the probability of obtaining it decreases with depth below the unconformity.

Another possible locus of petroleum in the subsurface is the contact of the Tanyard and Gorman formations, used as a datum in the correlation chart for the Llano uplift (Pl. 14). The fine to coarse grained, commonly vuggy dolomites of the Tanyard formation are the most porous parts of the Ellenburger group known at the surface, and, except in the northwestern part of the Llano region, they are overlain by the very compact, microgranular to very fine grained dolomites of the basal part of the Gorman formation. This part of the Gorman is potentially a sealing zone below which oil might be trapped in the porous dolomites of the Tanyard formation on regional structural or stratigraphic features, so far as these characters persist. Moreover, distribution of springs in the Llano uplift (pp. 126–127) suggests that the upper unit of the Tanyard formation (Staendebach member) contains the more permeable dolomites. Preliminary studies of subsurface data, however, indicate that grain size differentiation within the Ellenburger group appears to break down west of the Bend arch and that the suggestion made may be potentially applicable only in areas east of the crest-line of the Bend arch for an uncertain distance north of the Llano uplift. West of the crest-line of the Bend arch the occurrence of petroleum within the Ellenburger may be related to essentially fortuitous variations in facies.

The only parts of the Ellenburger group in which traces of petroleum have been detected at the surface is in the very fine grained to microgranular dolomites of the Gorman and Honeycut formations of the Johnson City area, where Barnes and L. E. Warren noticed that freshly fractured surfaces of these dolomites locally give off a petroliferous odor. However, Barnes found that extraction of the volatiles from these rocks by means of ether does not yield an appreciable amount of petroleum. Similar traces of petroleum have been detected by Barnes in the Upper Cambrian Pedernales dolomite member of the Wilberns formation of Gillespie County. These occurrences probably represent autochthonous petroleum that was unable to escape to the atmosphere because of the extremely compact nature of the rocks in which it is imprisoned.

Petroleum will probably not be found by drilling in the Llano region because of the complex faulting of the potential source beds and their present exposure to the atmosphere.

Topographic and dendrologic expression of the formations.—On aerial photographs the Ellenburger strata seldom show such well-defined vegetation alignments as do the Cambrian, Carboniferous, and Cretaceous strata of the Llano region. Where the Pedernales dolomite member of the Wilberns formation (uppermost Cambrian) is present it too forms a zone of few bedding alignments, typically expressing itself as a lowland area or an upland flat that is locally strewn with chert and commonly displays numerous well-developed pimple mounds. In fact such areas of pimple mounds are typical of the Pedernales outcrop belt, though not restricted to it, and they grade

rather abruptly into the hilly terrane of the lower part of the Ellenburger (Pl. 31, fig. B; Pl. 32, fig. B). At places the Pedernales dolomite member supports an unusually thick growth of cedar for a dolomite. Areas of prominent "bald" or live oak dotted hills (Pl. 21, figs. A and B; Pl. 31, fig. A; Pl. 32, fig. A) are typically underlain by dolomites of the Tanyard formation and commonly are capped by rocks of the dolomitic facies of the Staendebach member, with one of several moderately conspicuous benches ordinarily coinciding with the Threadgill-Staendebach contact. Gently rolling and relatively well-wooded upland areas down dip from these bald hills in unfaulted areas will most likely be found to yield outcrops belonging to the calcitic facies of the Staendebach member (Pl. 33, fig. A) or to higher beds.

Undulating "bald" or live oak dotted prairies, ranges of low hills, or fairly open upland areas of little local relief commonly mark the outcrop belt of the dolomitic facies of the Gorman formation (Pl. 33, fig. A). Sinks and pimple mounds are a common feature of areas underlain by the basal dolomite of the Gorman formation (Pl. 33, fig. A).

Areas where the Ellenburger limestones outcrop, typically bear a heavy growth of cedar in which bedding alignment of the trees locally approaches that more generally displayed by the Cambrian and Carboniferous strata (Pl. 34, fig. B). The highest thickly bedded limestones of the Gorman formation give rise to characteristically prominent outcrops, expressing themselves in rough areas, commonly with thick, well-aligned growths of cedar, or with such a dense growth of cedar that alignment is subdued. In some areas they break abruptly to zones of poorer outcrop and more even topography underlain by the thinly bedded dolomites and limestones of the Honeycut formation (Pl. 34, fig. B), but in others the vegetation alignments are better in the Honeycut terrane (Pl. 35, fig. B). Where the dips are very low, the Gorman-Honeycut contact is likely to occur at the lower edge of a topographic bench (Pl. 34, fig. B; Pl. 35, fig. B), but where the dips exceed about 5 degrees, it is most commonly expressed by a conspicuous dip slope on the highest thick limestone bed of the Gorman formation.

Except locally, in areas of slight relief such as are apt to develop on the microgranular to very fine grained dolomites (Pl. 33, fig. A), the Ellenburger does not support more than occasional mesquite trees, and seldom anything like the thick growth of mesquite that thrives on the argillaceous units of the Carboniferous and pre-Cambrian rocks. The chaparral growths of bee-brush, blue-brush, and other stiff and thorny bushes that typically thrive on belts of argillaceous rocks are rare on Ellenburger strata, as are deciduous oaks and scrub elms; but the scrub mimosa known as catclaw and the black persimmon will grow almost anywhere, and bee-brush is at present invading the Ellenburger terrane in the western part of the Llano uplift. Tree growths typical of the Ellenburger are live oaks on the dolomite and cedars on the limestone, with local growths of mesquite and, less commonly, scrubby deciduous oaks. The first mesquite- or chaparral-covered bench above the Ellenburger is ordinarily underlain by shales of the Mississippian Barnett formation (Pl. 35, figs. A and B; Pl. 36, fig. A; Pl. 37).

Of course, the various parts of the Ellenburger group are not everywhere individually expressed, and not uncommonly the entire sequence, dolomite as well as limestone, supports a thick growth of cedar (Pl. 37; Pl. 33, fig. B). Extensive cedar and mesquite eradication programs locally affect the vegetation pattern, and in parts of the southwest corner of the Llano region submature topography along the major streams and a different dendrologic habit would be confusing, were their evidence alone considered. In general, the western part of the region (Pl. 36) is more sparsely vegetated than the east, and cedar seems to be less strongly entrenched in proportion to other types of vegetation. The sandstones in the San Saba limestone member of the Wilberns formation at the western margin of the region act as local aquifers that support relatively

thick growths of black persimmon and deciduous oaks (Pl. 36, fig. B) serving for quick approximate separation of the Cambrian from the Ellenburger.

Vegetal alignments along faults are common and locally conspicuous (Pl. 34, fig. A; Pl. 35, fig. A), but the major fault break does not invariably follow the more prominent alignment (Pl. 35. fig. A). Fault line scarps develop where the juxtaposed units have a marked differential to erosion (Pl. 34, fig. A).

Stratigraphic relations of the group and its component units.—The Ellenburger group represents the Lower Ordovician series in the Llano region. It is separated by profound and commonly marked erosional unconformity from the various Cretaceous, Carboniferous, and Devonian strata that rest upon it, but its contact with the Cambrian rocks below is inconspicuously disconformable or apparently conformable. Disconformity at the Cambrian-Ordovician boundary (base of the Ellenburger) in the eastern part of the Llano uplift, where it is in dolomite, is indicated by local evidences of truncation (Pl. 20, figs. A and B), as well as by conspicuous thinning of the Wilberns formation in the Johnson City area. In the western part of the region, where the contact is in limestone, it is evidently conformable (Pl. 19, fig. D). However, change in conditions of sedimentation, if not actual interruption in sedimentation, is indicated by the essential absence of glauconite from the Ellenburger rocks, by the change in lithology from mostly granular to mostly sublithographic limestones, and by the profound faunal changes.

At most places the Tanyard-Gorman contact looks conformable. Inconclusive evidence for disconformity is furnished by minor local irregularity along the contact (Pl. 24, fig. B) and apparent mixing of sand grains into the top bed of the Tanyard formation in the Bear Spring area. *Archaeoscyphia* in the Gorman formation ranges from 210 to 263 feet above the base of the formation but only 201 to 235 feet below the top, by actual measurement, perhaps suggesting slightly irregular resumption of sedimentation on a regionally truncated surface. Inferences drawn from data of this sort are clearly not established, but a possibility is suggested of slight regional disconformity at the Tanyard-Gorman contact. The abruptness of the faunal break at this place is striking.

The Gorman-Honeycut contact is uniformly even and conformable in appearance where seen. Interruption in sedimentation is suggested by sand-filled borings in the upper surface of the Gorman formation in the Gorman Falls area (Pl. 26, fig. A), and changes in conditions of sedimentation are evidenced by changes in lithology and fauna. The faunal break is abrupt.

Correlation.—Provisional correlation of the Ellenburger group with other Lower Ordovician rocks in the mid-Continent is shown on Plate 14 and the evidence for the correlations there suggested are considered in other parts of the text. It may be noted here that the Ellenburger group of central Texas comprises a less complete representation of Lower Ordovician rocks than any other studied by the writers in the mid-Continent, except that along the Rocky Mountain Front.

Tanyard Formation

Type section.—The Tanyard formation (Cloud, Barnes, and Bridge, 1945) was proposed as a name for rocks similar to and partially correlative with the Lower Ordovician rocks exposed at the type section at "The Tanyard," on the east bank of Buchanan Lake (Colorado River) opposite the mouth of Jim John Creek and Cedar Hollow and 2 to 3 miles north of the mouth of Fall Creek, in northwestern Burnet County. "The Tanyard" is a locality well known in central Texas and has given its name to Tanyard Spring, Tanyard Camp, and the old Tanyard Crossing of the Llano-Burnet folio (Paige, 1912). A detailed description of the type section is given on pages 244–250, and Plate 8 shows its location and geologic relationships.

Thickness.—Measurements of the Tanyard formation indicate that it includes between 520 and 660 feet (average 590 feet) of dolomite and limestone, about 550 feet of which are present from the

Cambrian-Ordovician boundary to the highest exposed beds in the type section. It is thinnest in the western part of the Llano uplift and thickest along the eastern margin of the uplift. The discrepancy in measured thicknesses is undoubtedly in part due to variations in dip or inaccuracies in the recorded data upon which calculations are based, but some actual variation in thickness is evident, and the measured thicknesses furnish an approximate expression of this variation. The differing thicknesses are probably to be attributed to the effects of unequal sedimentation (p. 101), cumulative local and temporary nondeposition (diastems), local nondeposition along the Cambrian-Ordovician boundary, and possibly local truncation along the Tanyard-Gorman boundary (Pl. 24, fig. B).

Lithic character.—The Tanyard formation consists predominantly of fine to coarse grained, commonly vuggy to porous, light yellowish gray to woodash gray, and pearl gray, irregularly bedded dolomites and sublithographic, pearl gray to woodash gray and old ivory, thickly to thinly bedded limestones. Both limestone and dolomite are essentially nonglauconitic. Variations in color among the dolomites take the form of mottles and streaks of a pinkish, yellowish, or purplish tinge; and the limestones are not uncommonly marked with streaks or blotches of sage green, chestnut or cedar brown, and dull pink, especially where dolomitic. The dolomite of the Tanyard formation characteristically weathers rough or smoothly irregular to pitted, craggy, and medium gray to iron gray with brownish tinges or to yellowish shades of gray and brown. The limestone weathers reticulate to smooth, slabby to thickly bedded, and to colors near woodash gray or pearl gray, old ivory, old silver, and cement gray. Gradation between dolomite and limestone tends to be abrupt laterally and is of no apparent stratigraphic significance. In general the limestones occur in the upper or lower parts of the formation, and the dolomite is typically coarser grained than usual where laterally gradational to limestone. Locally the formation is dolomite from bottom to top.

On the basis of chert, supported by grain size differences in the dolomites or, in the western part of the region, by a change from limestone to dolomite, the Tanyard formation is divided into the Threadgill member below and the Staendebach member above. Where the member boundary is in dolomite, the dolomites of the Threadgill member are predominantly medium to coarse grained and those of the Staendebach member are fine to medium grained. In the western part of the Llano region it is impracticable for mapping purposes strictly to follow the evidence of the chert types, and the boundary is placed between a calcitic lower unit representing the Threadgill member and a dolomitic upper unit representing the Staendebach member, with consequent instability in its mapped position. The Threadgill member has its maximum thickness in the western part of the Llano uplift, and the Staendebach is at its thickest in the east. The boundary between these members is transitional, though remarkably uniform in some areas. Both members include calcitic and dolomitic facies, both are locally dolomite from bottom to top, and the Threadgill is predominantly limestone at its type section and generally in the western part of the Llano region.

Sand was not found by the writers anywhere in the Tanyard formation of the Llano region, either in field studies of outcrops or in examination with a binocular microscope of chip-samples and uncontaminated hydrochloric acid residues from sample sections. However, examination with a petrographic microscope by Dr. S. S. Goldich and Mr. E. B. Parmelee of hydrochloric acid residues from samples of fresh, clean rock from the Tanyard formation of the composite Riley Mountain section revealed a few sand grains therein. They found sand positively at 180 feet (grains 0.18 mm. in diameter) above the base of the Tanyard formation and possibly a few grains at 7, 113, 513, and 548 feet above its base. Thus sand occurs rarely in the Tanyard formation, at least toward the

south side of the uplift. For general purposes the formation is sand-free, but unqualified reliance can not be placed on the stratigraphic significance of the mere presence of sand grains. Hydrochloric acid residues from the limestones of the Threadgill member of the western part of the Llano uplift show occasional angular fine silt grains (dimensions less than 0.05 mm.).

Threadgill member. — Although originally defined as the "Threadgill limestone" (Bridge and Barnes, *in* Barnes, 1944), this lower unit of the Tanyard formation was revised to include equivalent dolomite as well (Cloud, Barnes, and Bridge, 1945) and is now called the Threadgill member of the Tanyard formation. The type section of the Threadgill member is on Threadgill and Mormon creeks, south of Lange's Mill, in northwestern Gillespie County (Pl. 19, fig. C). The line along which this section was measured is shown on Plate 6, and the section is described in detail on pages 190–191. At its type section the Threadgill member measures 280 feet thick from its base to the Cretaceous overlap, and measured thicknesses elsewhere range from 91 feet in the eastern part of the Llano region to 294 feet in the west. As a general rule the Threadgill member is principally or wholly limestone in the west, grading eastward to a more generally dolomitic facies. Abrupt lateral transitions from limestone to dolomite feature the Threadgill member in the eastern areas, and it is commonly a puzzle whether a given contact is a lateral transition, a collapse contact, or a fault. In general, the limestones of the Threadgill member are more thinly bedded on the west side of the uplift than they are in the east (Pl. 19, figs. C and D; Pl. 20, fig. C). The western limestones are also less pure than the eastern ones, containing more numerous irregular argillaceous films and minor fine silt, and they are commonly marked by numerous selectively dolomitized casts and trails of gastropods (Pl. 20, fig. D).

On weathering, the dolomites of the Threadgill member yield vuggy or spongy masses of highly dolomoldic or cellular chert interlaced with quartz druse. They rarely yield chert of the types described as typical of the overlying Staendebach member of the Tanyard formation. The limestones of the Threadgill are generally noncherty and the dolomites locally so. The chert derived from the dolomites accumulates principally on gentle slopes long exposed to weathering. The general absence of chert in the limestones and the drusy character of that in the dolomites suggests partial secondary aggregation in the dolomites of silica originally highly disseminated in the limestones.

The southwest quarry of the Victoria Gravel Company, north of Sudduth, from which the magnesium plant of the International Minerals and Chemical Corporation at Austin obtained its ore, is in the low-silica upper dolomites of the Threadgill member (fig. 7).

Staendebach member.—The type section of the Staendebach member of the Tanyard formation (Cloud, Barnes, and Bridge, 1945) forms a portion of the Cherokee Creek section of the Cherokee area in southeastern San Saba County. The line of section is shown on Plates 2, 7, and 37, and the section is described in detail on pages 211–217. The name is derived from the Staendebach survey, a part of the T. H. Young ranch, which includes the upper beds of the type section. At its type section the Staendebach member measures 300 feet thick, and measured thicknesses elsewhere range from 229 feet in the western part of the Llano uplift to 456 feet in the east. As a rule, the upper one- to two-thirds of the Staendebach member is limestone in the northeastern part of the Llano region and in the Riley Mountains of Llano County, but in the southeast and west dolomite predominates and limestone is rare or absent.

The Staendebach or upper member of the Tanyard formation characteristically contains an abundance of sparingly dolomoldic porcelaneous to semiporcelaneous and chalcedonic to semichalcedonic chert. This weathers to solid, shiny, white or bluish white masses, slabs, or chips; and the semichalcedonic to subchalcedonic cherts are commonly oölitic to cryptooölitic and pseudospicular.

A feature typical of the upper beds of the Staendebach member of the Tanyard formation in certain areas is that the chert is commonly and the limestone is locally composed of aggregated small, elongate, algal bodies resembling worm castings. Dr. J. Harlan Johnson examined samples of this material and reported (letter to Barnes dated October 29, 1945) that about 95 per cent of the material studied by him was a primitive dasycladacean alga assignable to the genus *Rhabdoporella.* Where the *Rhabdoporella*-bearing chert or limestone is found, the top of the Tanyard formation is probably near by and its position may be confirmed by other fossils. Unfortunately this chert or limestone is not consistently present. Likewise, in the northern and western parts of the Llano uplift, the upper two-thirds to one-half of the Staendebach member displays several zones of a conspicuously oölitic to oömoldic, laminar chert, commonly with parallel bands of irregularly shaped holes or flattened elongate holes resembling the molds of flat pebbles. Locally this feature has been mapped, and originally a third member of the Tanyard formation was contemplated to include it. However, the chert involved proved to be a local development, especially common in the north half of the Llano region.

Fossils and correlation.—Fossils indicating equivalence to the Gasconade dolomite of Missouri and the Chepultepec dolomite of the Appalachian region (*see* Butts, 1926; Ulrich, Foerste, and Bridge, 1930) are locally abundant in the chert and limestone of the Tanyard formation. Equivalence to the McKenzie Hill limestone of Oklahoma is also indicated by these fossils. In general it is difficult on a faunal basis alone specifically to identify any particular part of the Tanyard formation. However, its upper 90 to 100 feet are characterized by the occurrence of species of *Rhabdoporella* (identified by Dr. J. H. Johnson), *Lichenaria* (identified by Dr. R. S. Bassler), *Clarkoceras, Paraplethopeltis* (resembling *Plethopeltis*), *Ribeiria,* and a few other fossils. In fact this fauna is sufficiently distinctive that the rocks containing it could be classed as a member were they distinct enough physically from those below, or were the fossils marking it sufficiently common over a wide area. Ranges of some of the more important Tanyard fossils are shown on Plate 14, and some of its regional correlates are indicated on Plate 15.

Gorman Formation

Type section.—The name Gorman formation (Cloud, Barnes, and Bridge, 1945) designates rocks similar to and partially correlative with those in the type section along and near the gorge of Colorado River in the vicinity of Gorman Falls, in southeastern San Saba County and southwestern Lampasas County. The water flowing over Gorman Falls cascades to Colorado River from a travertine brink that encrusts limestone of the Gorman formation at the Gorman Falls camp, terminating Gorman Creek, which flows approximately along the strike of the same limestones and is fed by Gorman Spring. The type section is described in detail on pages 235–239, and Plates 9 and 35 (fig. B) show its exact location and geologic relationships.

Thickness.—Measurements of the Gorman formation indicate that, where not thinned by post-Ellenburger truncation, it includes between 430 and 500 feet (average 470 feet) of dolomite and limestone. Cumulative local and temporary nondeposition, as well as inconspicuous regional disconformity at the formational contacts, probably accounts for such of the variation in apparent thickness as is not due to subjective elements. It may be suggestive of slightly irregular resumption of sedimentation on a regionally truncated surface, especially in consideration of the greater variation in thickness of the Tanyard formation, that, by actual measurement, the distance of the sponge *Archaeoscyphia* below the top of the Gorman formation ranges only from 201 to 235 feet, whereas its distance above the base ranges from 210 to 263 feet.

Lithic character.—Except in the northwestern corner of the Llano uplift the lowest microgranular dolomite in significant quantities in the outcropping Ellenburger rocks is at the base of the Gorman formation, and it occurs intermit-

tently from the Tanyard-Gorman contact to the top of the Ellenburger group. In the eastern part of the Llano region the microgranular to very fine grained dolomites of the Gorman formation are varicolored in yellowish, pinkish, and brownish tones such as beige, yellow beige, rose beige, rose, cinnamon pink, tan, old ivory, and nutria, but in the southwest the less vivid tones predominate. These dolomites commonly weather to smooth, crudely sphenoidal blocks or hackly or blocky ledges in tones of gray and dull yellow such as cement gray, tan, manila, and peach beige. The basal zone of the Gorman formation, characterized by dolomites of this type, is probably the most conspicuous stratigraphic marker of the Ellenburger group and is generally persistent throughout the Llano uplift, except in the northwestern corner. For this reason, and because of its median position and the faunal break with which it coincides, the Tanyard-Gorman contact was selected as a datum for correlations within the Llano region. Local confusion as to the placement of this boundary may ordinarily be dispelled by lateral tracing or by faunal evidence, and seldom are more than a few feet of section in question.

For the most part the Gorman formation is predominantly dolomitic below the zone of *Archaeoscyphia* and calcitic above; but measurements show that the dolomitic facies ranges from about 80 to 240 feet thick, and perhaps thinner, whereas the calcitic facies ranges from about 240 to 390 feet thick.

The upper calcitic facies of the Gorman formation consists principally of sublithographic, thickly to thinly bedded limestone with locally interbedded microgranular to fine grained dolomite. The limestone is mostly pearl gray to woodash gray, grading to old ivory and brownish gray, and locally with mottles of pinkish or yellowish tones such as cinnamon pink or beige. It weathers to medium or light tones of bluish gray and is not so commonly reticulated from the weathering of a dolomite meshwork as are the limestones of the Tanyard formation. A sequence of unusually pure and thickly bedded limestone occurs in the top 40 to 60 feet of the Gorman formation and is succeeded immediately by interbedded and relatively thinly bedded dolomites and limestones of the lower Honeycut, commonly arenaceous at the base.

Examination of Plate 14 will show that the calcitic facies of the Gorman formation east of the Cherokee area (sections 5–8) is divisible into upper and lower portions composed predominantly of limestone, and a middle portion that is predominantly microgranular dolomite. This tripartite division into upper and lower calcitic and middle dolomitic parvafacies fades out westward, suggesting westward deepening of the sea and shoaling to the east at the time the original sediments were accumulating (p. 94).

Chert and sand.—The chert of the Gorman formation partakes of the characters both of that found in the upper part of the Tanyard formation and that of the Honeycut formation. In the lower beds of the Gorman at some localities is a peculiarly layered chert not quite like that known from any other part of the section. It consists of porcelaneous, white to woodash gray chert with scattered dolomolds and quartzose matter, irregularly interlayered with quartz druse, weathering russet and commonly containing fossils. From this lower chert of the Gorman to the top of the Ellenburger strata, conspicuously dolomoldic chert and quartz druse are noticeably less common than in the Tanyard formation.

Porcelaneous to subporcelaneous, white, shiny-weathering chert is perhaps more common, less quartzose, and with tinier, more scattered dolomolds in the lower Gorman formation than in the upper Tanyard formation, but this is only a general impression and one difficult to check statistically. As a rule nodular and concretionary, subchalcedonic to chalcedonic chert is more common in the Gorman and Honeycut formations than in the Tanyard. From the Honeycut formation the chert of the Gorman differs principally in being more commonly porcelaneous, less commonly nodular or concretionary; and especially in the general rarity of cannonball chert (p. 16)

except in the vicinity of the *Archaeoscyphia* zone of the Gorman formation.

Scattered to moderately abundant sand grains occur intermittently in the limestones and dolomites of the Gorman formation, in contrast to the essentially sand-free strata of the Tanyard formation and the more sparingly arenaceous beds of the Honeycut formation. One must commonly search for sand grains even in the Gorman formation; but it is, generally speaking, the arenaceous part of the Ellenburger group.

Fossils and correlation.—Although for the most part sparingly fossiliferous, both the chert and the limestone of the Gorman formation yield fossils on search; and representative though sparse faunas have been obtained from the base to the top of the formation. *Archaeoscyphia, Diaphelasma, Syntrophinella, Lecanospira, Rhombella* (formerly called "*Roubidouxia*"), "*Euconia,*" mostly undetermined cephalopods, and *Hystricurus* are the most common, and the first five genera named are especially useful in correlation.

Rhombella and *Lecanospira* are restricted to the Gorman formation, occur throughout it, and are relatively common in comparison with other Gorman fossils. A possible source of confusion with *Lecanospira* and apparent stratigraphic inconsistency is furnished by the occurrence in the Honeycut formation of the gastropod *Barnesella lecanospiroides,* intermediate in resemblance between *Lecanospira* and *Maclurites,* and congeneric with "*Maclurea*" *affinis* Billings. More than one whorl is required to distinguish *Rhombella* surely from *Euconia* (strict sense). *Hystricurus,* although suggestive of the Gorman formation, also occurs in Tanyard strata.

The sponge *Archaeoscyphia* has been found in the Gorman formation only near the middle of the formation, at a position ranging from 210 to 263 feet above the base and 201 to 235 feet below the top, according to data from measured sections. It occurs throughout the uplift and is an important datum marker. Ordinarily it ranges through only 3 to 5 feet of the Gorman strata; but its range is slightly extended at some places, and at one locality in Mason County specimens of *Archaeoscyphia* were found about 25 feet above its principal occurrence.

The fossils of the Gorman formation indicate its homotaxial equivalence with the Roubidoux formation of Missouri, as most generally defined, and the Longview limestone of the Appalachian region. The presence of *Diaphelasma* about 300 feet above the base of the Cool Creek formation in the Arbuckle Mountains of Oklahoma and, accompanied by *Lecanospira,* extending into strata assigned by Decker to the base of the Kindblade formation of the Wichita Mountains suggests general equivalence between Gorman and Cool Creek strata. However, Tanyard fossils occur about 100 feet above the base of the Cool Creek formation as drawn by Decker in the Wichita Mountains. The ranges of the more useful Gorman fossils are shown on Plate 14, their significance in local correlation being determinable therefrom. It should be noted that the lowest recorded occurrence of the brachiopod *Xenelasma* is from the top of the uppermost bed of the Gorman formation, but it is locally very abundant there. Some approximate regional correlates of the Gorman formation are shown on Plate 15.

Honeycut Formation

Type section.—All known Ellenburger strata above the Gorman formation at the surface in central Texas are termed the Honeycut formation (Cloud, Barnes, and Bridge, 1945). The type section and thickest known development of this formation at the surface is in the reach of Pedernales River known as Honeycut Bend, about 5 miles east of Johnson City in Blanco County. The line of this section is shown on Plates 3 and 13, and it is described in detail on pages 321–331.

Thickness.—Owing to post-Ellenburger truncation, the Honeycut formation ranges in measured thickness from a maximum of 678 feet at the type section in the southeast corner of the Llano uplift to a feather edge. It appears to be entirely absent west of 98° 55′ longitude in western San Saba County.

Lithic character.—The rock types of the Honeycut formation resemble those of the Gorman formation, differing principally in distribution, bedding, and color. For the most part the limestones of the Honeycut are more thinly bedded than those of the Gorman and more intimately interbedded with dolomite, a difference most apparent at the Gorman-Honeycut contact. The microgranular to very fine grained dolomites of the Honeycut formation are given to relatively pale colors such as light gray to yellowish gray, pale beige, flax, and old ivory, as contrasted to the more vivid shades of rose and beige characterizing the dolomites of the Gorman formation in some parts of the Llano region. Where fully developed, the Honeycut formation may ordinarily be divided into a lower facies of interbedded limestones and dolomites, a median facies in which microgranular to very fine grained dolomite predominates, and an upper facies in which limestone predominates (Pl. 14).

Chert and sand.—Comparison of the chert of the Honeycut formation with that of the Gorman is given in a preceding part of this paper. Cannonballs (*see* pp. 16, 95–96) of chert and siliceous limestone are typical of the Honeycut formation but uncommon below it except near the *Archaeoscyphia* zone of the Gorman formation. Sand is locally common in the basal 50 feet of the Honeycut formation but rare above. The basal bed of the Honeycut is typically arenaceous.

Fossils and correlation.—Many of the fossils described from the Jefferson City strata of Missouri by J. S. Cullison in 1944 are specifically identical with fossils common in the Honeycut formation of Texas. They show that the base of the Honeycut formation coincides faunally with the base of the Jefferson City group of Missouri, and that the highest Honeycut strata known are not far below the top of the Jefferson City group as conceived by Cullison. One piece of contradictory evidence is the occurrence of *Tarphyceras* resembling *T. chadwickense* U.F.M.F. at the base of the *Ceratopea keithi* zone, about 400 feet above the base of the Honeycut formation in the type section and elsewhere along the eastern margin of the Llano region. Ulrich, Foerste, Miller, and Furnish (1942, p. 4) do not record *Tarphyceras* below the Cotter dolomite; but inasmuch as the writers have found, in west Texas, a tarphyceratid cephalopod even farther below its normally accepted range than the one in central Texas (p. 367), they are not disturbed by this occurrence.

Outside Missouri the Honeycut formation finds partial equivalents in approximately the lower three-fourths of the Kindblade formation of Oklahoma and in an unknown part of the Newala limestone of the Appalachian region. Some other correlates are indicated on Plate 15.

Most importantly the Honeycut formation is the zone of *Ceratopea* in the Llano uplift. *Ceratopea* occurs intermittently from top to bottom of the formation, and five subzones, characterized by six species or subspecies of *Ceratopea*, are indicated on Plate 14. A single specimen of a seventh species of *Ceratopea*, very close to if not identical with *C. tennessensis* Oder, was found at the top of the thickest section of the Honeycut formation, at Honeycut Bend. These several species of *Ceratopea* are useful both in local and regional correlation. The gastropod *Orospira* also ranges from bottom to top of the Honeycut formation, and species of the trilobites *Jeffersonia*, *Bathyurellus*, and *Rananasus* are important index fossils.

The brachiopod *Xenelasma* is common in chert of the lower Honeycut formation and typical of this part of the Ellenburger group. Silicified specimens of *Xenelasma* are also locally abundant in the top of the uppermost ledge of the Gorman formation, where they occur with unsilicified *Rhombella* and less commonly *Lecanospira*. This is the lowest recorded occurrence of *Xenelasma* from the Ellenburger, and its highest is about 140 feet above the base of the Honeycut formation. In general, however, *Xenelasma* appears to mark the lower 60 to 70 feet of the Honeycut formation, and its lowest occurrence essentially coincides with the Gorman-Honeycut boundary.

The sponge *Archaeoscyphia* is common in the Honeycut strata but rare below them, being recorded elsewhere only from

near the middle of the Gorman formation. Ordinarily *Archaeoscyphia* from the Gorman is not well preserved externally, being detected principally by the spicular meshwork displayed on freshly broken surfaces of certain chert nodules. In the Honeycut strata, however, an *Archaeoscyphia* assignable to *A. annulata* Cullison commonly preserves its external structure and general form almost as faithfully as it does the spicular structure of the sponge wall. Although it seldom occurs in dolomite, *Archaeoscyphia* is very abundant in some limestone beds of the Honeycut. Such beds have locally been mapped to determine structure. Although very abundant in some beds, the specimens of *Archaeoscyphia* so far seen are haphazardly scattered about as broken fragments, and no indication has yet been found that any of them are in the position of growth. With *Archaeoscyphia* is commonly found a flat-ended, slightly tapering siphuncle having a flattened spiculum and therefore assigned to *Mcqueenoceras*.

Ranges of some of the more important Honeycut fossils are graphically indicated on Plate 14.

BEDS THAT OVERLAP THE ELLENBURGER

Introductory Remarks

Rocks of Devonian, Carboniferous, and Cretaceous age rest with profound unconformity on strata of various parts of the Ellenburger group. The nature and history of this unconformity and the character and correlation of the overlapping beds are a part of the Ellenburger problem and bear directly on the production of petroleum from Ellenburger strata. The ensuing discussion considers the character and correlation of the overlapping beds, whereas the nature and history of the unconformity is treated under "Geologic history."

Devonian

The stratigraphy of the Devonian in central Texas has been considered by Barnes, Cloud, and Warren (1945, 1947). Figure 1 indicates the sequence and correlation of Devonian rocks in central Texas brought out by these papers. Discussion in the present paper is limited to brief notice under the areas in which rocks of Devonian age outcrop (pp. 138, 159, 315, 320, 349), the reader being referred for further detail to the papers cited.

Mississippian

The named Mississippian formations of the Llano region and their suggested correlations and relationships are shown in figures 2, 3, and 4. In considering figure 3 it should be noted that the use of the base of the Barnett formation as a datum fails to differentiate between the variation in thickness of the Barnett due to overlap and nondeposition at its base and that due to truncation at the top.

Slight revision of the names by which the formations of Mississippian age were originally known is thought advisable. It is, accordingly, here proposed that the rocks originally designated as the Barnett shale shall be known as the Barnett formation (following Sellards, 1932, p. 91), the Chappel formation as the Chappel limestone, and the Ives conglomerate member of the Chappel formation as the Ives breccia, a unit of formational rank.

The Barnett formation and the Chappel limestone have long been known to be of Mississippian age, but new evidence as to their limits and composition has resulted from detailed mapping of the upper surface of the Ellenburger. The Ives breccia correlates with beds considered to be basal Mississippian by some and uppermost Devonian by others. Further work will probably lead to the naming of additional Mississippian units (p. 27), but the proposal of new names for Carboniferous rocks is not a function of the present report. Some unnamed rocks of pre-Chappel age that occur in the Johnson City area are described on pages 316–317, and evidence cited shows that they may correlate with the Glen Park formation and Hannibal shale. Other rocks of possible Glen Park and Grassy Creek age occur in the Lost Creek area (p. 347).

Rocks of Mississippian age, though locally discontinuous, are widespread in

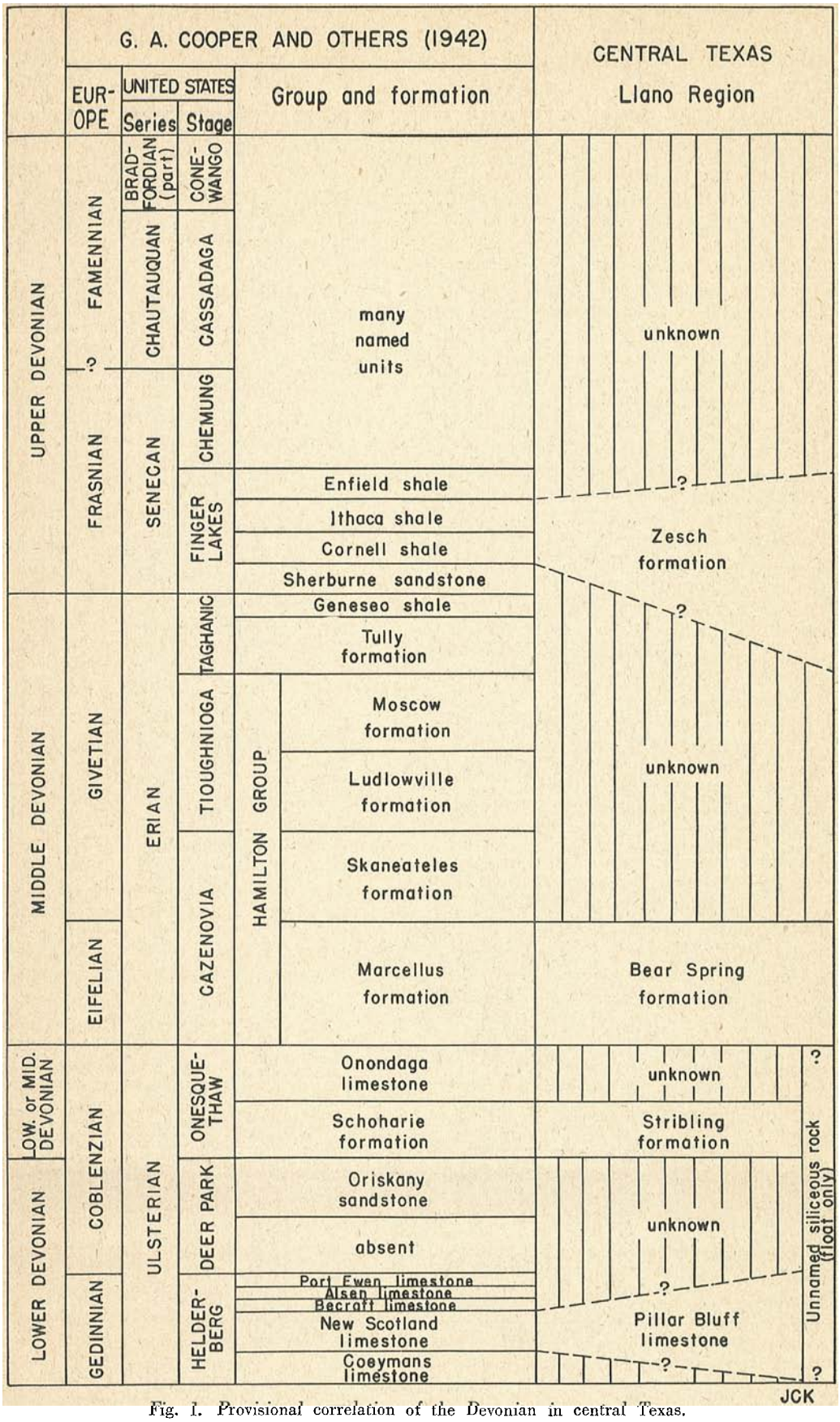

Fig. 1. Provisional correlation of the Devonian in central Texas.

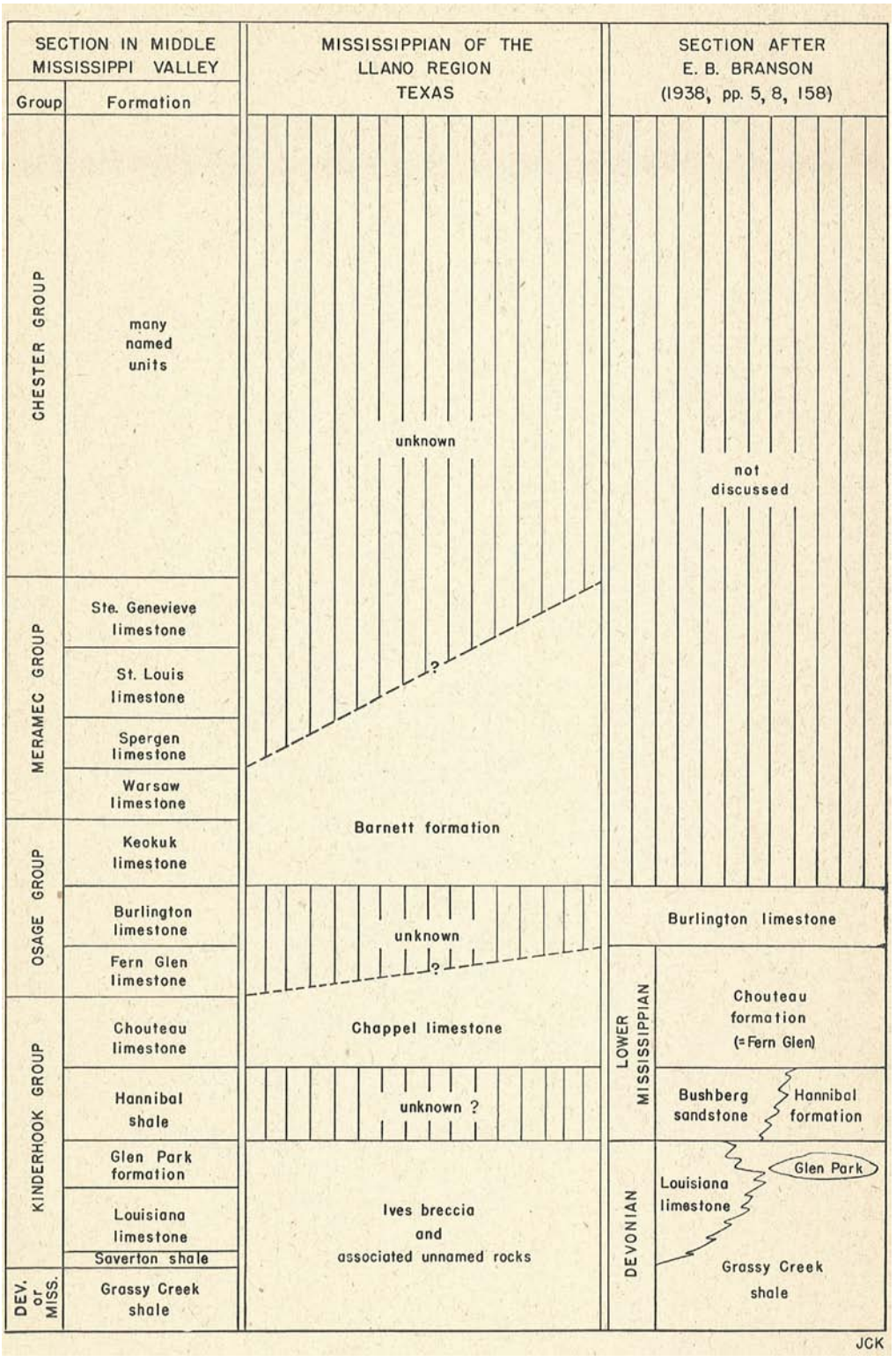

Fig. 2. Provisional correlation of the Mississippian in central Texas. *(See* also pp. 27, 316–317.)

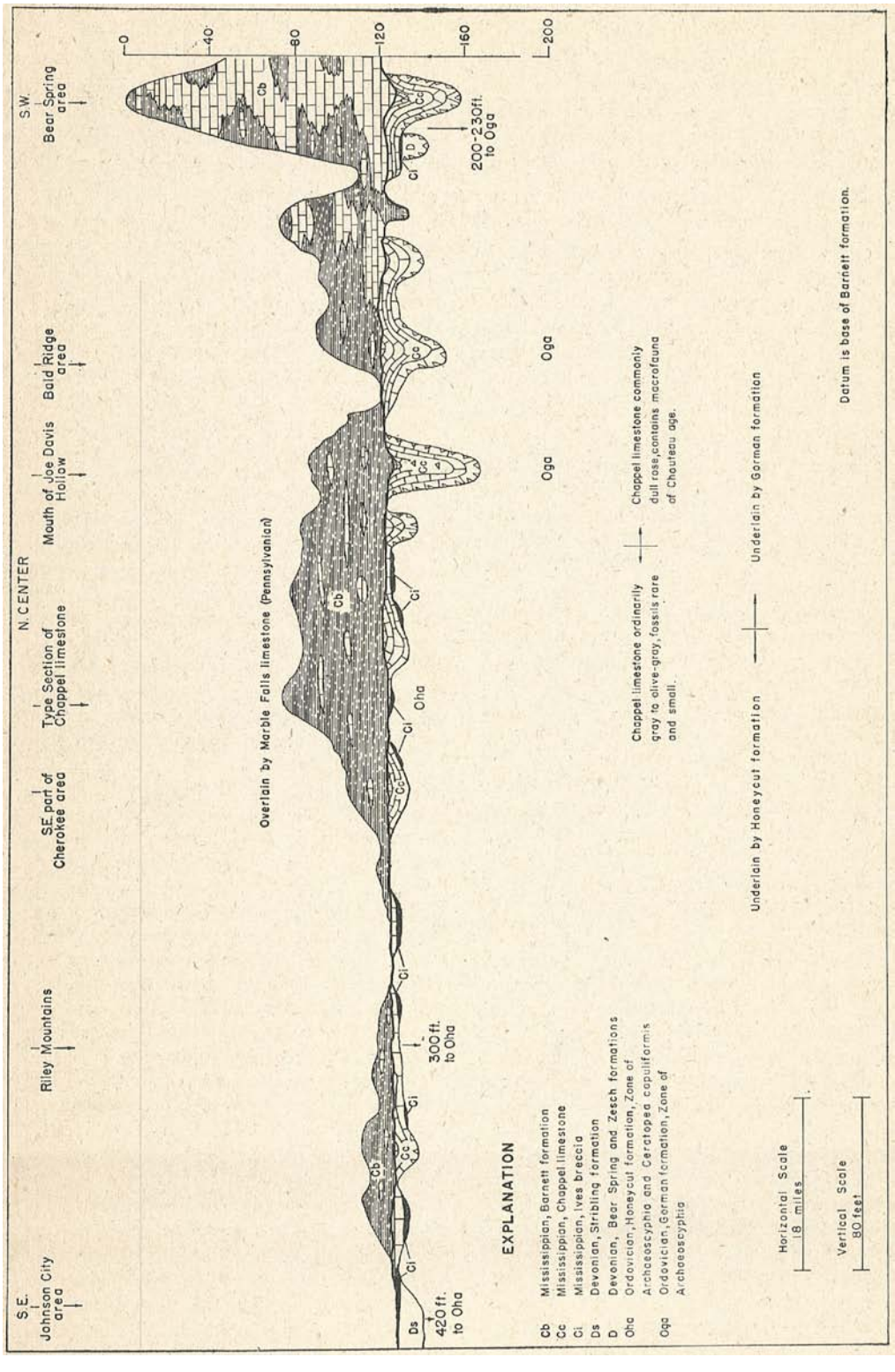

Fig. 3. Schematic representation of the Mississippian in central Texas. (Triangles along line of contact indicate solution structures and collapse.)

the Llano region and are much more persistent laterally than beds of known Devonian age. Occasional glauconite globules occur in various parts of the Mississippian strata, but glauconite of this age has been seen to be abundant only locally at the base of the Barnett formation.

The partial analysis here presented of the named Mississippian rocks was a wholly incidental by-product of a study primarily concerned with Lower Ordovician rocks and is not to be considered definitive; but it should serve to emphasize some of the problems and add to the groundwork from which future studies may proceed.

Ives breccia.—F. B. Plummer (*in* Bullard and Plummer, 1939, p. 15) describes this unit as "the basal conglomerate of the Chappel formation, named the Ives conglomerate." The locality cited by Plummer is in southeastern San Saba County on the south side of the county road from Chappel to Cherokee, 3.2 miles by speedometer south-southwest of the rock crossing of Cherokee Creek. The character and stratigraphic position of this thin but widely distributed coarsely clastic unit is clearly displayed at this place, and there is no question about the proper application of the name. At the locality cited, the Ives breccia overlaps beds of the Honeycut formation in the zone of *Ceratopea* 4 and 5. A type locality has not yet been designated in the published record.

The Ives is here recognized as a unit of formational rank, distinct from and older than the Chappel limestone, to be designated the Ives breccia because of the commonly angular character of the chert pebbles and granules which it contains. Although more sporadic in occurrence than the Chappel limestone and the Barnett formation which overlie it, the Ives breccia is to a large extent coextensive with them in the northern part of the Llano region. It occurs widely though discontinuously throughout the eastern and northern parts of the Llano uplift, and outcrops are common as far west as western San Saba County. Few outcrops are known from the areas mapped in the southwestern part of the uplift.

Ranging in thickness from 18 inches to a feather-edge, the Ives breccia is a persistent, though intermittent, detrital zone typically comprised of relatively fresh and unabraded pebble- to granule-sized phenoclasts of chert, far exceeding in volume the siliceous, calcareous, or phosphatic matrix.

Most of the phenoclasts are either freshly broken and highly angular, or they consist of unabraded chert concretions or nodules which are naturally ovoid in form. Although the angular phenoclasts within the breccia are fresh clear to their margins, the concretionary pebbles commonly preserve an anciently developed patina. The roundness of the Ives phenoclasts at some localities appears to be wholly a matter of the faithful preservation of chert nodules or concretions in their primary form, for evidence of rounding due to abrasion has not been seen, and erosive activity appears to have been limited to the chemical weathering that freed the chert from the carbonate matrix of the underlying rocks and sufficient movement to shatter quantities of it. The accumulation of chert in the Ives breccia resembles that seen on some of the more deeply weathered gentle slopes in the areas of Ellenburger outcrop at the present day, except that it is probably thicker than any of the modern accumulations resulting from normal weathering processes unaided by transportation. Statistical studies of sizes of phenoclasts have not been made; but as a rough generalization, it may be said that they seldom exceed a diameter of 12 cm., that a diameter of 8 cm. is large, and that the average range in size is probably from a diameter of about 8 cm. to one of only a few millimeters.

Although ordinarily inconspicuous, the matrix of the Ives breccia varies considerably in relative volume as well as in lithic character. At many places the phenoclasts are in contact, and the matrix is interstitial; but at some places the matrix increases in volume to form pockets within the breccia or even to exceed the volume of the phenoclasts. Locally,

the breccia seems to grade laterally into or to overlie (pp. 315–316) or underlie a reddish brown, olive gray, brownish, or yellowish impure limestone or phosphatic rock containing conodonts, fragments of bones, phosphatic pellets, and sand grains. Apparently more than one limestone or "bone bed" is involved, but relationships are obscure. The matrix of the Ives brecia has been found, at widely spaced localities and in varying lithic character, to contain conodonts similar to those stated by Branson and Mehl (1933a) to be characteristic of the Grassy Creek shale of Missouri. Where it is calcareous or calcareo-phosphatic the conodonts may be freed by acetic acid, but where it is highly phosphatic, or where it is siliceous, as it commonly is where it forms a volumetrically very small portion of the breccia, the conodonts must be mechanically obtained by crushing the rock.

That the Ives breccia was locally derived from immediately subjacent rocks is indicated by the fact that the chert phenoclasts in it are similar to the chert of the underlying rocks, as well as by their fresh and unabraded nature. Moreover, at some places (for example about 200 feet east of the Chappel to Cherokee road from a point 1.3 miles by speedometer south of the rock-crossing of Cherokee Creek) specimens of *Ceratopea* and fragments of chert containing other Ellenburger fossils similar to those of the underlying chert occur as pebbles in the Ives breccia. Although a geologically short period of aggregation of the phenoclasts which comprise this breccia is suggested by their poorly sorted and unabraded character and their local derivation, a relatively long period of time would be suggested by the abundance of conodonts in the matrix of the breccia at some places, if it could be assumed that they were not reworked.

The characters displayed by the Ives breccia suggest a fairly rapid marine invasion of a surface of little relief in an area underlain by chert-bearing rocks subject to chemical weathering, following a long period of exposure to the atmosphere. The invasion was marine because conodonts are widespread in the Ives. It must have been fairly rapid, because the phenoclasts of the Ives breccia show little or no evidence of wear. The surface must have been one of little relief, because the breccia is uniformly thin and does not display thick lenses such as would have accumulated in valleys or other depressions; moreover, it is inconceivable that so rapid a marine invasion as indicated could have spread the breccia so widely and so uniformly over any but a nearly flat surface already fairly well blanketed with chert. That the carbonate rocks on which the Ives breccia rests were chert-bearing and subject to chemical weathering is self-evident, and a long period of subaerial exposure would be required for chemical weathering to free such an accumulation of chert as is represented by the Ives breccia and reduce the land surface to one of such little relief that the chert formed a fairly uniform blanket. Either the numerous conodonts that occur in the interstices of the Ives breccia at some places were derived from an older offshore accumulation and clastically introduced during the postulated marine invasion, or else the ancient bottom of the Ives sea was quickly put below effective wave-base and failed to receive significant quantities of sediment other than conodonts for a long time. If the former alternative is the case, it may explain the uneven distribution of the conodonts, as well as their seemingly conflicting evidence at such localities as 16T–2–27A, in Blanco County (pp. 315–316). The apparent scarcity of other than locally derived clastic materials in or associated with the Ives breccia suggests either that invasion by the Ives sea was so sudden and so extensive that contaminant clastic sediments from adjacent invaded areas were not effectively transported, or that they were totally by-passed, or that a near-by source of other clastic materials was lacking. If central Texas was not a low-lying island immediately prior to Ives time, it was probably part of a larger hinterland of uniformly gentle topography.

At locality 16T–2–27A$_1$, in Blanco County, a lower Mississippian macrofauna, possibly correlative with and certainly no older than that of the Glen Park formation, was found in reddish

brown, bone-bearing limestone that appears to underlie the Ives breccia (pp. 315–316). The same rock yielded a mixed conodont assemblage containing both Grassy Creek and post-Grassy Creek types, according to stratigraphic ranges given by Branson and Mehl (*in* Shimer and Shrock, 1944); and, on the basis of criteria for the interpretation of mixed conodont assemblages (Branson and Mehl, 1933, pp. 265–267; 1941), it would be interpreted as younger than Grassy Creek. Although the Ives breccia apparently overlies this rock at locality 16T–2–27A, at other places the breccia seems to grade laterally to a similar rock, and it is not yet clear how many chronologic units are involved. Moreover, correlation is complicated by the fact that the conodonts of the Ives breccia at most places would be considered a Grassy Creek assemblage (W. H. Hass, oral and written communications). In this connection it is of interest that Branson and Mehl state (1933a, p. 174) that "at the type locality of the Glen Park it forms limestone lenses in the Grassy Creek," and as recently as 1938, E. B. Branson shows this same interpretation diagrammatically (1938, p. 8, fig. 2) and states further that "the Glen Park is referred to the Devonian by the writer (Branson) on the basis of relationships and fauna."

But the Glen Park formation (= Hamburg oölite, preoccupied) is generally considered to be Mississippian, even by stratigraphers who question the age of the Grassy Creek shale and the Louisiana limestone; and James S. Williams (1943) contends that the Louisiana limestone is of Mississippian age. The occurrence of *Paryphorhynchus* at the base, of *Protocanites* in it, and of "*Spirifer*" *marionensis* throughout the Louisiana limestone (Williams, 1943) supports Williams' contention, and E. B. Branson himself states (1938, p. 127) that *Paryphorhynchus* "has been found only in the Lower Mississippian." In addition to these forms, Williams (1943, p. 36) has listed 14 genera which he considers to indicate a post-Devonian age.

Attention should be called to the fact that C. L. Cooper (1935), in contradiction to Branson and Mehl, regards the conodont assemblage of rocks generally correlated with the Grassy Creek shale (Woodford chert, etc.) as Mississippian in age.

Inasmuch as the Grassy Creek conodont assemblage of Branson and Mehl, which generally characterizes the Ives breccia, is said by them to represent not only the Grassy Creek shale of the standard column, but also the Louisiana limestone (Branson and Mehl, 1938, p. 175) and presumably the Glen Park formation, a closer correlation of the Ives breccia than is indicated in figure 2 cannot at present be made on the basis of conodonts. A tie with lower Mississippian strata of Glen Park or possibly younger age is indicated by stratigraphic evidence at locality 16T–2–27A_1, in Blanco County (pp. 315–316), as well as at locality TF–395 in the Lost Creek area (p. 347).

The Ives breccia in the Llano region is here referred to the base of the Mississippian, although at a few localities (pp. 316 and 348) still older Mississippian strata may be present in the formation. Although the evidence of the conodonts on this problem is equivocal, the correlation here proposed is supported by stratigraphic evidence indicating superjacent relationships to and possibly partial equivalence with rocks containing lower Mississippian macrofossils at locality 16T–2–27A_1, and locality TF–273, as noted above. It is further suggested by physical evidence as follows: (1) The Ives breccia is much more widespread than the known Devonian rocks of the area and nearly coextensive with the known Mississippian rocks in the northern part of the Llano region. In the southeastern part of the Llano region it widely overlaps the Devonian rocks, but is in contact with rocks of Mississippian or Pennsylvanian age above, and in the more westerly parts of the region it is largely absent. (2) Although it is itself discontinuous, the Ives breccia intervenes between Devonian strata and post-Ives rocks at all localities where they are known to be in normal sequence, whereas both Ives and younger Mississippian beds overlap directly and extensively onto Ellenburger rocks. A long period of subaerial erosion and weathering, therefore, necessarily intervened be-

tween the deposition of known Devonian rocks and the Ives breccia, as contrasted to a much shorter period of erosion, or possibly merely an interruption in or change in conditions of sedimentation, between the thin Ives breccia and the overlying Chappel limestone. (3) Reworked clastic fragments from the Ives, which should be very resistant and persistent, are absent or rare in the Chappel limestone, further indicating a relatively brief interruption in sedimentation between these two units; whereas a comparatively long period of weathering was probably required to free such an accumulation of chert as is represented by the Ives breccia from the rocks that underlie it. (4) Faunal evidence shows that the Ives breccia is widely separated in time from the youngest beds of known Devonian age in the Llano region (figs. 1 and 2); and, if it is Devonian rather than basal Mississippian, it is neither a basal nor a regressive breccia, occupying a position of stratigraphic isolation unique among coarsely clastic deposits. On the other hand, it forms an ideal basal breccia for the Mississippian sequence, only very locally displaying anomalous subjacent Mississippian limestones.

Chappel limestone.—Originally named the "Chappel formation" by E. H. Sellards (1932, p. 91) this widespread unit has been found to be persistently calcitic and can therefore appropriately bear the more descriptive appellation of Chappel limestone. Sellards applied the name to the so-called "Boone-age" limestone described by Roundy, Girty, and Goldman (1926) and stated that the type locality is "three miles southeast of San Saba" (Sellards, 1932, p. 92), a fairly evident reference to the earlier report by Roundy, Girty, and Goldman wherein Roundy describes the "Boone-age" limestone as "a gray, medium-hard, somewhat crinoidal limestone exposed, so far as I am aware, only along the road to Chappel about 3 miles southeast of the courthouse at San Saba." Of the 41 species and varieties of fossils noted by Girty and Roundy as occurring in "limestone of Boone age" 38 are recorded only from their station 2623 which is described by Roundy (*in* Roundy, Girty, and Goldman, 1926, p. 17, ref. 2613D–2613H) as being "On the southwest side of road to Chappel, about 3 miles southeast of San Saba courthouse, at first sharp turn well up hill."

Fortunately the geology and topography of the area is such that only one locality fits the description given. This locality is about 2.4 miles by speedometer southeast along the San Saba-Chappel road from the south side of the courthouse at San Saba, immediately east of and downhill from the present road at a point just south of the V-bend made by the road about midway in its ascent of the fault-line scarp of the Simpson Creek fault zone. It is at the west side of the old road, which is downhill from and about 80 feet east of the present road at this point; between two branches of the Simpson Creek fault zone; and about 600 feet north-northwest of locality TF–22 on the geologic map of the Cherokee area (Pl. 2).

The approximately 24 inches of Chappel limestone exposed at the type locality is a crinoidal limestone wherein abundant to scattered larger pelmatozoan fragments are tightly bonded or cemented by a matrix of fine grained limestone. The upper 10 to 11 inches is a tough, medium to rather dark gray rock with a brownish, olive, or bluish cast, fairly typical of much of the Chappel limestone on the east side of the Llano uplift. The lower 13 to 14 inches, however, have been leached to a marly appearance and a lighter yellowish gray color, presumably by movement of ground water along the Chappel-Honeycut contact. Residues from its dissolution in acetic acid yield a few conodonts, occasionally globules of glauconite, and rare grains of sand. At the type locality the Chappel is directly overlain by about 50 feet of shales of the Barnett formation, and a few hundred feet to the south a lens of the Ives breccia up to 1 foot thick intervenes between the Chappel limestone and the Honeycut formation of the Ellenburger group. The top of the Honeycut formation at this place is in the zone of *Ceratopea capuliformis*, and the principal zone of *Archaeoscyphia* in the Cherokee area.

In the eastern half of the Llano uplift the Chappel limestone is generally similar

to that exposed in the type section, being gray to olive gray or brownish gray, tough, crinoidal limestone with fossils rare and mostly very small. It ranges in thickness from a feather-edge to a maximum observed thickness of possibly 14 feet in the southeastern part of the Cherokee area (TF–427), but it seldom exceeds 3 to 5 feet, and the suggested maximum of 14 feet is based on a quite unsatisfactory measurement. The macrofauna described by Girty (*in* Roundy, Girty, and Goldman) was, at the time of its description "wholly unknown and . . . in many respects peculiar," and "the species . . . small, almost minute," in fact suggesting dwarfed or infantile specimens. It was provisionally considered to be of "Boone" (roughly Osage) age.

In the western half of the Llano region limestones occupying the stratigraphic position of the Chappel are texturally similar to the Chappel limestone of the type section; but their color, in addition to and locally to the near exclusion of the gray and olive gray tones, is commonly rose or dull pink to rose brown and pinkish orange. Although gray to olive gray beds may predominate locally in the west, few sections fail to display some beds of a rose color; whereas rose-colored limestones are unusual in the Chappel limestone of the east. These rose-toned limestones of the western areas vary in observed thickness from 45 feet to a feather-edge, and they are much more erratic in their occurrence than the gray limestones of the east.

As an aid to clarity, the following discussion of correlation maintains a distinction between the type Chappel limestone at its type section and other localities in the eastern Llano uplift, and the apparently equivalent limestones of the western areas, by referring to the latter as the "rose limestone."

At several localities the rose limestones of the western half of the Llano region have yielded a varied and abundant macrofauna, consisting principally of brachiopods and trilobites closely similar to those described from the Chouteau limestone of Missouri. Important localities in central Texas at which Chouteau fauna may be seen are TF–390 to 393 in southeastern McCulloch County, about 1500 feet east of the mouth of Joe Davis Hollow on the north bank of San Saba River; TF–406 and TF–385 to 385a, 386, and 389 to 389c in the Bald Ridge area of McCulloch County; and TF–417b and 417c, just off the map of the Bear Spring area from TF–417a in Mason County. Brachiopods recognized by G. A. Cooper as being close to, if not specifically identical with, *Leptaena analoga* (Phillips) of Weller, *Plicatifera calhounensis* (Moore), *Shumardella obsolens* (Hall), *Rhynchopora cooperensis* (Shumard), *Brachythyris chouteauensis* Weller, *Spirifer gregeri* Weller, *Plectospira sexplicata* (White and Whitfield), a procline *Pseudosyrinx*, and many others occur at these localities, demonstrating the correlation of the rose limestones of the western part of the Llano uplift with the Chouteau limestone of Missouri.

It should be noted, however, that the rose limestones, even though much more commonly productive of macrofossils than the typically gray limestones of the Chappel in the east, at many places yield few macrofossils even to the most persistent efforts. It is at these localities and in subsurface studies that the commonly occurring conodonts will be most useful.

Comparison of the depauperate macrofauna of the type Chappel limestone of the east with the macrofauna of the rose limestones of the western part of the Llano uplift yields no evidence inconsistent with their correlation; and, in fact, some of the fossils illustrated by Girty (1926) resemble early growth stages of the larger fossils found in the rose limestones. Studies of the conodonts by W. H. Hass show that the assemblages from the rose limestones have a large proportion of "species" in common with assemblages from the Chappel limestone at its type section and from other localities in the eastern part of the Llano uplift. The Chappel limestone and the rose limestones are texturally very similar, and they occupy an identical stratigraphic position between either the Ives breccia or the Ellenburger, and the Barnett formation. For these reasons the rose lime-

stones of the western half of the Llano region are here considered to represent the Chappel limestone, and the Chappel limestone is, therefore, held to have its closest faunal affinities with the Chouteau limestone.

The Chappel limestone of the present report overlies beds of Glen Park or younger age in Blanco and McCulloch counties (pp. 317, 347) and underlies beds of Keokuk age (TF–184, TF–418; Pl. 5) in Mason County. It may, therefore, be considered to be younger than the Glen Park formation and older than the Keokuk limestone on the basis of stratigraphic position alone. Figure 2 shows graphically the correlation of the Chappel limestone here suggested, and figure 3 shows its relationships to adjacent strata in the Llano region.

Although the fauna of the Chappel limestone as here conceived clearly correlates with that of the typical Chouteau limestone, the available collections contain some specimens that are similar to Fern Glen species. In this connection, the ideas of E. B. Branson are to be noted. Branson (1938) in a redescription of the Chouteau fauna, includes in his Chouteau limestone not only the Chouteau as generally restricted (*see* Wilmarth, 1938, p. 439, for history) but the Sedalia-Fern Glen sequence as well. He claims (E. B. Branson, 1938, p. 17) that "about eleven miles northwest of the village of Fern Glen the entire Fern Glen section is exposed in a new cut, and the interfingering of the Chouteau and Fern Glen is so well exposed that no question remains concerning the contemporaneity of the two." (*See* also Branson, 1944, pp. 198–199, fig. 35.) As for the Sedalia, Branson (1938, p. 12) states that at the Easley section in Boone County "Moore calls the upper 22 feet Sedalia but there is no break between it and the lower (Chouteau) either in lithology or fauna." Branson's correlations are shown in figure 2 of his report (1938, p. 8), and they are compared with the sequence in central Texas and that accepted by the U.S. Geological Survey for the middle Mississippi Valley in figure 2 of the present report.

The Chappel limestone of the eastern areas overlaps the Honeycut formation, whereas that of the western areas overlaps limestones of the Gorman formation. The limestones of the Gorman are characteristically the most readily soluble part of the Ellenburger sequence. Throughout the Llano region their area of outcrop is more commonly marked by solution crevasses and small caves than any other part of the section, and the only large caves known in the Llano region (Longhorn Cavern and Richland Springs Cavern) are in the upper limestones of the Gorman formation. Figure 3 shows that solution in ancient times followed the same rules as that of more recent times, and that the Chappel limestone is much more commonly preserved as collapse fillings in the western part of the Llano region than in the east. The erratic distribution and greater thicknesses shown by the Chappel limestone of the western areas in contrast to that of the eastern areas is satisfactorily explained by the fact that the former overlaps limestones of the Gorman formation and is therefore more commonly preserved in solution structures that developed previous to Barnett time. These solution or collapse features have the structure but commonly not the topographic expression of sinks, and it is therefore suggested that they be called *structural sinks.* At places pre-Barnett erosion has wholly removed the Chappel limestone immediately adjacent to these sinks. Approximately 45 feet of Chappel limestone was measured in one of these structural sinks about 1500 feet east of the mouth of the Joe Davis Hollow on the north bank of San Saba River in southeastern McCulloch County, yet at the margins of the collapsed area the Barnett formation rests directly on limestones of the Gorman formation about 80 feet above the zone of *Archaeoscyphia* in the Gorman. Similar occurrences are common, though seldom so well displayed. The Chappel limestone dips steeply at the edges of the structural sink, and where Chappel strata can be traced beyond the immediate area of collapse they arch over the sink-wall without

change of character, in the manner of folded beds. It is evident from their lithic character, attitudes, and distribution that these limestones were not deposited as detrital fillings of ordinary sinks. Rather they have been let down from an original subhorizontal attitude, concomitantly with solution, or have fallen into caves that developed by solution, mainly before Barnett time, of the limestones of the Gorman formation below. Rocks of the Barnett formation locally sag into these structural sinks due to subsequent reactivation of solution and slump, and at a few localities the Barnett strata alone appear to occupy them; but for the most part the Barnett rocks simply overlap these collapse structures and their contents on a normal erosion surface.

Barnett formation.—Named the "Barnett shale" by F. B. Plummer and R. C. Moore (1921, p. 24), this important unit was later designated the "Barnett formation" by E. H. Sellards (1932, p. 91). The emendation suggested by Sellards is adopted in the present report; for, although the Barnett strata are largely shale in the east and north, and contain a fauna similar to that of the Moorefield formation and Ruddell shale of Arkansas, strata of Barnett age in the southwestern part of the Llano region grade laterally into detrital limestones containing fossils of strong Keokuk affinities and lesser affinities with younger strata. Present ideas of correlation and relationships are summarized in figures 2, 3, and 4.

The Barnett formation is named "from Barnett Springs, about five (nearer four) miles east of San Saba, near which is a typical exposure of the shale" (Plummer and Moore, 1921, p. 24). The only section described by Plummer and Moore (1921, p. 25) was presumably immediately above the type section of the Chappel limestone and about 2.2 miles airline southwest along the Simpson Creek fault zone from the type locality (Pl. 2). This is the locality 205–T–24 from which Plummer and Scott (1937) recorded seven species of goniatites,[3] and it displays the best section of the Barnett formation in the vicinity of the type locality. The closest reasonably good exposure of the Barnett formation to Barnett Springs is just east of Big Tank, on the W. W. Holman ranch, where a partial section of about 12 feet of shale is well exposed. In a fault sliver along the Simpson Creek fault zone immediately east of Barnett Falls, about 3 feet of petroliferous shale and limestone is exposed in a cut on the northeast side of an old road, and perhaps 40 feet of section is represented between the Chappel and the Marble Falls limestones at this place.

The Barnett formation ranges in thickness and character from the 40 to 50 feet of mostly shale exposed in the vicinity of the type section to a feather-edge on the one hand, and on the other hand, to a thickness of probably as much as 140 feet of mostly crinoidal limesands in the Bear Spring area in Mason County. Much of this variation in thickness is evidently due to truncation of the upper surface, but a significant part of it is known from mapping to be attributable to nondeposition at the base, and some may be due to variation in character of the original sediments.

In the eastern and northern parts of the Llano region the Barnett formation is a dark gray to brown or black, fissile to hackly, petroliferous shale that weathers dull grayish yellow to yellowish gray. It contains scattered to abundant concretions and lenses and local beds of petroliferous limestone that is gray to brown or black and commonly contains layers or patches that are light yellowish gray to tan in color. Numerous irregular pellets and occasional tiny fossils superficially resembling oöids are a characteristic feature of these limestones. Acetic acid residues of samples of this oölitic-looking limestone from some localities contain numbers of tiny

[3] *Nuculoceras incisum* (Hyatt), *N. barnettense* Plummer and Scott, *Goniatites choctawensis* Shumard, *"Neoglyphioceras" (= Lyrogoniatites) entogonum* (Gabb), *"Neoglyphioceras" (= Lyrogoniatites) newsomi* (Smith), *"Adelphoceras" (= Girtyoceras) meslerianum* Girty, and *Eumorphoceras bisulcatum* Girty.

fossils, mostly nepionic goniatites. Characteristic fossils are *Leiorhynchus carboniferum* Girty; an unusual small *Linoproductus*, specifically identical with one from the Moorefield equivalent in Cherokee and Muskogee counties, Oklahoma; species of *Caneyella, Aviculopecten,* and *Posidonia;* and species of *Goniatites, Lyrogoniatites, Girtyoceras, Cravenoceras,* and *Eumorphoceras.*

The lithic character and faunas of the shale facies of the Barnett formation are well displayed in a 50-foot section at the Plummer and Scott locality 205–T–24, mentioned above. At this place fossils were collected from limestone concretions and beds at three different stratigraphic positions by G. A. Cooper and Cloud in February, 1946. From a 7- to 9-inch limestone bed, ranging, because of overlap, from 3 to 8 feet above the base of the formation, and in part concretionary; they obtained *Leiorhynchus carboniferum* Girty, *Caneyella* cf. *C. wapanuckensis* Girty, *Parallelodon* sp., *Goniatites cumminsi* (Hyatt), *Lyrogoniatites newsomi* (Smith), *L. entogonus* (Gabb), *Girtyoceras* sp., *Cravenoceras* cf. *C. hesperium* Miller and Furnish, and *Eumorphoceras* sp. From limestone concretions 14 feet below the top of the formation, small *Caneyella, Goniatites* sp., *Cravenoceras* cf. *C. hesperium* Miller and Furnish, and *Eumorphoceras bisulcatum* Girty were obtained. Two feet below the top of the formation *Leiorhynchus carboniferum* Girty and small *Linoproductus* were obtained. There are thus associated in the same beds goniatites that would be regarded by some as evidence of widely divergent stratigraphic position (e.g,. *Eumorphoceras* and *Goniatites*). Moreover, neither physical evidence nor the evidence of the conodonts will support subdivision of the Barnett strata at this place. It is important, therefore, to reëxamine the correlation of the Barnett formation.

The Barnett formation was considered to be probably Pennsylvanian at the time of its description (Plummer and Moore, 1921, p. 32), but is now generally accepted as Mississippian. The published discussion, through which the Barnett formation came to be accepted as Mississippian, was participated in by Girty, Goldman, Moore, Plummer and Moore, and others. It is a matter of historic interest only, but the correlation of the Barnett formation within the Mississippian is a question of present concern. The history of its correlation from 1926 to the present report is graphically shown in figure 4.

In 1926 Girty correlated the Barnett formation with the lower Caney shale of Oklahoma and stated that their faunas were "strikingly similar to the Moorefield fauna in northern Arkansas" (*see* Roundy, Girty, and Goldman, 1926, p. 3). "The Moorefield," Girty wrote *(loc. cit.)* "is overlain by rocks that contain a whole series of faunas . . . universally recognized as of Chester age." He implied (*op. cit.*, p. 4), with qualifications, that the Barnett and the lower Caney, together with his Moorefield (equals Moorefield formation plus Ruddell shale of Gordon, 1944), were of pre-Chester age; but his provisional conclusion was that "the lower Caney (and therefore the Barnett) may represent the whole Moorefield-Fayetteville interval of the Arkansas section" (*op. cit.*, p. 4). Sellards (1932, pp. 91–94) cited Girty's earlier correlation of the Barnett formation but assigned a Chester age to it. More recently, correlation of the Barnett formation has been considered primarily on the basis of goniatite zones. The evidence of the goniatites, on which was based the views of Plummer and Scott (1937), Miller and Furnish (1940), and Gordon (1944) as summarized in figure 4, may be found by reference to the works of those authors as well as to that of Bisat (1936).

Correlation of the Barnett formation on the basis of goniatites alone, however, is rendered uncertain by discrepancies in the published conception of named goniatite species and of the geologic positions indicated by particular forms. Reference to papers by Plummer and Scott (1937, p. 114), Miller and Furnish (1940, p. 362), Gordon (1944), Hyatt (1893), Shumard (1863), and S. A. Miller (1889, pp. 439–440) leaves confusion as to what, if any, are the differences between *Gonia-*

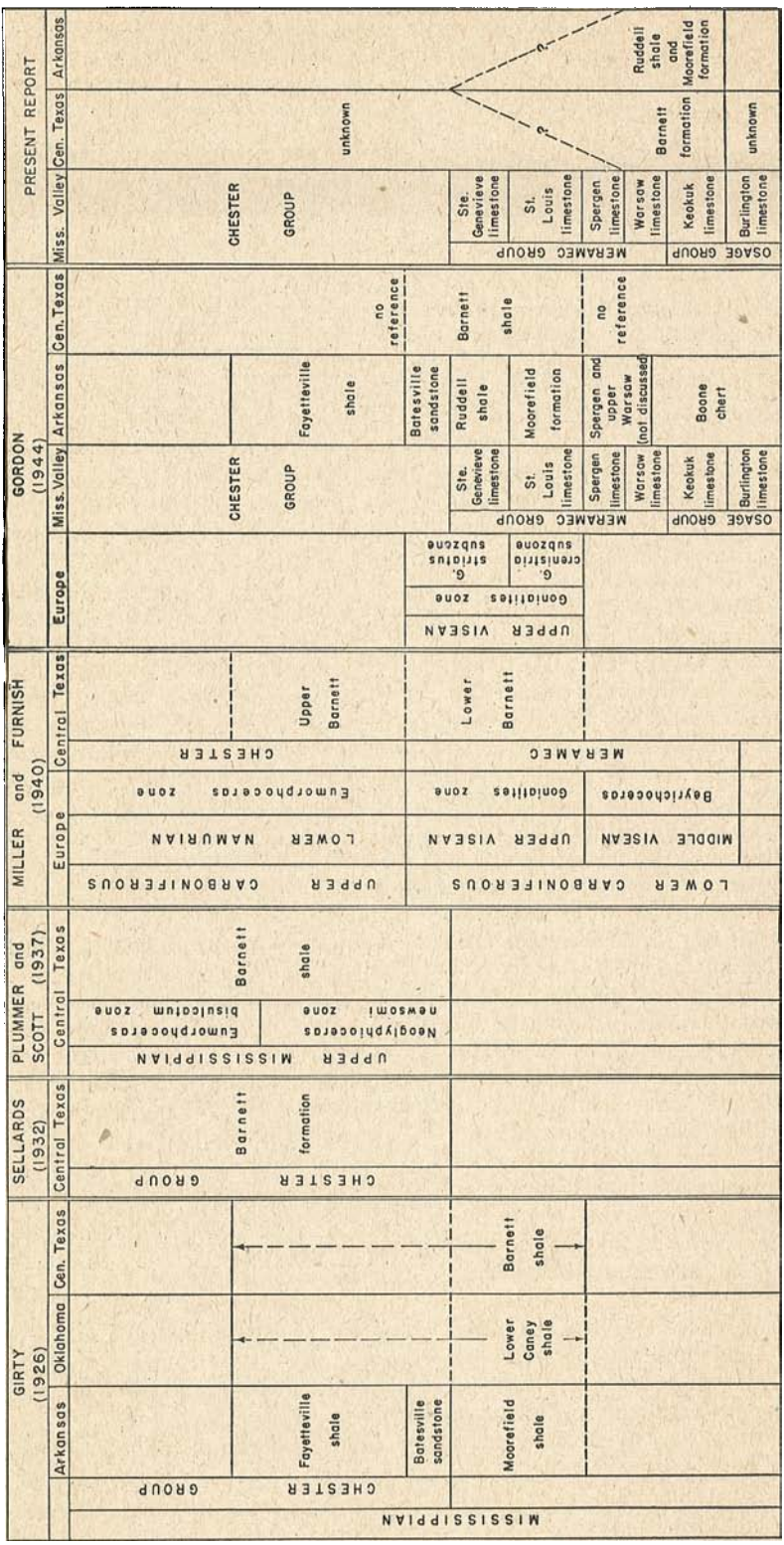

Fig. 4. Graphic history of the correlation of the Barnett formation, 1926 to 1946.

tites choctawensis, G. kentuckiensis, G. cumminsi, G. crenistria, and *G. striatus,* and what, if any, is the stratigraphic significance of possible specific distinctions in this closely similar group of shells. Plummer and Scott, as well as Miller and Furnish, state that the types of *Goniatites choctawensis* Shumard have been lost, neither has designated neotypes, and Shumard figured no specimens. The original figures of *G. kentuckiensis* S. A. Miller (1889, pp. 439–440, fig. 740, 2 views) are of an internal mold which does not show the important features of external ornamentation; and S. A. Miller does not discuss the external ornamentation. Of the other species discussed *G. crenistria* and *G. striatus* are European shells; but *G. cumminsi* is a Texas species whose types are extant.

Through the courtesy of Dr. F. L. Whitney, Hyatt's types of goniatites at The University of Texas were made available to Cloud for study (11/24/45). He found, as had been suggested by Miller and Furnish (1940, pp. 362–363), that the best specimen of *Glyphioceras cumminsi* Hyatt in the original type lot (Hyatt, 1893, Pl. 47, figs. 36, 37) had been refigured by Plummer and Scott (1937, Pl. 7, fig. 10) as a cotype of *Glyphioceras incisum* Hyatt. It is suggested that this specimen be designated the holotype of *Goniatites cumminsi* (Hyatt), and that that name be retained unless and until the type specimens or adequate illustrations of the types of any supposed senior synonym can be produced and demonstrated by comparison to be the same species, whether it be *G. choctawensis* or *G. kentuckiensis* or both. In the present report the name *Goniatites cumminsi* (Hyatt) refers to specimens that are slightly compressed laterally and resemble the holotype in having *Goniatites*-type sutures in which the adult bifid middle lobe is narrow and exceeds half the height of the bounding lateral lobes (Pl. 44, figs. 39–40). The ornamentation consists of prominent revolving lirae and fainter transverse threads (growth lines) resulting in a cancellate pattern. This cancellation is ordinarily clear enough to the hand lens, but, where the growth lines are subdued, it is commonly not readily evident to the unaided eye.

Although Gordon (1944) recognizes *Goniatites* of the type of *G. crenistria* (his *G. choctawensis* = *G. cumminsi* of the present report) as indicative of a zone distinct from and stratigraphically lower than *Goniatites* of the type of *G. striatus* (his *G. kentuckiensis*), Miller and Furnish (1940, p. 362) state that "in Northern England, *G. striatus* occurs with similar forms . . . generally regarded as specifically distinct and . . . grouped with *G. crenistria.*"

Goniatites, in the strict sense, is said by Miller and Furnish (1940, p. 358) to be "represented in only the Viséan," and they further restrict (p. 357) this *Goniatites* zone to the upper Viséan, which they correlate with the upper Meramec. The same authors have written (Miller and Furnish, 1940, p. 358) that an upper ammonoid fauna "of Chester age, which is characterized by *Eumorphoceras,* corresponds to the lower Namurian of western Europe." However, Plummer and Scott (1937, p. 15) record *Goniatites* in their *Eumorphoceras bisculatum* zone, and this association is confirmed by the work of the present authors (TF–422, TF–429, 205T–24). Shimer and Shrock (1944, p. 571) also have recorded "*Goniatites crenistria* Phillips" [presumably the same as *G. choctawensis* Girty of Gordon and *Goniatites cumminsi* (Hyatt) of the present report] from the Fayetteville shale of Arkansas, a formation generally considered to be Chester in age. Girty, himself, reported *Eumorphoceras bisulcatum* from about 30 feet below the top of his Moorefield shale at Howard's Wells in Independence County, Arkansas (Girty, 1911, pp. 141, 19–20). This would be about 30 feet below the top of the Ruddell shale of Gordon (1944) and there is no reasonable possibility of contamination at the locality mentioned. Gordon (1944) correlates the Ruddell shale with the Ste. Genevieve limestone, and to the best knowledge of the authors no one has yet correlated either the Moorefield formation or the Ruddell shale with beds of Chester age.

Additional complication is suggested by Dr. G. A. Cooper's discovery of an incomplete specimen strongly resembling the typically Pennsylvanian genus *Goniolobo-*

ceras[3a] in association with *Eumorphoceras* and with *Goniatites* and other fossils indicating equivalence to the Moorefield formation and Ruddell shale at locality TF–422 in the Bear Spring area. To confine discussion to unequivocally identified genera, it is seen that *Eumorphoceras,* supposed by some to indicate a Namurian age, and *Goniatites,* supposed to indicate a Viséan age, have been found in the same bed and even in the same concretion by the writers. The dilemma is obvious. It appears that convincing correlation between central Texas and European goniatite zones must await further study in both places, and that any tenable correlation of the Barnett formation with the Mississippian of the middle Mississippi Valley must take other evidence into consideration.

It is, therefore, fortunate for the correlation of the Barnett formation and equivalent strata that the fauna of the dark shale and petroliferous limestone facies has been found in direct association with limesands containing typical Keokuk brachiopods, thus establishing at least the lower limit of strata equivalent to the Barnett formation.

This happens in the Bear Spring area of Mason County, in the southwestern part of the Llano region. In this area the Barnett formation is in large part represented by white to light gray, coarse to medium grained, crinoidal limesands that in part go laterally and vertically to fine grained and sublithographic limestones and are separated by covered intervals or intervals of caliche that probably represent shale zones. In the Bear Spring area the relative proportion of the outcropping detrital limestones varies from 16 to 90 per cent of the total Barnett strata by actual measurement. Where the covered intervals or those of caliche, and therefore probably the shale, account for a large proportion of the section, the interbedded limestones are commonly petroliferous and darker than usual, and some are brown and conspicuously pelleted, like those that occur as concretions in the shales of the east and north. Moreover, like the concretionary eastern limestones, they yield a normal Barnett fauna with obvious resemblance to that of the Moorefield strata of Arkansas and Oklahoma.

These are important considerations, for it has been known at least since C. L. Dake's work in the area in 1931 that a fauna of Osage age occurs in white and pink-stained limesands at White's Crossing of Llano River. Although it has been supposed by some that these limesands belong to the Chappel limestone, the fact is that they rest unconformably on and overlap the dark rose to gray or olive gray, much less crinoidal, compact limestones of Chouteau age that comprise the Chappel formation; and at one locality in the west end of the panhandle of the Pat Rogers ranch a conglomerate bed was observed between the two. From the base of the limesands at White's Crossing, Dr. Edwin Kirk identified, in addition to the ubiquitous *Platycrinites,* species of *Orbitremites* and *Metablastus,* which he states (oral communication, March 18, 1946) are intermediate in aspect between upper Burlington and lower Keokuk forms. In addition to these, fossils such as *Spirifer logani* Hall, *S.* cf. *S. washingtonensis* Weller, *Brachythyris* cf. *B. suborbicularis* (Hall), *Orthotetes keokuk* (Hall), *Dictyoclostus* cf. *D. crawfordsvillensis* (Weller), *Echinoconchus* cf. *E. alternatus* (Norwood and Pratten), and a large species of *Leptaena,* found in the lower 20 feet of the white limesands at White's Crossing and at TF–418 indicate a Keokuk age for the beds in which they occur. Many other fossils occur at these localities in addition to those named; and some, such as *Orthotetes keokuk* (Hall), *Brachythyris* cf. *B. suborbicularis* (Hall), and *Echinoconchus* cf. *E. biseriatus* (Hall), range upward into higher beds at locality TF–418.

At White's Crossing the common Barnett and Moorefield brachiopod *Leiorhynchus carboniferum* Girty was found in association with the Keokuk fossils noted above. At locality TF–418 the genus *Goniatites* occurs with a normal Keokuk assemblage at 20 feet above the base of the limesand facies of the Barnett formation, and a well-preserved *Goniatites* occurs 92 feet above the base and 48 feet below the top of the same section. In

[3a]Dr. A. K. Miller and Mr. Walter Youngquist have in press a paper on the Barnett goniatites in which they assign this specimen to *Girtyoceras meslerianum* (Girty).

addition to the evidence of *Goniatites*, the equivalence of the limesand section at TF–418 with that containing a normal Barnett fauna at locality TF–422 is shown by the occurrence in both of identical species of *Pleurodictyum*, *Aviculopecten*, a small "*Spirifer*" resembling *S. bifurcatus* Hall, and a brachiopod with strong resemblance to *Diaphragmus fasciculatus* (McChesney). Of 10 specimens of the supposed *Diaphragmus* that were split longitudinally, only one showed a dorsal valve and its characters were not clear. However, one exfoliated dorsal valve is carinate at the point of geniculation, and suggests the presence of a diaphragm. This probable *Diaphragmus* occurs with the upper *Goniatites* at TF–418, and again 24 feet below it and 42 feet below the highest occurrence of *Orthotetes keokuk* (Hall) at the same locality. At TF–422 it occurs in petroliferous limestone interbedded with limesands and covered intervals suggesting shale. With it at the latter locality, in addition to normal Barnett fossils such as *Leiorhynchus carboniferum* Girty, small *Linoproductus*, *Aviculopecten* sp., and many *Goniatites*, are *Archimedes* sp., *Echinoconchus* cf. *E. genevievensis* Weller, "*Spirifer*" aff. *S. bifurcatus* Hall, *Dictyoclostus* cf. *D. inflatus* (McChesney), *D.* cf. *D. burlingtonensis* (Hall), *Eumorphoceras* cf. *E. bisculatum* Girty, and *Goniolobo-ceras* sp. Anyone familiar with the normally cited ranges of the fossils named will appreciate the conflicting testimony given by them, if interpreted in terms of these ranges.

The fact remains, however, that it has not been possible consistently to subdivide either the shale or the limesand facies of the Barnett formation on the basis of any evidence applied. In fact, at TF–420, in a zone of dark petroliferous limestone and shale at the middle of a 130-foot sequence of mostly very similar crinoidal limesands, the authors and G. A. Cooper found the following fossils in conflicting association: *Pleurodictyum* sp., *Orthotetes* aff. *O. keokuk* (Hall), *Brachythyris* cf. *B. suborbicularis*, small *Linoproductus*, *Productella hirsutiformis* Walcott, *Moore-fieldella* cf. *M. eurekensis* (Walcott), *Diaphragmus* (?), and other fossils. *Spirifer logani* was not found at this locality, although it and other Keokuk types of fossils were found in association with *Leiorhynchus carboniferum* Girty at White's Crossing (TF–184).

The conclusion that the white limesands of the Bear Spring area, including those that contain a Keokuk fauna at White's Crossing and at TF–418, are simply a facies of the Barnett formation, was reached from three lines of evidence. It was first suspected from mapping. It was later independently confirmed by W. H. Hass (letter to Cloud, October 31, 1945), who found that samples from the original Keokuk locality at White's Crossing contained typical Barnett conodonts, and that Barnett conodonts occurred from within at least 20 feet of the bottom to 10 feet of the top of the section at TF–418. And finally, in February 1945, G. A. Cooper and the authors cracked the white limestones and limesands until enough macrofossils were obtained, in addition to those previously collected, to establish that the normal Barnett fauna and that of the coarse white limesand facies are associated at TF–418 and TF–420.

Relationships very similar to those described for the Barnett formation in the present report were found by H. D. Miser between the Ridgetop shale and beds of crinoidal limestone in the Waynesboro quadrangle in western Tennessee over 30 years ago and were described by G. H. Girty in 1915. Girty pointed out that "the fauna of the Ridgetop shale . . . strongly and obviously resembles the fauna of the Moorefield shale," whereas the crinoidal limestones that were considered to be laterally equivalent to the Ridgetop shale by Miser contain a fauna that "in many respects presents a typical Burlington facies." The fauna of the limesand facies of the Barnett formation at White's Crossing certainly has some Burlington aspects, although they appear to be outweighed by Keokuk affinities, and the facies changes displayed by the Barnett formation suggest those shown by beds of Ridgetop age.*

The salient faunal elements of the shale facies of the Barnett formation—*Leiorhynchus carboniferum* Girty, rare specimens of *Moorefieldella*, a small *Linoproductus*,

*See also Wilson, C. W., Jr., and Spain, W. L., Jr., Age of Mississippian "Ridgetop shale" of central Tennessee: Bull. Amer. Assoc. Petr. Geol., vol. 20, pp. 805–809, 1936.

species of *Caneyella*, *Goniatites*,[4] and *Eumorphoceras*—strongly indicate correlation with the Moorefield formation and Ruddell shale of Arkansas and strata of Moorefield age in Cherokee and Muskogee counties, Oklahoma. Wherever the Barnett formation fits into the standard section a large proportion of the Moorefield and Ruddell strata, the lower Caney shale, the Ridgetop shale, and other correlative rocks must also fit. The reverse, of course, is also true; but it may be noted that correlation of these other rocks with the formations of the middle Mississippi Valley has been based largely on elements (goniatites) which, to judge from the lack of published references, are extremely rare in those formations, and the cited ranges of which have been here shown to be open to question. In fact, although the most recent study provisionally reiterates the view that the Moorefield fauna is approximately St. Louis in age, its author states (Gordon, 1944, p. 1631) that "direct evidence to support this correlation is still lacking."

Although Gordon (1944, p. 1629) states that the uppermost beds of the Boone formation, on which the Moorefield formation rests, are lower Warsaw in age, Girty (1915, p. 15) wrote of the same beds that he found "nothing in the Boone indicating an age younger than the Keokuk." Indeed Girty states (1915, p. 17) that "the peculiar Spring Creek fauna (equals Moorefield fauna of Gordon) need not necessarily be placed above the Keokuk in the time scale."

The present authors submit that the evidence obtained at and in the vicinity of White's Crossing in the Bear Spring area of central Texas is cogent reason for believing that the base of the Barnett formation correlates with strata at least as old as and probably not older than the Keokuk limestone. The upper age limit of the beds in question is an open subject, and one that cannot satisfactorily be settled without a more intensive study of the faunas of the Barnett formation and its possible correlatives than has yet been made.

[4]Ostracods and conodonts occur in both the limestones and the shales of the Barnett formation and should be helpful in subsurface studies. A species of a compound coral resembling *Pleurodictyum* is common in the Barnett in Mason County.

Without doubt the possible *Goniolobo-ceras* can be discounted as a dating element, but there are other fossils that favor partial correlation of the Barnett formation with post-Keokuk strata. *Echinoconchus* cf. *E. biseriatus* (Hall) and "*Spirifer*" aff. *S. bifurcatus* Hall suggest Warsaw and Spergen equivalence; *Archimedes* is uncommon below the Warsaw limestone; *Echinoconchus* cf. *E. genevievensis* Weller suggests Ste. Genevieve equivalence; and *Diaphragmus* (?), suggests a Ste. Genevieve or Chester age. *Eumorphoceras* is also considered by most students[4a] of goniatites to indicate a Chester (lower Namurian) age and the *Dictyoclostus* here compared with *D. inflatus* (McChesney) might be considered by some to indicate a Chester age. However, of the elements noted, *Echinoconchus biseriatus* occurs in strata of Moorefield age in Cherokee and Muskogee counties, Oklahoma, and is recorded from the Keokuk by Moore (1928, p. 215); the "*Spirifer*" compared with *S. bifurcatus* is clearly a new species and cannot be considered an important dating element; it also occurs in shale of Moorefield age in northeastern Oklahoma; *Archimedes* has been recorded from the Keokuk limestone (Moore, 1928, pp. 208, 209); *Echinoconchus genevievensis* may be but a variety of the Keokuk fossil *E. alternatus* (Norwood and Pratten) and is too similar to be critical; *Eumorphoceras* is of doubtful correlative value; and a variety of *Dictyoclostus inflatus* similar to the one here noted occurs in the Moorefield (Girty, 1911, p. 42, Pl. 4). *Diaphragmus* (?) cf. *D.? fasciculatus* (McChesney) alone remains, but a fossil that was enough like *Diaphragmus* to be identified by L. R. Laudon as *Diaphragmus elegans* is reported by him (Laudon, 1939, p. 329) to be common in the Keokuk equivalent of northeastern Oklahoma in association with *Orthotetes keokuk* and *Spirifer logani*. The specimen of *Diaphragmus*, figured by Girty (1911, Pl. 4, fig. 4) as coming from the Moorefield strata at Spring Creek, in the Batesville District of Arkansas, and said by

[4a]A. K. Miller (Bull. Geol. Soc. Amer., vol. 59, pp. 117, 118, 1948) now indicates *Eumorphoceras* to be restricted to the lower Meramecian. The present authors would extend its range-line downward into the Keokuk and leave it as probable (Bisat, 1936) that it also ranges upward into rocks of Chester age (Namurian, in part).

Gordon (1944) to be a contaminant element, is very like the *Diaphragmus* (?) that occurs in the Barnett formation. This specimen is from a collection made by H. S. Williams in 1890 (Girty, 1911, pp. 12–14) at a locality over 2 miles northeast of and across White River from the nearest Fayetteville outcrops (*see* map by Gordon and Kinney, 1944).

Despite its lateral gradations the Barnett formation, in the full normal development of either the shale facies or the lime-sand facies, is compact and seemingly indivisible. The lower limit of its age is virtually fixed as Keokuk, but the upper limit might be as high as Ste. Genevieve. The present authors consider it extremely unlikely that any part of the Barnett formation is as young as Chester in age, and it is their opinion that it is actually entirely pre-St. Louis if not pre-Spergen. The greater number of species from the middle Mississippi Valley region that compare closely with Barnett species are either restricted to the Keokuk limestone or are known to occur in it. It is possible, therefore, that the Barnett formation and its correlatives, although provisionally referred to Keokuk plus Warsaw, are wholly of Keokuk age.

Pennsylvanian

In the Llano uplift, rocks of Pennsylvanian age do not ordinarily rest directly on strata of the Ellenburger group. For this reason it is not necessary in connection with the Ellenburger problem to consider the Pennsylvanian rocks in the detail demanded by the more commonly overlapping Mississippian strata. Various stratigraphic units of Pennsylvanian age have been mapped under a single symbol on some of the geologic maps accompanying the present report, and only in the southeastern part of the uplift (Johnson City area) have units been differentiated in the "Marble Falls limestone."

Brief discussion of the Marble Falls limestone and of the structural information furnished by the overlapping strata of Canyon age is pertinent to the Ellenburger study.

Moore and others (1944, p. 697) state that "studies by Plummer indicate that the so-called Marble Falls limestone really consists of two distinct formations, the lower of which is Morrowan in age and the upper post-Morrowan," and they restrict the name Marble Falls to the strata of Morrow age. Now whether or not both "formations" are present in the vicinity of the town of Marble Falls (Thompson, 1944; pp. 417, 423; Plummer, 1945, p. 66; Spivey and Roberts, 1946, p. 183; Thompson, 1947, p. 149), the waterfall there is over the highest post-Morrow beds in the type section, and post-Morrow beds are much more widely distributed in central Texas than are beds of Morrow age, occupying the larger part of the areas shown as "Marble Falls" on present maps. It is to be regretted, therefore, that the Pennsylvanian subcommittee chose as it did. A final decision on this important matter should consider the type section, general usage, and areal distribution; preferably restricting the name Marble Falls to the rocks most generally known by that name, that is, the beds of post-Morrow age, or retaining it in unrestricted usage as a group name. The present authors favor restricting the term Marble Falls limestone as a formation name to apply to post-Morrow beds below the Smithwick shale; but that is a problem demanding more extended study than they have made, and the Marble Falls limestone (unrestricted) of the present report locally includes strata that contain a Morrow fauna (pp. 229–230, 318), as well as younger Pennsylvanian beds. The beds of Morrow age, at least locally and perhaps commonly, contain limestone lenses suggesting bioherms possibly of organic origin, and they are unconformably overlain by the younger Pennsylvanian strata. However, the two are generally similar gray to black, fine grained limestones containing black to speckled gray, nodular chert. Fusiform fusulines have not been seen in the strata of Morrow age but occur locally in both limestone and chert of the post-Morrow beds. In the Bald Ridge and Bear Spring areas, near the western edge of the Llano region, beds of Morrow age are absent, and the lowest beds of the Marble Falls limestone contain *Fusiella*. Globular glauconite and phosphate pellets are commonly abundant in the basal foot of the Marble Falls limestone and have been observed locally as scattered pellets in higher strata. In the Bear Spring area, at the western

edge of the Llano region, scattered to abundant, highly colored, sub-rounded to angular, small chert pebbles occur at the base of the Marble Falls limestone.

The Smithwick shale and beds of the Strawn formation are not known directly to overlap Ellenburger strata in the Llano uplift. However, undisturbed beds of Canyon age have been observed to overlap faulted strata of the Tanyard formation in western McCulloch County, south of the village of Calf Creek, on the Blockhouse ranch. Inasmuch as the faults which cut the Ellenburger rocks also transect the Marble Falls limestone and Smithwick shale, and probably locally the Strawn formation, but not the strata of the Canyon group or younger formations, it is evident that the major faulting in the Llano region after pre-Cambrian time was a post-Smithwick and pre-Canyon event. Evidence is not at present clear as to whether faulting occurred during Strawn time, or whether it was entirely a post-Strawn and pre-Canyon event.

REGIONAL CORRELATION

INTRODUCTORY REMARKS

The Ellenburger group is but a part of a Lower Ordovician series of mostly carbonate rocks that occur widely at and below the surface of the mid-Continent region. To understand its place in this series requires consideration of its regional stratigraphic and facies relationships.

The critical sites of outcropping Lower Ordovician rocks are those which may be said to rim a broadly conceived Permian basin region—the Llano and Marathon uplifts, both of which are topographic basins; the Sierra Diablo; the Hueco Mountains; the Franklin Mountains; the Rocky Mountain Front; and the Wichita and Arbuckle Mountains of Oklahoma. Petroleum production from the Lower Ordovician of the Permian basin region and the structural highs that limit it is doubtless not restricted to strata of the facies revealed in the Llano uplift, and a fuller comprehension of the variations displayed by these rocks in their various areas of outcrop is desirable. Reconnaissance studies of the lower Paleozoic rocks in the areas named were made, therefore; and the results of those studies, as well as a discussion of the important Ozark sequence and brief consideration of other areas, is here given.

The conclusions suggested are provisional. The time spent in the field in the various areas discussed was necessarily limited. The physical aspects of correlative strata vary considerably from one region to another and cannot ordinarily be relied upon for correlation. The faunal evidence, which is necessarily the basis of regional correlation, is not uncommonly conflicting. In some instances it is a case of one so-called index fossil against another and adjudication between such contendents involves philosophical considerations with which some may disagree. The published faunal evidence itself is so scattered and commonly so difficult to interpret that some has probably been missed completely or misinterpreted. Even where faunal evidence is good, the limits within which unit boundaries may fall are not ordinarily as closely restricted as could be desired. It is evident that painstaking biostratigraphic studies in many regions will be required to solve all of our problems satisfactorily; but as a temporary measure the authors propose to state the evidence at hand, indicate contradictions, suggest reasonable inferences, and reserve the right to change their minds where new evidence so advises.

The correlations suggested are individually discussed in the ensuing pages and summarized on Plate 15.

The discussions that follow are scaled to the importance of the region considered in relation to the Ellenburger problem, the amount of data available, and the adequacy of the previously published record. Descriptions of three sections in Trans-Pecos Texas and central Colorado and lists of fossils from two sections in Oklahoma are given in Part 3 of this report, and the reader is referred to published descriptions of important sections. Because the authors understand the sequence of faunas in the Ellenburger group more clearly than in other Lower Ordovician strata, it is thought advisable to refer to faunal equivalents in terms of the various units of the Ellenburger in

so far as practicable. Above rocks equivalent to the Honeycut formation it is necessary to go to the Ozark sequence of Missouri and northern Arkansas for names. Naturally, strata younger than the Honeycut formation are also younger than the Ellenburger group of the Llano uplift, and it is of special interest that the upper half of the El Paso formation at the south end of the Franklin Mountains and its upper two-thirds at the north end of Beach Mountain appear to be of post-Honeycut age.

Two minor nomenclatural revisions are considered advisable as a result of the regional field studies made. The El Paso "limestone" of previous authors contains limestone, dolomite, minor sandstone, and local shale beds and is therefore referred to as the El Paso formation in the present report. Likewise the so-called Manitou "limestone" is largely dolomite at many localities, and is here called the Manitou formation. It is recognized that further nomenclatural revision may prove desirable, but provisional faunal and physical subdivisions of well-known stratigraphic divisions of a composite nature are here indicated by letter only, pending detailed studies of the rocks in question.

Attention is invited to the fact that one of the most persistent faunal and physical breaks in the strata considered is between probable correlatives of the Tanyard and Gorman formations. This is essentially the position at which Ulrich last placed his "Ozarkian-Canadian" boundary (*see* Ulrich and Cooper, 1938, Pl. 58). It should be kept in mind in the ensuing discussion that Ulrich's Ozarkian system straddles the Cambrian-Ordovician boundary and that his Canadian system extends essentially from the boundary between the faunal equivalents of the Tanyard and Gorman formations through the Lower Ordovician of most geologists. It is also worth noting that, whereas fossils in the Gorman and Roubidoux formations and their correlatives are generally scarce and largely undescribed, the more commonly occurring faunas of the normally underlying and superjacent rocks are fairly diversified and reasonably well known. The extension into rocks of Gorman-Roubidoux age of the stratigraphic ranges of certain fossils generally supposed to be restricted to higher or lower beds should, therefore, not cause surprise.

The studies on which were based the regional correlations here offered were greatly facilitated by the availability of the splendid reports on "Ozarkian and Canadian" fossils by E. O. Ulrich and co-authors G. A. Cooper, A. F. Foerste, A. K. Miller, W. M. Furnish, and A. G. Unklesbay (1938, 1942, 1943, 1944). These reports contain some stratigraphic inconsistencies, but they have at the same time furnished the tools for solution of these inconsistencies, and their publication should greatly stimulate needed biostratigraphic studies of the Lower Ordovician rocks. Such studies in the vicinity of Phillipsburg, Quebec, for instance, might serve to answer some of the most vexing problems of faunal distribution (*see* Ulrich, *in* Ulrich and Cooper, 1938, Pl. 58, and pp. 69–70 of the present report).

Inasmuch as the correlations suggested are based upon the opinions of the authors of the present report about the ranges of fossils in particular regions, some of these *opinions*, most of them not original, are here summarized:

1. *Billingsella, Eoorthis, Huenella, Owenella,* and saukiinid trilobites are restricted to Upper Cambrian rocks equivalent to the Wilberns formation.
2. Any strata containing cephalopods of other than the most primitive types are suspected to be post-Cambrian.
3. *Ophileta* and *Lytospira (Ecculiomphalus* of some authors) first appear at the base of the Lower Ordovician, although *Ophileta* has a long range within the Lower Ordovician and *Lytospira* within the Ordovician.
4. *Helicotoma* of the type of *H. uniangulata, Ozarkina, Gasconadia, Clarkoceras,* and other fossils whose ranges in central Texas are shown on Plate 14 are restricted to strata of Tanyard age.
5. The presence of either piloceratid siphuncles or coiled cephalopods indicates post-Tanyard strata, but several types of coiled cephalopods range much lower than has previously been supposed.
6. *Clarkella* and *Tetralobula* suggest a Tanyard age but range into strata of Gorman age. *Syntrophina* likewise occurs in strata of both Gorman and Tanyard age and is recorded from the Upper Cambrian by Ulrich and Cooper (1938, p. 219).

7. *Diaphelasma* (*see* item 8, below), *Syntrophinella*, and *Lecanospira* are considered to mark equivalents of the Gorman formation. *Rhombella* (formerly called "*Roubidouxia*") generally denotes a Gorman age, but ranges into younger strata.
8. *Barnesella* (of which "*Maclurea*" *affinis* is a species) ordinarily occurs only in strata younger than the Gorman formation. This fossil and *Diaphelasma* occur together at the top of the Manitou formation, and it is uncertain which should there be considered the dating element. In general, small macluritids suggest high Lower Ordovician.
9. *Xenelasma* marks the lower part of the Honeycut faunal equivalents.
10. *Orospira* is probably restricted to rocks of Honeycut age.
11. Other fossils, whose ranges in central Texas are shown on Plate 15, serve to identify rocks of Honeycut age.
12. *Ceratopea* is invariably of post-Gorman age, and various forms are useful as index fossils to particular zones.
13. *Tritoechia* occurs in strata of Honeycut age and ranges through strata equivalent to the Black Rock formation, but most species are probably post-Honeycut. *Archaeorthis* begins in rocks of Honeycut age and ranges through strata equivalent to the Black Rock formation.
14. *Hesperonomia*, *Diparelasma*, *Polytoechia*, *Syntrophia*, and most species of *Syntrophopsis* mark strata younger than the Honeycut formation.
15. *Syntrophopsis magna* Ulrich and Cooper, *Buttsoceras*, and trilobites and snails of "Middle Ordovician" aspect occur in strata equivalent to the Black Rock formation, the highest known Lower Ordovician. *Diparelasma typicum* Ulrich and Cooper, suggests, but does not prove, the same correlation.

MISSOURI AND ARKANSAS

Ozark Region

Perhaps the most intensively studied and best known sequence of lower Paleozoic rocks of the carbonate facies in North America is that of the Ozark region in Missouri and northern Arkansas, and this sequence serves as a standard to which other sections in the carbonate facies may be referred. Its stratigraphy has been made known through the efforts of many workers, and salient faunal elements of its rocks have been described.

Although the following brief remarks necessarily lean heavily on the published record, they owe much to the informal teachings of Drs. Josiah Bridge and J. S. Cullison and are supplemented by a somewhat casual acquaintance with the Missouri section on the part of Cloud. For further discussion of the early Paleozoic rocks of the Ozark uplift, their faunas, and their siliceous residues, the reader is referred to Josiah Bridge (1930), C. L. Dake (1930), H. S. McQueen (1931), and J. S. Cullison (1944).

The fossils leave little question as to where the correlations are between the Ellenburger rocks and those of the Ozark region, although actual placement of the boundaries of the Roubidoux formation needs clarification. Comparison of the few illustrations of Ellenburger fossils in the present report (Pls. 38–43) with published illustrations of the Lower Ordovician faunas of Missouri will show the reader some of the reasons for these correlations. Briefly, the fossils indicate that the equivalent of the Tanyard formation in the Ozark region is the Gasconade dolomite (including the Van Buren "formation"), the correlative of the Gorman formation is the Roubidoux formation, and the Honeycut formation includes most of Cullison's Jefferson City group. Of the 1600 to 1700 feet of Lower Ordovician strata in the composite Ozark section (about 2200 if cumulative maximum thicknesses are taken), the upper 700 to 800 feet apparently have no representatives in the Llano region.

Of all the correlatives of the Ellenburger group with which the authors are acquainted, those in the Ozark and southern Appalachian regions are most similar to it in faunal facies and types of chert. In Missouri the rocks equivalent to the Ellenburger group consist of cherty dolomite and thin sandstone beds. Apparently limestone is absent in the rocks equivalent to Ellenburger strata, although present in the younger strata of the Smithville and Black Rock formations in the Ozark region.

The Gasconade dolomite, averaging perhaps 300 feet thick, has a sandstone member at its base locally (the Gunter sandstone), apparently does not show important grain size distinctions from the rocks immediately above and below, and contains compact white cherts near its base (Bridge, 1930, p. 104) as well as in the

upper part (Bridge, 1930, p. 113). Otherwise it has a general resemblance to the Tanyard formation where the latter is in the dolomitic facies, and the faunas of the two are strikingly similar.

The Roubidoux formation, averaging about 120 feet thick, is characterized by interbedded sandstones and dolomites. Commonly three of the sandstone intervals are more prominent than others and express themselves topographically. Curiously, although sand is scarce in the Lower Ordovician of central Texas, the Gorman formation, which is the faunal equivalent of the Roubidoux here, is to some extent characterized by the presence of sand. It seems to be a general truism in Missouri, the Appalachians, and central Texas that the Roubidoux correlatives are apt to be poor in both number and variety of fossils. Of the described faunal elements, *Lecanospira* and *Rhombella* are the most generally known. Their general order of appearance in strata equivalent to the Roubidoux formation seems to be *Rhombella* at the base and *Lecanospira* a little higher, with both ranging to the top. At a few places *Lecanospira* has been seen in the basal strata. The experience of the writers in central Texas leads them to agree with Bridge (1930, p. 123) that the zone of *Syntrophina campbelli* (Walcott) is at the base of the Roubidoux formation and not the top of the Gasconade dolomite as stated by Ulrich and Cooper (1938, p. 218). The present report does not support Kirk's implication (1934, p. 457) that the "Roubidoux equivalent (in central Texas) of Dake and Bridge (1932) . . . does not range lower than the Jefferson City."

The Jefferson City group of Cullison (1944), about 530 feet thick and including his Rich Fountain and Theodosia formations, is a zone of dolomites with beds and lenses of sandstone up to 12 feet thick. The "cotton rock" which characterizes much of this formation is evidently the result of partial leaching of very fine grained silty dolomites (Cullison, 1945, p. 49). Although fossiliferous cherts of the cannonball type occur in both units, there is little actual similarity between the rocks of the Jefferson City group and those of the Honeycut formation. Faunal correspondence, however, is striking. This is especially true of the Rich Fountain fauna, representatives of which may be found in the lower 250 to 350 feet of the Honeycut formation in Texas. It was not possible, on the basis of present studies, to recognize within the Honeycut formation clear-cut units equivalent to the Rich Fountain and Theodosia formations, but it is evident that both are represented.

No rocks younger than the Jefferson City group were recognized in central Texas, although the El Paso formation of Trans-Pecos Texas includes strata as young as the Black Rock formation of Missouri. Except that they are in the carbonate facies in both regions there is no apparent physical similarity between the post-Jefferson City rocks of the Ozark uplift and equivalents in west Texas.

OKLAHOMA

Arbuckle and Wichita Mountains

The Lower Ordovician and Upper Cambrian rocks of the Arbuckle and Wichita Mountains have been described by C. E. Decker (1939), Decker and Merritt (1928), and E. O. Ulrich (1932); and the position of the Cambrian-Ordovician boundary has been discussed by Josiah Bridge (1936) and E. A. Frederickson, Jr. (1941). Under the guidance of C. E. Decker, W. E. Ham, H. A. Ireland, and R. H. Dott the authors spent four days in the spring of 1944 studying lower Paleozoic sections in the Arbuckle and Wichita Mountains. Previously Cloud spent a day at the well-known section along U.S. highway 77 between Davis and Ardmore (in December, 1943), guided by H. A. Ireland, and in company with A. P. Wishart and R. L. Heller. Upon data obtained during these reconnaissance field studies, as well as on the published record, the following discussion is based.

Although the Lower Ordovician rocks of the Arbuckle and Wichita Mountains are in the carbonate facies, they differ from those of the Ellenburger group in many important features. Rocks equivalent to the Ellenburger strata are almost twice as thick, contain dissimilar chert

and little of it, contain much larger amounts of clastic material in the form of disseminated sand and shale and interbedded shale, and were obviously better supplied with clastic materials at the time of their deposition. The Arbuckle sequence is, in fact, quite the thickest section of Lower Ordovician and late Cambrian carbonate rocks in the mid-Continent region, totaling about 7000 feet of rocks correlative with the Wilberns formation, the Ellenburger group, and Lower Ordovician rocks younger than the Ellenburger. Computations and provisional location of faunal boundaries in the Arbuckle Mountains by the present authors indicate that about 3200 feet of Arbuckle rocks are equivalent to a generalized section of 1730 feet of Lower Ordovician in central Texas.

The faunal facies of the formations of Oklahoma is like that of the El Paso formation of the Franklin and Hueco Mountains in west Texas, being characterized by brachiopods. It contrasts with the predominantly molluscan faunas of the Lower Ordovician in central Texas, the Ozark region, and the southern Appalachians.

Physical distinctions between the Lower Ordovician formations in the Arbuckle and Wichita Mountains are not conspicuous, and the boundaries between them were not readily apparent to the authors. However, the presence of faunal units essentially corresponding to the named formations is evident, and failure to see the boundaries can be explained by any combination of the following possible factors: (1) unfamiliarity with the area or lack of discernment on the part of the authors, (2) absence of well-defined boundaries, or (3) evidence for subdivision not yet adequately worked out. Evidently the vicinity of the Arbuckle and Wichita Mountains was the site of much more active sedimentary accumulation than central Texas or the Ozark region, and it is possible that continuous sedimentation may have there obscured boundaries that are elsewhere well defined. It is fundamental to stratigraphic thinking to keep in mind that the more complete the sedimentary record is, the fewer and the less conspicuous are stratigraphic breaks apt to be. That refinement in the criteria for subdivision of the Arbuckle group is possible is indicated by the probability that some of the formation boundaries indicated by Dr. Decker (1939) fall at different stratigraphic levels in the Wichita Mountains from their placement in the Arbuckles, and by the observed fact that the lithic boundaries between calcitic and dolomitic units in the Cambrian part of the section are widely transitional.

Provisional correlation and unit thicknesses within the Arbuckle group are summarized on Plate 15 under sections 5 and 6. The basis for this correlation is wholly faunal. Some of the supporting faunas are listed in Part 3 of the present report and reference to them is indicated on Plate 15 by locality numbers. The others are listed by Decker (1939), in his described sections, from identifications said to be in large part made by Drs. G. A. Cooper and Josiah Bridge. Reference to Decker's report of 1939 is indispensable to critical consideration of the correlations suggested on Plate 15.

The Lower Ordovician of the Arbuckle and Wichita Mountains, where not overlapped by younger beds, includes beds of all ages represented in the Ellenburger group, as well as strata as young as the Odenville limestone of Alabama, the Black Rock formation of the Ozark uplift, and Unit C of the El Paso formation of Trans-Pecos Texas. In general the McKenzie Hill formation seems to be about of Tanyard age, the Cool Creek formation about of Gorman age, the lower two-thirds of the Kindblade formation of Honeycut-Jefferson City age, the upper third of the Kindblade formation and probably the lower part of the West Spring Creek formation of Cotter age, and the bulk of the West Spring Creek formation of Powell, Smithville, and at least locally of Black Rock age. Ulrich and Cooper (1938, p. 235) report the occurrence of *Syntrophopsis magna* Ulrich and Cooper near the top of the Arbuckle group in the Ardmore quadrangle not far west of the Chapman ranch section, and the same species occurs in the Odenville limestone,

the Black Rock formation, and Unit C of the El Paso formation at El Paso.

There is no reason to doubt that determined search would reveal enough faunal evidence to permit fairly close placement of faunal boundaries through much of the Arbuckle group. Physical distinctions are apt to become more evident once faunal divisions are closely worked out and coördination of the two lines of evidence may eventually permit the recognition of clearer unit boundaries than at present.

TEXAS

Marathon Basin

Outcrops of Lower Ordovician rocks in Texas occur in isolated basins, plateaus, or mountains, where erosion or uplift has brought them to view. Of these, the nearest to the Llano uplift is the Marathon basin, a structural uplift of basinlike topography. Here is exposed the Marathon limestone and the thin Alsate shale described by P. B. King (1931, pp. 1066–1070; 1937, pp. 26–32, Pl. 2). The writers and Mr. L. E. Warren, under the guidance of Dr. Josiah Bridge, spent two days studying and collecting from the Marathon limestone in November, 1944 (especially section number 4 of King, 1937, Pl. 2), and Dr. J. B. Knight and Cloud made additional collections from the Monument Spring dolomite member of the Marathon limestone on Alsate Creek in July, 1945 (*see* King, 1937, fig. 12). Edwin Kirk (1934, pp. 451–452) has discussed the correlation of the Marathon limestone and Alsate shale, and the present writers have little to add to his suggestions. The following discussion presents the salient described features of these rocks and adds a few previously unpublished data.

No sequence of Lower Ordovician rocks discussed in the present report is more persistently different from rocks of the Ellenburger group than the Marathon limestone and Alsate shale, unless it be the clastically contaminated carbonate rocks of the Ordovician part of the Arbuckle group in Oklahoma. In fact the Marathon and Arbuckle rocks are nearly intermediate in character between the purer carbonate facies of the Ellenburger group and the clastic facies that characterizes the Lower Ordovician of the Ouachita Mountains of Oklahoma and Arkansas.

Averaging, according to King, between 500 and 1000 feet thick, the Marathon limestone consists principally of dark gray to black, sublithographic, platy, argillaceous limestone, with interbedded shale and "scattered layers of conglomerate and sandstone" (King, 1937, p. 27), indicating its deposition near shore or within the range of offshore currents competent to carry such detritus. Only near the middle of the formation does it resemble any part of the Ellenburger group. Here heavy-bedded, medium to light gray, sublithographic, siliceous and very slightly dolomitic limestones weather light gray with yellowish to buff siliceous films and yield minor quantities of chert. These beds, named the Monument Spring dolomite member of the Marathon limestone, contain a mollusk-brachiopod fauna such as more normally characterizes Lower Ordovician rocks in the carbonate facies. In the interbedded limestones and shales above and below, however, only graptolites, inarticulate brachiopods, and sponges were found.

The Alsate shale is said by King to range from less than 20 to more than 100 feet thick and to consist of green shale with minor chert, limestone, and sandstone. Ruedemann (*see* King, 1931, p. 1070; 1937, p. 32) and Kirk (1934, p. 452) consider the Alsate shale to be of high Lower Ordovician age on the basis of graptolites, and Kirk (1934, pp. 452, 451) provisionally correlates it with the "uppermost horizon" of the El Paso formation (about Unit C), "although," he says, "it may fall somewhat lower."

Overlying the Alsate shale is the Fort Peña formation of King, the Middle Ordovician age of which is established, and beneath the Marathon limestone is the Upper Cambrian Dagger Flat sandstone, from limestone beds at the top of which Bridge, Warren, and the writers obtained the gastropod *Owenella* (TF–305), an upper Wilberns fossil in central Texas.

Evidence from the beds above and below thus seems to bracket the Marathon limestone as younger than the Wilberns formation (uppermost Cambrian) and older than Unit C of the El Paso formation (equivalent to the high Lower Ordovician Black Rock formation of Arkansas). Fossils obtained from the lower 100 feet of the Marathon limestone below the Monument Spring dolomite member by Bridge, Warren, and the writers were only an unidentified sponge, *Didymograptus* sp. and *"Lingula"* sp. (TF–304, 306, and 307); and correlation within the Lower Ordovician on the basis of these fossils would be difficult to defend. From the Monument Spring dolomite member itself were obtained *Calathium*, an unidentified sponge, cystoid plates and columnals, *Diaphelasma* sp., *"Orthis"* sp., unidentified gastropods, *Allopiloceras* cf. *A. coarctum* (Ulrich and Foerste), fragments of other piloceratid cephalopods, and a trocholitid cephalopod (TF–303, 308, 309, 310). This fauna is definitely post-Tanyard in age, and *Diaphelasma* indicates correlation with Unit A (the Gorman equivalent) of the El Paso formation. Unfortunately this fossil was found in float only and its derivation is not certain. *"Orthis"* and the trocholitid cephalopod suggest a post-Gorman age and there is no question as to their source. It seems best, in view of the conflicting evidence, to consider the assemblage listed as simply post-Tanyard. Above the Monument Spring dolomite member were procured *Phyllograptus, Didymograptus protobifidus* Elles, *Loganograptus, Dichograptus, "Orthis"* sp., and fragments of a piloceratid (?) siphuncle (TF–312, 301, 302). *Didymograptus protobifidus* Elles is said by Decker (1944, p. 383) to occur in the Smithville formation of Arkansas and 80 feet below the top of the West Spring Creek formation of the Arbuckle Mountains, in that portion of the formation which is of post-Cotter and pre-Black Rock age; so it is likely that about the upper 100 feet of the Marathon limestone is at least as young as Smithville in age.

What is known about the Marathon limestone, then, is that it is post-Cambrian and probably pre-Black Rock in age. Fossils of post-Tanyard age are known in the Monument Spring dolomite member of the Marathon limestone and fossils of Smithville or younger age above it. One may infer from this that the Marathon limestone and Alsate shale together are about equivalent to the El Paso formation and perhaps the Bliss sandstone of the Franklin Mountains. The reader who is inclined to further speculation is warned that no fauna of recognizable Tanyard age has been found in either the Marathon basin or the Franklin Mountains.

Sierra Diablo Region

Beach Mountain.—At the north end of Beach Mountain, in the southwestern part of the Van Horn quadrangle, southwestern Culberson County, 1115 feet of principally dolomitic rocks are assignable to the El Paso formation of Lower Ordovician age (*see* P. B. King and J. B. Knight, 1944). Above the El Paso formation is the Montoya limestone of Upper Ordovician age and below it is 125 feet of the so-called Bliss sandstone, of which the upper 8 feet contain Lower Ordovician fossils believed to be of upper Tanyard age. The Bliss (?) sandstone rests with angular unconformity on the Van Horn sandstone of Cambrian (?) or pre-Cambrian age and on known pre-Cambrian rocks.

The Beach Mountain section (Pls. 15, 16, and 29) displays a complete and well-exposed sequence of the El Paso formation, is readily accessible, and has been visited by many geologists. For these reasons, and because it offers the nearest good section of Lower Ordovician rocks west of the Llano region that can be closely correlated with those of the Ellenburger group, it is of foremost importance to regional conceptions of Lower Ordovician stratigraphy and is, therefore, described in detail in Part 3 of this report.

The following observations are based on information obtained during visits to the section by Josiah Bridge, L. E. Warren, and the authors on November 11, 1944; the authors on October 9 and 10 and November 10, 1945; and Josiah Bridge, John C. Dunlap, Ralph King,

Eugene Callaghan, and the writers on November 9, 1945. Particular thanks are due to Dr. Bridge, who made a special trip to the region to guide the authors to the locality at which Ordovician fossils were obtained from the Bliss sandstone, and to Mr. Dunlap who found the first and best specimens of the cephalopods obtained at this locality.

Although the Lower Ordovician of the Beach Mountain section can, within limits, be correlated faunally with that of the Llano region and the Franklin Mountains, there is little physical similarity between the rocks of the various faunal units in the regions noted. Sand occurs intermittently from bottom to top of the Beach Mountain section and forms prominent sandstone beds in the faunal equivalents of the Tanyard and Gorman formations. Very fine grained to microgranular dolomite characterizes the strata of the post-Gorman faunal equivalent. Glauconite occurs locally but is uncommon, and the section is essentially nonglauconitic. The Lower Ordovician rocks of the Beach Mountain section resemble those of the Llano region more closely than either resembles the intervening Marathon limestone; but specific similarities between correlative units, other than faunal, are few if existent.

The 1240 feet of pre-Montoya (Upper Ordovician) and post-Van Horn (pre-Cambrian or Cambrian[?]) rocks of the Beach Mountain section are readily divisible into four units, as follows:

The so-called Bliss sandstone of the vicinity of Beach Mountain is of particular interest to the present study. It consists of well-indurated beds of sandstone up to 2 feet thick, alternating with poorly indurated zones that contain considerable argillaceous material. Tests with dilute HCl show that most beds are slightly calcareous, and one 10-inch bed of dolomite was seen near the middle of the unit at the north end of Beach Mountain. The well-indurated sandstones commonly display numerous, closely spaced, slightly undulating, vertical tubes generally referred to as "*Scolithus*," although the name *Sabellarifex* R. Richter, 1921, has been proposed for the undulating vertical tubes as distinct from the straight ones. As was pointed out by P. B. King (1940, p. 154), the Bliss (?) sandstone of Beach Mountain is abruptly and disconformably succeeded by an interval of sandy and silty dolomite, dolomitic siltstone and sandstone, and much argillaceous material belonging at the base of the El Paso formation. Commonly up to 10 inches of the basal El Paso is a calcareous reworked sand, and locally it contains pebbles and cobbles of quartz and sandstone, one incompletely exposed cobble of sandstone in a section at the north end of Beach Mountain measuring 10 by 5 by 2 inches. Lower Ordovician fossils were collected from beds 4 to 8 feet below the top of the Bliss (?) sandstone on the west side of Beach Mountain, opposite the top of Tumble-

Stratigraphic unit	*Thickness in feet*	*Provisional correlation*
El Paso formation (1115 feet thick)		
Unit C (zone of earthy dolomites)	50	Black Rock fm. and Odenville ls.
Unit B (813 feet thick; zone of very fine grained to microgranular dolomite)		
Subunit B2 (a faunal division that is provisionally subdivided at the base of a 50-foot zone of repeated thin arenaceous intervals into an upper portion 331 feet thick called Subunit B2b and a lower portion 334 feet thick called B2a)	665	Strata of post-Honeycut and pre-Black Rock age.
Subunit B1 (a faunal division)	148	Honeycut fm.
Unit A (zone of sandstone, dolomite, and limestone)	252	Gorman fm.
Bliss (?) sandstone	125	Tanyard fm.
Total	1240	Lower Ordovician.

down Mountain, on a spur about 700 or 800 yards south of the abandoned shafts of the Dallas Mine (TF–438). They consist of fragmentary specimens of a cephalopod referred to the genus *Clarkoceras*,[5] *Lytospira* sp., *Ophileta* sp., cf. *Helicotoma* of the type of *H. uniangulata* (Hall), numerous cross sections and impressions of gastropods of debatable generic affinities, and many unidentified archaeostracan crustaceans. Dr. Bridge states that this is the locality from which C. L. Dake and he obtained gastropods and the trilobites *Hystricurus* cited by P. B. King (1940, p. 154) as evidence for the Ordovician age of the Bliss sandstone. The fossiliferous zone is below the highest well-indurated, slightly calcareous sandstone bed containing irregular tangential borings and a few "*Scolithus*" tubes and 19 feet above a bed containing the brachiopod *Lingulepis* (TF–438), generally regarded as an Upper Cambrian index fossil (*see* Cooper *in* Shimer and Shrock, 1944, p. 285). Although numerous casts and impressions and a few cross sections of gastropods were seen in and below the *Lingulepis* bed, none was found in place with or below *Lingulepis* that could unequivocally be said to be an Ordovician form, no *Lingulepis* was found in the upper zone with the Lower Ordovician gastropods, and no evidence of a break in sedimentation could be found between collections TF–437 (Ordovician) and TF–438 *(Lingulepis)*. However, archaeostracan crustaceans and a gastropod probably referrable to *Lytospira* were found immediately above but apparently in the same bed with *Lingulepis* at the north end of Beach Mountain (TF–438). Although the faunal evidence does not permit positive dating of the beds below the upper 8 feet, the abundance of gastropods in the Bliss (?) sandstone of the Beach Mountain sequence, below and with as well as above *Lingulepis*, is a feature unusual in Cambrian strata; and, in view of the striking similarity of the various portions of this sandstone the authors are inclined to regard it as a single unit and to agree with King and Bridge (*in* King, 1940, pp. 154–155) that it is probably of Lower Ordovician age throughout. This conclusion is supported by the presence of *Clarkoceras*, normally an upper Tanyard fossil, and *Hystricurus*, normally Tanyard or higher, at the top of the Bliss (?) sandstone. If *Lingulepis* be discounted and the disconformity at the top of the Bliss (?) be regarded as the Tanyard-Gorman boundary (discussed below), the Bliss (?) sandstone of the Beach Mountain section may be considered a correlative of the Tanyard formation of the Llano region.

Comparison of the Bliss sandstone of the type section in the Franklin Mountains with the so-called Bliss sandstone of the Beach Mountain section shows some similarities and many differences. Each is a thick basal sand, resting unconformably on the pre-Cambrian and overlain disconformably by the El Paso formation. In the Beach Mountain section this sand is 125 feet thick, in the Franklin Mountains it is about 300 feet thick. That in the Franklin Mountains is commonly quartzitic, mostly noncalcareous, and contains some prominently glauconitic beds in the upper half; that in the Beach Mountain section is well to poorly indurated but not quartzitic, for the most part slightly to moderately calcareous, and contains little if any glauconite but has considerable argillaceous material. The type Bliss contains

[5]Large cyrtendoceratid cephalopods mostly represented by sandstone molds and impressions of siphuncles but with two fragmentary specimens showing sections of the camerae and one fragment furnishing a plan view of a camera showing the cross sectional shape of the conch and the position of the siphuncle with reference to the conch wall. These specimens show that the large brevicone conch is slightly curved endogastrically, compressed laterally, ovate in cross section and narrower ventrad than dorsad, and fairly rapidly expanded orad. The septa are concave orad and the sutures make slight lateral lobes, a fairly prominent dorsal saddle, and probably an inconspicuous ventral saddle. The siphuncle is large, slightly compressed laterally to almost circular in cross section, and ventral but not quite marginal in position. Measurements of an incomplete shell show that the cross sectional breadth was greater than 30 mm. dorso-ventrally and more than 20 mm. laterally. The specimen that shows a plan view of the conch is approximately 17 by 22 mm across and has a siphuncular diameter of 6 mm. at that point. Partial impressions of siphuncles up to 55 mm. long were obtained and the average diameter of these at the oral end is 10 mm., with diameters up to 15 mm. obtained. If the shell broadened proportionately its adult oral section may have averaged about 28 by 37 mm. and probably attained breadths as great as 42 by 55 mm.

a few irregular tangential borings, few if any of the vertical "*Scolithus*" tubes, and no observed gastropods; whereas the so-called Bliss sandstone of Beach Mountain contains numerous conspicuous "*Scolithus*" beds and abundant impressions of gastropods. Some of these differences are probably attributable to the fact that the sections compared are 110 miles apart and overlap entirely different types of pre-Cambrian rocks, the Bliss sandstone at the south end of the Franklin Mountains resting on a rhyolite porphyry and the sandstone at Beach Mountain overlapping miscellaneous pre-Cambrian rocks in which arkosic sandstones predominate. Correlation of the two sandstones is suggested by stratigraphic position, paleogeography (*see* Schuchert and Dunbar, 1941, pp. 126, 152), and the occurrence in both of *Lingulepis*. It is negated by the absence of gastropods in the Bliss sandstone at its type locality, in contrast to their abundance in the so-called Bliss of the Beach Mountain section, and by specific physical dissimilarities. Unfortunately *Lingulepis* can no more logically be used to correlate these two sandstones than it could be used to prove a Cambrian age for the Bliss sandstone in its type section. The presence of abundantly glauconitic zones in the Bliss sandstone of the type section in contrast to its absence in the Bliss (?) of the Beach Mountain section would be presumptive evidence of a Cambrian age for the former if the stratigraphic distribution of glauconite found in the Llano region could be extended to west Texas; but, on the other hand, the contrasting character of the adjacent source rocks might explain this difference, as has been repeatedly stated in papers by E. W. Galliher. The relationships and correlation of the basal Paleozoic sandstones of Trans-Pecos Texas are, therefore, moot; and additional evidence must be sought before a finally tenable conclusion may be reached. The burden of proof perhaps rests with those who would dispute the correlation of these two stratigraphically commensurate basal sands.

As in the case of the age of the basal sands, the evidence on the placement of the boundary between the faunal equivalents of the Tanyard and Gorman formations in the Beach Mountain section is contradictory. The lowest El Paso fossils collected by the authors occur 68 to 70 feet above the base of the El Paso formation (TF–433) and consist of *Clarkella, Syntrophina, Ophileta* aff. *O. rotuliformis* (Meek), and *Hormotoma*. Four to 6 feet above these (TF–434) were collected an imbricate *Tetralobula, Ophileta (Ozarkispira)* aff. *O. rotuliformis* (Meek), *Piloceras, Allopiloceras,* and *Kirkoceras?*. Ulrich, Foerste, and Miller state (1943, p. 25) that P. B. King and J. B. Knight found *Piloceras* "in the lower part of the El Paso limestone just above the Bliss sandstone." According to Ulrich, Foerste, and Miller (1943, pp. 16, 19, 20, 26, and 45) the Piloceratidae, which include the cephalopods listed, are "exclusively Canadian (post-Tanyard) in age." On the other hand, Ulrich and Cooper report (1938, pp. 33, 42, 211, 218) that *Clarkella* and *Syntrophina* have been found only in rocks of "Ozarkian" (pre-Gorman) age, and that the same is true of *Tetralobula* (*op. cit.*, pp. 43, 203); except for its occurrence in the Tribes Hill limestone which they consider to be of "Lower Canadian" (post-Tanyard) age, but which the present authors correlate with the Tanyard formation. Field studies in central Texas have failed to reveal *Hormotoma* below the Gorman formation and have shown that *Ophileta* of the type of *O. rotuliformis* (Meek) (= *Ozarkispira* Walcott, 1924) is ordinarily a Gorman or a high Tanyard fossil. They show that *Syntrophina* is characteristic of the lower part of the Gorman formation and uncommon in the Tanyard; but they also suggest that *Tetralobula* is an index to the Tanyard formation. From the authors' experience in collecting the sparingly fossiliferous Lower Ordovician carbonate rocks it seems more likely that the known range of *Clarkella* and *Tetralobula* may be extended by future collecting than that the range of such conspicuous and commonly numerous objects as the siphuncles of *Piloceras* and *Allopiloceras* would be extended. The law of probability as well as the weight of the available

faunal and physical evidence is against the brachiopods, and the present report holds that the fossils listed are of Gorman age. Further evidence bearing on the correlation of these beds is cited in Part 3 of this report, being omitted here because its validity is in question.

An analogous situation is found in the vicinity of Phillipsburg, Quebec, in the Hastings Creek and Luke Hill formations, where *Tetralobula, Clarkella,* and *Syntrophina* occur in association with *Archaeorthis, Tritoechia, Diaphelasma,* and *Syntrophia* (Ulrich and Cooper, 1938). The present authors have found *Archaeorthis, Tritoechia,* and *Diaphelasma* only in post-Tanyard strata; and Ulrich and Cooper (1938, pp. 42–44, 160, 245) note that, except for occurrences in the Luke Hill and Hastings Creek formations, all known occurrences of *Tritoechia* "are from strata high in the Canadian period," and that, adding an occurrence in erratics (?) of the Levis formation, the same is true of *Syntrophia.* The first appearance of *Tritoechia* represents the first appearance of the brachiopod suborder Clitambonoidea, whereas *Tetralobula* and *Clarkella* belong to the suborder Syntrophioidea which had its beginnings in Cambrian time. It is a widely accepted biostratigraphic precept that first appearances of new organic groups are likely to be more pertinent to correlation than holdovers of previously established groups, and it would seem more reasonable to the authors to date the beds in question on the basis of *Tritoechia* than of *Tetralobula* and *Clarkella,* even were no other evidence available. So far as the Luke Hill formation is concerned, however, there is other evidence in the form of the fauna of the Naylor Ledge formation which intervenes between the Hastings Creek and Luke Hill formations and contains a cephalopod fauna so markedly "Canadian" in aspect (Ulrich, Foerste, Miller, and Unklesbay, 1944, p. 19) that Ulrich (*in* Ulrich and Cooper, 1938, p. 25, Pl. 58) was forced to postulate a submarine cave deposit in order to explain it. The present authors consider the Naylor Ledge and Luke Hill formations at least, and probably part or all of the Hastings Creek formation, to be of post-Tanyard age; and they call attention to the fact at this place as substantiation of the extended range of *Clarkella* and *Tetralobula* and the placement of the Tanyard-Gorman boundary of the Beach Mountain section at the Bliss(?)-El Paso contact.

If the disconformable Bliss(?)-El Paso contact does not coincide with the Tanyard-Gorman contact as is here suggested, there is then a disconformity within the faunal equivalent of the upper Tanyard formation. More disconcerting, the only logical alternative position for the "contact," the "faunal boundary" between the *Clarkella-Tetralobula* fauna and the *Diaphelasma* fauna, occurs within a series of intergrading limestone and dolomite beds.

The contact between the faunal equivalents of the Gorman and Honeycut formations in the Beach Mountain section is most appropriately located at the top of a 4-foot bed of dolomitic sandstone and arenaceous dolomite that occurs 19 feet above the second or upper prominent bluff-forming sandstone in the El Paso formation. The lowest diagnostic Honeycut fossils (*Xenelasma*) occur 4 feet above this point (TF–319) and the highest undoubted Gorman fossils *(Diaphelasma)* were found 133 feet below it. However, poorly preserved syntrophioid brachiopods suggesting *Diaphelasma* were found 8 feet below the contact designated and its location is probably fairly accurate. The contact chosen is a marked lithic break and places the major sand zones of the El Paso formation within the faunal zone that is the more characteristically arenaceous in the Llano and Ozark regions (Gorman and Roubidoux formations). The Gorman faunal equivalent so conceived (Unit A) has a prominent bluff-making dolomitic sandstone in the lower part, another near the top, and a third but much less prominent sand at the top, with intergrading limestone and dolomite between the two principal sandstone zones and with sandy, silty, and shaly dolomite between the lower sand and the Bliss (?).

Above the Gorman-Honeycut faunal boundary, and below the 50 feet of earthy dolomites at the top, the Beach Mountain section presents a difficultly divisible sequence of predominantly very fine grained to microgranular dolomites about 813

feet thick and here known as Unit B. At least the lower 148 feet of Unit B (Subunit B1) is faunally equivalent to the Honeycut formation, and is arbitrarily separated from the 665 feet of post-Honeycut and pre-Black Rock dolomites above (Subunit B2). Like any group of rocks along an undeviating line of section, the dolomites of Subunit B2 are divisible into intervals in the Beach Mountain section, but whether any of these intervals or groups of intervals displays persistent features is a problem which can be settled only by detailed areal or subsurface studies. A feature of possible zonal value in Subunit B2 is the 60 to 70 feet of recurrently arenaceous dolomite near its middle which may correspond to a 50-foot interval of arenaceous dolomite at the middle of Subunit B2 in the El Paso section. The observed data are recorded in detail in Part 3 of the present report and further suggestions on subdivision are made at that place.

The upper 50 feet of the El Paso formation, called Unit C, is a zone of earthy dolomites probably correlative with the Odenville limestone of Alabama and the Black Rock formation of Arkansas.

As potential petroleum reservoirs, both the Tanyard and Gorman faunal equivalents of the Beach Mountain section are significant. Each is conspicuously arenaceous in the vicinity of Beach Mountain, whereas in the Llano uplift the Tanyard formation contains no sand and the Gorman formation very little. Stratigraphic-type traps are to be looked for in these units, particularly where the change in facies takes place, at some intervening point. It is also of interest that a petroliferous odor was noticed locally in the post-Honeycut dolomites of the Beach Mountain section, especially from 500 to 515 feet below the base of the Montoya limestone.

Diablo Plateau.—A difficultly measurable but quite fossiliferous section of the El Paso formation in a small horst on the Diablo Plateau between Black Knobs and Cox Mountain, about 17 miles airline northwest of the Beach Mountain section, was recommended by Dr. J. B. Knight as a good locality for study. This section was visited by Josiah Bridge, L. E. Warren, and the authors on November 12, 1944. It was estimated that between 340 and 400 feet of beds are exposed between the top of the lower prominent calcareous sandstone zone and the overlapping Hueco limestone at the top of the section. Faunal evidence proves that if this sandstone correlates with one of those in the Beach Mountain section it is the lower one, and the upper prominent sand of the Beach Mountain section is absent or inconspicuous in the Diablo Plateau section. Field studies were hurried and this point was not clearly ascertained. The exposed rocks are largely impure, brownish gray, granular, locally cherty limestones. Except for the sandstone at its base the rocks in this section are more like those of the Hueco and Franklin Mountains than those of Beach Mountain. Grains of a green mineral suggesting glauconite were noted in several beds and are locally abundant. A sample of this mineral from a ledge about 115 feet above the sandstone, however, shows a flaky crystalline structure and is probably a hydrous mica or one of the group of minerals known as chamosites. Fossils were seen at a number of places in the section and collected at seven (TF–329 to 335). They denote faunal equivalents of the Gorman and Honeycut formations, but no boundary was selected. If the prominent sand at the base of this sequence were the exact correlative of the basal sand of the El Paso formation at Beach Mountain and the overlying strata did not vary in thickness, the boundary between the faunal equivalents of the Gorman and Honeycut formations should fall 193 feet above its top and the top of the Honeycut faunal equivalent at 341 feet. The brachiopod *Xenelasma*, which should occur at or just above the base of the Honeycut faunal equivalent, was found 145 feet above this prominent sand zone (TF–331), suggesting that the top of the lower prominent sand zone may rise in the section westward from Beach Mountain. The highest fossils seen in the El Paso formation at this place were Honeycut types, but they were probably near the top of the Honeycut faunal equivalent.

Hueco Mountains

In November 1944, in company with Josiah Bridge and L. E. Warren, the writers spent two days in the Hueco Mountains, the west edge of the Diablo Plateau, studying and collecting fossils from two sections of the El Paso formation. One of these sections is in west-central Hudspeth County, northeast of the Old Padre Mine; and the other is in east-central El Paso County, north of Helms West Well. These sections were known to Barnes from a field trip with Leo Hendricks and Bruce Harlton in November 1941. Their position and geologic relationships may be found on a Geologic Map of the Hueco Mountains by P. B. King, R. E. King, and J. B. Knight (1945). The following observations are principally from the section north of Helms West Well; the section at the Old Padre Mine was not completed but seemed to be essentially like that at Helms West Well.

Cumulative estimates and measurements between fossil collections in the section north of Helms West Well amounted to 960 feet of strata of the El Paso formation between the overlying Upper Ordovician Montoya limestone and the bolson deposits that conceal the base of the El Paso formation in the vicinity of Helms West Well. If the roughly approximate position of the contact between the faunal equivalents of the Gorman and Honeycut formations in this section is compared with the contact between Units A and B of the El Paso section, about 330 feet of lower El Paso strata and all of the Bliss sandstone would be indicated as covered by bolson deposits north of Helms West Well. The derived figure of approximately 1300 feet may be taken as the approximate thickness of the El Paso formation in the Hueco Mountains until better data are available. The lower El Paso beds and the Bliss sandstone may be seen to the south of Helms West Well toward the Old Padre Mine.

The El Paso formation in the section north of Helms West Well resembles that of the El Paso section in being predominantly dolomite with minor sandy intervals below the approximate contact of the Gorman and Honeycut faunal equivalents, and predominantly granular, impure limestone above. It is not sufficiently different from the El Paso section nor accurately enough measured to warrant description at this time, but it is quite fossiliferous and deserves detailed study.

Only 11 collections of fossils (TF–340 through TF–350) were made from the section north of Helms West Well, but many more could have been obtained and fossils were recorded by field identification at 22 other levels in the El Paso formation. The little brachiopod *Archaeorthis* is abundant at many stratigraphic levels above Unit A, and exquisite specimens of *Polytoechia* were obtained from the upper beds of Unit B. The fossils collected demonstrate the presence of all the units and subunits recognized in the El Paso formation of the Franklin Mountains and the reader is referred to the description of the El Paso section for further detail on the character of the rocks involved.

Franklin Mountains

The El Paso section (figs. 5, 6; Pls. 15, 16), at the south end of the Franklin Mountains, and just outside the corporate limits of El Paso, El Paso County, Texas, would make a good type section for the El Paso formation. It is the thickest section of the El Paso formation known to the authors, comprising about 1590 feet of limestone, dolomite, a little shale, and less sand; and it contains enough fossils for biostratigraphic studies. Edwin Kirk (1934) discussed the El Paso section and the broader aspects of its correlation, and the reader is referred to his paper as directly complementary to the present one. The reader should bear in mind that Kirk's "*Taffia* near *ione*s" has since become *Hesperonomia* (see Ulrich and Cooper, 1938, p. 119) and that the observed range of *Calathium* has been extended. The present report takes exception to Kirk's view (1934, p. 457) that "the El Paso does not range lower than the Jefferson City."

Like the Beach Mountain section, from which it differs lithically, the El Paso section is of primary importance to regional stratigraphic studies of rocks related to the Ellenburger group and is

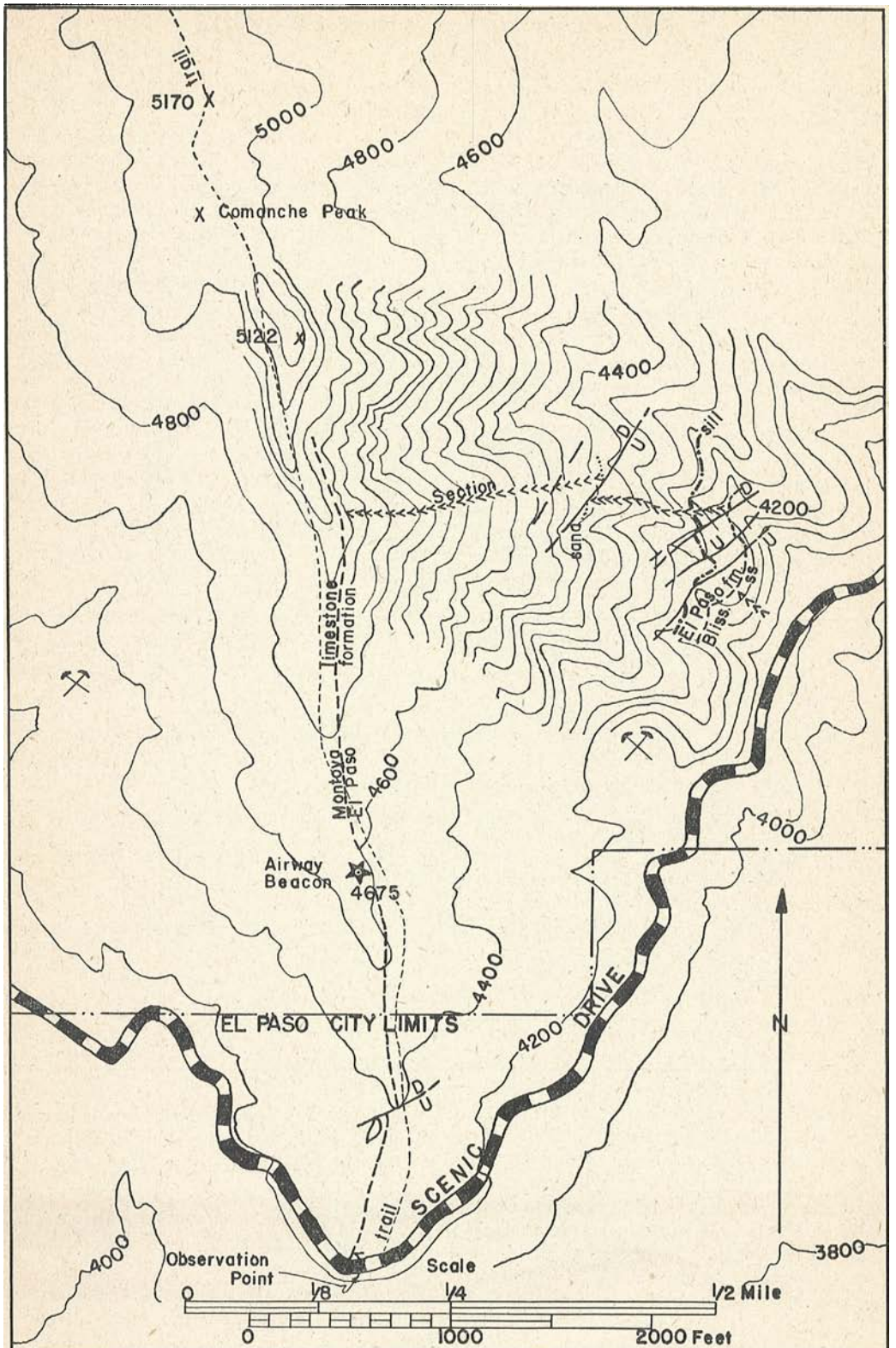

Fig. 5. Map of the south end of the Franklin Mountains, El Paso County, Texas, showing location and approximate geologic relationships of the El Paso section. (Topography and culture enlarged from 7½ minute El Paso Quadrangle, U. S. Geol. Survey, ed. 1943.)

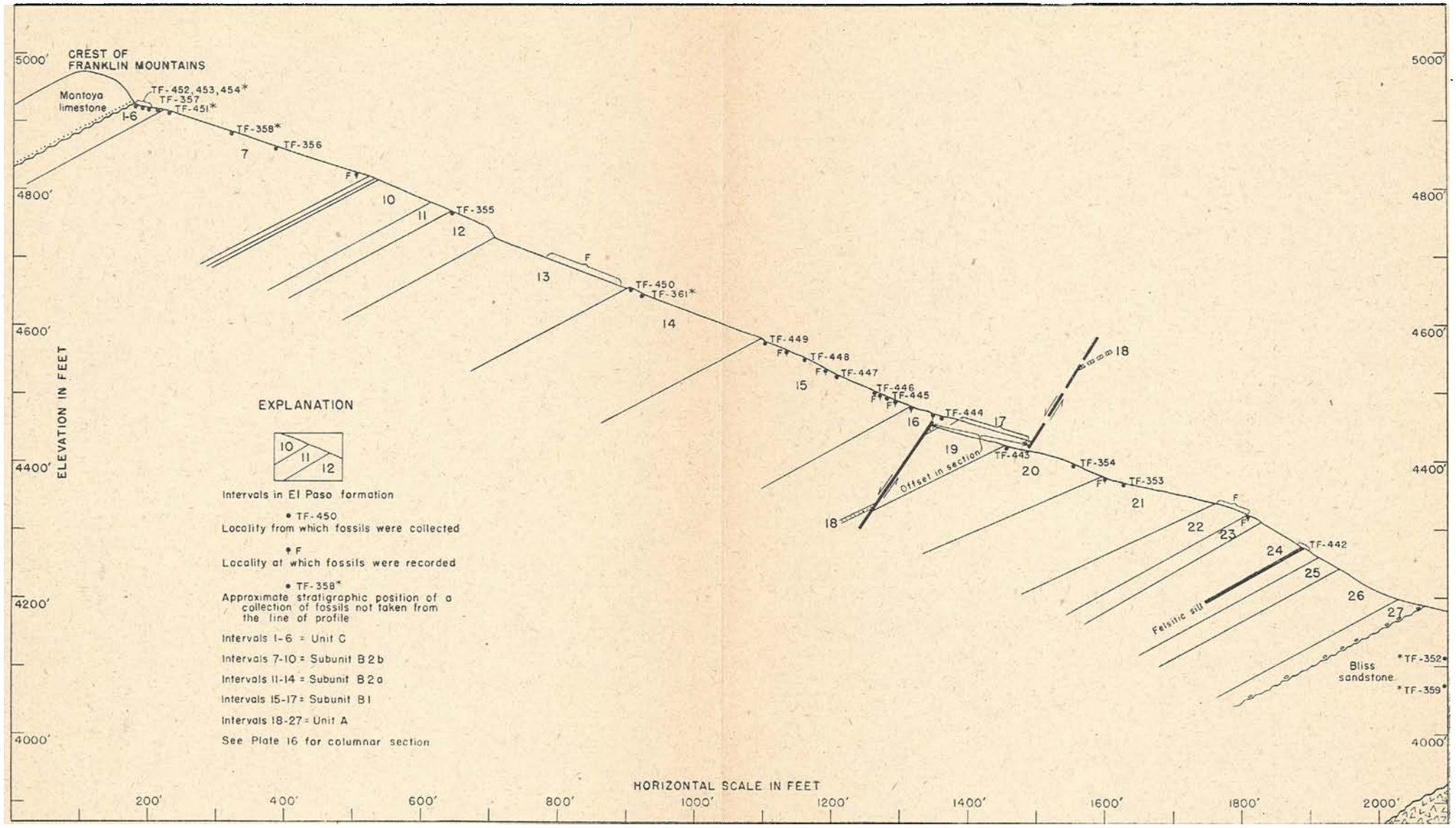

Fig. 6. Profile of the El Paso section, Franklin Mountains, El Paso County, Texas.

described in detail in Part 3 of this report.

The remarks that follow are based on observations made by the writers and L. E. Warren on November 26 and 27, 1944, and by the writers on October 7 and 8, 1945. In 1944 a section at the head of McKelligon Canyon was studied, as well as the one here designated the El Paso section. The Bliss sandstone is well displayed in the McKelligon Canyon section, and the sequence in the El Paso formation, except that it shows more dolomite and is much faulted, is about the same as that in the El Paso section.

The El Paso formation of the type area contains much more limestone and much less sand and dolomite than it does in the section at the north end of Beach Mountain, and although sand occurs at places from top to bottom of the El Paso section it is sufficiently concentrated to form a sandstone only at the top of the Gorman faunal equivalent (Unit A). Rocks equivalent to the Gorman formation are predominantly dolomite, and granular limestone characterizes the strata younger than the Gorman. That there is some lateral gradation between limestone and dolomite both in the El Paso and the Beach Mountain sections is evident, but how much is not known. In all sections of the El Paso formation west of Beach Mountain that were examined by the authors limestone predominated over dolomite.

The age of the Bliss sandstone in the Franklin Mountains, its type area, is not known, but analogy with the so-called Bliss sandstone of Beach Mountain suggests that it be considered lowest Ordovician until diagnostic evidence is found. There is, however, room enough for a Tanyard equivalent fully as thick as that of the Beach Mountain section between the lowest recognized Gorman fossils and the top of the Bliss sandstone of the El Paso section. The correlation of the Bliss sandstone is considered further under the discussion of the Sierra Diablo region and the description of the El Paso section.

The 1840 feet of pre-Montoya (Upper Ordovician) Paleozoic rocks in the El Paso and McKelligon Canyon sections are divisible into four units, as follows:

Stratigraphic unit	*Thickness in feet*	*Provisional correlation*
El Paso formation (1590 feet thick)		
Unit C (zone of inequigranular shell-limestones, shale, and minor dolomite)	36	Black Rock fm. and Odenville ls.
Unit B (1014 feet thick; zone of predominating limestone)		
Subunit B2 (a faunal division that is provisionally subdivided at the base of a 50-foot zone of arenaceous dolomite into an upper portion 335 feet thick, called Subunit B2b and a lower portion 364 feet thick called B2a)	699	Strata of post-Honeycut and pre-Black Rock age.
Subunit B1 (a faunal division)	315	Honeycut fm.
Unit A (zone of predominating dolomite, with arenaceous intervals)	540	Gorman fm.
Bliss sandstone	250	Tanyard fm. (?)
Total	1840	Lower Ordovician.

In terms of characteristic fossils these divisions might be referred to as follows: A, zone of *Diaphelasma;* B, zone of *Ceratopea* and *Archaeorthis;* B1, subzone of *Orospira* and *Xenelasma;* B2a, subzone of *Polytoechia;* B2b, subzone of *Polytoechia* and *Hesperonomia;* C, zone of *Syntrophopsis magna.* Correlation with the divisions of similar designation in the Beach Mountain section is indicated by faunal evidence, stratigraphic position, and the

probable continuity of arenaceous intervals at the top of Unit A and the base of Subunit B2b. Correlation of Subunit B2 between the two sections is not directly supported by the known faunal sequence within these units and more faunal information is needed in this part of the Beach Mountain section especially. Except that they both consist predominantly of carbonate rocks and seem to have a certain correspondence of arenaceous zones, there is little lithic similarity between these two sections, and neither is at all similar to equivalent parts of the Ellenburger group.

For detail on the El Paso formation in the El Paso section, its description, in Part 3 of this report, should be consulted. Although the general equivalence of the El Paso and Beach Mountain sections and their correlation with standard rock units in the Llano and Ozark uplifts seems to be established within indicated limits by the faunal evidence, it should be kept in mind that the exact placement of the faunal boundaries is still open to question.

COLORADO

Rocky Mountain Front

Rocks equivalent to the Ellenburger group in the Rocky Mountain Front are included in the Manitou formation, a stratigraphic interval of brick red to gray dolomite and limestone referred to in reports as the Manitou limestone and the Manitou dolomite. The Manitou formation and the Sawatch quartzite (?) upon which it rests have been described by Brainerd, Baldwin, and Keyte (1933); G. I. Finlay (1916); G. B. Richardson (1915); and others. The following remarks are based on the published record, supplemented by four days of field observation by the authors under the guidance of Harry W. Oborne in October 1945. Time in the field was limited and results inconclusive, but discussion may serve to indicate some of the questions which detailed work in the lower Paleozoic of the Front Range should seek to answer.

The brick red arkosic sandstones and light yellow sandstones that underlie the Manitou formation in the Front Range north of Deadman's Canyon have been correlated with the Sawatch quartzite "because of lithologic character and stratigraphic position" (Finlay, 1916). The cited faunal evidence for this correlation is weak, and a published list of identifications by E. O. Ulrich (*in* Richardson, 1915) of fossils from the "basal red arenaceous limestone" of the Manitou formation contains names of fossils that would now be considered diagnostic of the Upper Cambrian along with names of equally diagnostic Lower Ordovician fossils. Judged from the names cited, either this collection is mixed and represents a considerable time interval, or the ranges of ordinary Cambrian and Ordovician fossils are hopelessly extended. The degree of apparent mixture *(Billingsella* and *Cameroceras)* is so great that the first possibility is considered the more likely, and the listing of such fossils as *Billingsella plicatella* and *Owenella* seems to leave little room for doubt that Upper Cambrian rocks immediately underlie the Manitou formation in the Front Range. On the basis of the published information, therefore, and not as a result of their own observations in the field, the authors provisionally accept the designation of the sandstones below the Manitou formation as Upper Cambrian and a correlative of the Sawatch quartzite.

In the considerable metamorphosis which the concept implied by the term Manitou has undergone since its proposal by Cross in 1894 the recent contribution of Brainerd, Baldwin, and Keyte (1933) scored a significant advance by the removal of younger rocks from the top of the Manitou limestone of Richardson (1915) and Finlay (1916). The six sections examined by the present authors were at or near sections 1, 3, 5, 7, 8, and 11 shown in the stratigraphic cross sections of Brainerd, Baldwin, and Keyte (their figures 9 and 10) and the reader is referred to their report for visualization of local stratigraphic relationships.

The present authors saw no limestone in the Manitou formation south of Williams Canyon; a section west of Beulah (No. 1 of Brainerd, Baldwin, and Keyte) contains no representative of the Manitou; a section west of Wellsville (No. 11) is largely a very fine grained to

microgranular, gray to olive gray dolomite; and sections near Priest's Canyon (No. 3) and in Phantom Canyon (No. 5) are entirely of very fine grained rose to brick red dolomite with irregularly distributed semichalcedonic to subchalcedonic, spiculiferous chert. On the other hand, the sections at Williams Canyon (No. 7) and Missouri Gulch (No. 8) are largely limestone. The dolomitic sections seen all rest directly on pre-Cambrian rocks, whereas the calcitic sections rest on strata correlated with the Sawatch quartzite. This is in line with the concept of dolomitization as a near-shore or shallow water phenomenon (p. 94). The dolomitic sections were also very sparingly fossiliferous, only one collection being obtained from each (CF–1, CF–2, CF–3). This meager representation permits only the suggestion that, as would be expected, the lower Manitou strata are missing where that formation directly overlaps the pre-Cambrian.

The thickest, best exposed, and most fossiliferous section visited was that above the "Narrows" in Williams Canyon (Pl. 30, fig. D; Pl. 15) at the town of Manitou, and the suggestion by Brainerd, Baldwin, and Keyte that it be considered representative of the type section is endorsed by the present writers. The Manitou formation in this section is approximately 200 feet thick and is comprised largely of fine grained, light gray limestone. Fossils were obtained at 14 levels within it (CF–4 through CF–17). Tanyard, Gorman, and possibly Honeycut affinities are indicated by the various collections, but the authors are unable at this time to suggest logical boundaries between faunal units. No clearly defined boundary was found between the Manitou formation and the rocks correlated with the Sawatch quartzite. It was, therefore, arbitrarily placed above the highest bed containing a conspicuous quantity of glauconite. Thinly interbedded dolomite, earthy dolomite, dolomitic limestone, calcareous sandstone, and arenaceous dolomite and limestone above the Manitou formation in the Williams Canyon section was named the Williams Canyon limestone by Brainerd, Baldwin, and Keyte (1933) and considered by them to be possibly of Devonian age. These beds occupy a stratigraphic position held by the Middle Ordovician Harding sandstone farther south and, until faunal evidence of a different age is submitted, their correlation with the Harding sandstone remains a probability. The Williams Canyon section is described more fully in Part 3 of the present report.

Manitou Park is an alternative type area for the Manitou formation and the one which strict grammatical construction of Cross's original description (1894, p. 2) might consider to be the designated type area. A section in Missouri Gulch (No. 8 of Brainerd, Baldwin, and Keyte), on the mountain slope east of Manitou Park, near the headwaters of Trout Creek, displays in the vicinity of 100 feet of Manitou strata. This section is not quite a mile by speedometer east of Colorado highway 67 between the gulch-side quarry of the Manitou Forest Experiment Station (Pl. 30, fig. C) and a Forest Service weir. The rocks included in the Manitou at this place are mostly fine grained, slabby-weathering, in part slightly dolomitic, rose to gray limestone with a few intervals of nodular and marly limestone near the middle. *Apheoörthis* is abundantly represented by two or more species that occur silicified in rose limestone from about 20 to 40 feet below the top (CF–18). It suggests that rocks equivalent to the lower part of the Manitou formation in the Williams Canyon section are here more thickly represented, whereas most of the higher strata of the Manitou of the Williams Canyon section are absent at Missouri Gulch.

OTHER REGIONS

The areas of outcropping Lower Ordovician rocks most directly related to the Ellenburger group have been discussed above and it is beyond both the scope of this report, and, in most instances, of the authors' experience to consider other areas in detail. Edwin Kirk (1934) has discussed the correlation of Lower Ordovician rocks over a wide area, and the correlation chart in preparation by the National Research Council's subcommittee on the Ordovician will show the correlation of Lower Ordovician rocks in many parts of North America not considered in

the present report. Four regions containing carbonate rocks of particular interest to the student of Lower Ordovician stratigraphy are, however, briefly noted below. Except for the southern Appalachian region, the descriptive and faunal data are taken wholly from the writings of others, but the present authors are responsible for all conclusions not consistent with those generally accepted.

Upper Mississippian Valley

The characters, history, and correlation of the Lower Ordovician Prairie du Chien group of the upper Mississippi Valley have been excellently summarized by G. M. Kay (1935), E. H. Powers (1935), and A. C. Trowbridge and others (1935), and the faunas of the Oneota and Shakopee dolomites have been described by L. H. Powell (1935) and C. R. Stauffer (1937).

The Prairie du Chien group, according to Trowbridge and others (1935), averages 190 to 245 feet thick, and it consists principally of dolomite with minor sandstone and siltstone. The Oneota dolomite, with the Kasota sandstone and Blue Earth siltstone at its base locally, comprises the lower two-thirds to three-fourths of this sequence and is, judged from fossils figured by Powell, of Tanyard age.

At many places, a thin sandstone with locally interbedded dolomite intervenes between the Oneota dolomite and the next dolomitic unit above. This sandstone has generally gone by the name of the New Richmond sandstone. Except for the stromatolite cryptozoon, no fossils have been recorded from the New Richmond; but its stratigraphic position and arenaceous nature suggest correlation with the Roubidoux formation of the Ozark uplift and indirectly with the Gorman formation of the Llano uplift.

A unit predominantly of dolomite, but with minor thin sandstone beds, constitutes the upper one-third to one-fifth of the Prairie du Chien group and is called the Shakopee dolomite by some and the Willow River limestone or dolomite by others. Powers (1935, p. 394) states that information from well cuttings from the city well at Shakopee "shows that the Shakopee type section belongs within the lower 65 feet of the 126 feet of Oneota dolomite, which is overlain by 2–4 feet of New Richmond sandstone, and that in turn by 61 feet of Willow River dolomite." He says, "It is preferable to return to the term Willow River" (of L. C. Wooster, 1882). The U.S. Geological Survey recognizes the name Shakopee dolomite, as does Dr. Stauffer, who has described its fossils. Josiah Bridge (1930, p. 129) recognized partial equivalence between Jefferson City and Shakopee strata. J. S. Cullison (1944, pp. 23, 32) holds that "the fauna described by Stauffer (1937) from the Shakopee dolomite at Cannon Falls, Minnesota," has its closest affinities with the middle part of his Jefferson City group and thus probably about the middle of the Honeycut formation; but a small capuliform *Ceratopea* figured by Stauffer (1937, Pl. 9, figs. 3, 9, and 10) suggests to the present authors the lower third of the Honeycut formation. The Shakopee fauna described by Stauffer (1937) from Stillwater, Minnesota, is recognized by both Stauffer and Cullison (1944, p. 39) as of Cotter age.

Of the Prairie du Chien group in general Powers (1935, p. 390) says, "Intraformational conglomerates, oölites, glauconite, chert, Cryptozoon reefs, porosity, kind of dolomite, shale and siltstone serve as means of identifying many beds."

Champlain Valley in Vermont and New York

An historic sequence of Lower Ordovician rocks in the Champlain Valley region of Vermont and New York State, known as the Beekmantown group, consists of dolomite, limestone, and sandstone and has a total thickness of about 1300 feet (Brainerd and Seely, 1890; *see* Wilmarth, 1938, pp. 145–148). This group of rocks includes the upper part of Division A and all of Divisions B, C, D, and E of Brainerd and Seely (1890). Judged from lists of fossils compiled from the reports of E. O. Ulrich and coauthors on the "Ozarkian and Canadian" faunas (1938, 1942, 1943, 1944), it includes correlatives of rocks from the age of the

Tanyard formation through the Powell dolomite and perhaps higher. A threefold stratigraphic division is generally recognized.

The Tribes Hill limestone is equivalent to the upper part of Division A and all of Division B of Brainerd and Seely. It comprises the basal portion of the Ordovician in this region, and was last correlated with strata of post-Tanyard age by Ulrich (*in* Ulrich and Cooper, 1938, Pl. 58) but the fossils said to occur in it by Ulrich and coauthors indicate a Tanyard age to the present writers. The boundary between the faunal equivalents of the Tanyard and Gorman formations (Ulrich's Ozarkian-Canadian boundary) in the Champlain Valley south of Canada probably should fall at or near the top of the Tribes Hill limestone.

The middle unit of the Lower Ordovician in the Champlain Valley includes Division C and the lower part of Division D of Brainerd and Seeley, consisting of dolomite with interbeds of sandstone following a basal calcareous sandstone about 60 feet thick and grading to limestone in the upper part. It is known to many geologists as the Ogdensburg formation, contains *Lecanospira* in the lower part (lower part of Division C, *fide* Bridge, 1930, p. 124), and is therefore at least in part of Gorman age. Like the equivalent Gorman and Roubidoux formations, the Ogdensburg is characteristically more arenaceous than the immediately overlying and underlying rocks.

It is apparent from the contained faunas, and it has long been known, that the upper unit of the Champlain Valley sequence, comprising the upper part of Division D and all of Division E of Brainerd and Seeley, and known to many geologists as the Fort Cassin or Cassin formation or limestone, is of late Lower Ordovician age, younger than rocks equivalent to the Gorman formation. The fossils listed by Ulrich and coauthors indicate that its upper portion is at least as young as the Powell formation of the Ozark region and possibly younger, and Cullison (1944, p. 46) states that, "The general aspect of the Powell fauna is like that of the Ft. Cassin beds of Vermont."

Vicinity of Phillipsburg, Quebec

The Lower Ordovician carbonate rocks in the vicinity of Phillipsburg, Quebec, are of special biostratigraphic interest because of the peculiar mechanism postulated by Dr. Ulrich to explain the apparent mixture of "Ozarkian" and "Canadian" faunas in the "Hastings Creek and Luke Hill formations" (*see* Ulrich and Cooper, 1938, Pl. 58). A similar problem faced the present authors in the lower part of the Beach Mountain section (pp. 69–70) but they were prevented by unimpeachable physical evidence from postulating either a submarine cave, such as the "Naylor Ledge formation," or a collapse of younger beds into older, such as they have evidence for at many other places.

An interpretation of the Phillipsburg sequence that would be consistent with the evidence in the Beach Mountain section would move Ulrich's "Ozarkian-Canadian" boundary (coincident with the boundary between the faunal equivalents of the Tanyard and Gorman formations) downward to a point within or at the base of the "Hastings Creek formation."

Southern Appalachian Region

The Lower Ordovician rocks of this region and of the Ozark region of Missouri and northern Arkansas, as was mentioned thereunder, are more like those of the Ellenburger group in their faunas and the types of residual chert they yield on weathering than any other strata of like age known to the authors. Like the Ellenburger they include both limestone and dolomite, but unlike the Ellenburger they contain definite beds and zones of sand at several stratigraphic levels. Weathering is so intense and outcrops so few in the part of the region familiar to the authors (northeastern Alabama) that the proportions of limestone and dolomite and their lateral behavior are not known, but it is safe to say that lateral transition occurs there as it does in Texas.

The Lower Ordovician of Alabama has been described and some of its fossils figured by Charles Butts (1926, pp. 87–101, Pls. 15–19). From the base upward, the named stratigraphic units are the

Chepultepec dolomite, the Longview limestone, the Newala limestone, and the Odenville limestone. According to Butts the Chepultepec dolomite is "at least 1000 feet thick" at Chepultepec, while the Longview and Newala limestones are said by him to be about 500 and 1000 feet thick, respectively, in the Cahaba Valley region. The Odenville limestone is reported to outcrop at only one locality, where it is about 50 feet thick, but its fossils have been found in the residuum above the Newala limestone at other places. In Cherokee County, in northeastern Alabama, the Chepultepec dolomite and the Longview limestone appear to be a little thinner, and the Newala limestone much thinner, than the same units in the Cahaba Valley, and no trace of the Odenville limestone was found. Exposures of the Longview in Cherokee County were mostly dolomite and sandstone, but limestone does not outcrop well in that area.

Equivalence of the Lower Ordovician rocks of the southern Appalachian region to those of the Ellenburger group and El Paso formation is as follows: the Chepultepec dolomite correlates with the Tanyard formation; the Longview limestone is approximately equivalent to the Gorman formation; the Newala limestone is in part equivalent to the Honeycut formation, but includes younger rocks as well; and the Odenville limestone is about equivalent to Unit C of the El Paso formation.

LITHOGENIC AND PALEOECOLOGIC SPECULATIONS

INTRODUCTORY STATEMENT

The genesis of sedimentary rocks involves three closely related problems: (1) under what conditions were the original sediments formed and brought to rest; (2) what was the character of the original sediments; and (3) through what diagenetic processes, acting at what time, did the rocks in question attain their present lithic character. The character of the original sediments is indicative of the environment under which they formed and came to rest, and the study of the relations of this environment to the life of the times is paleoecology.

The sorts of recent sediments that might, upon diagenesis, form rocks comparable with those of the Ellenburger group has important bearing on the probable genesis of the lithic constituents of the Ellenburger rocks. The discussion that follows attempts to correlate observed lithic and biologic features of the Ellenburger rocks with known sedimentary and biologic conditions in recent seas.

It is of value to do this for the reason that the origin and accumulation of petroleum is ultimately related to biologic and sedimentary processes, and to the environment in which they had their being.

In the ensuing discussion the descriptive and theoretical background, on the basis of which geologic conclusions are reached, is presented first. This is followed by sections on "Probable oceanography and ecography of the Ellenburger sea" and "Comparison of the Ellenburger sea with other ancient marine provinces." The reader interested in conclusions alone may turn to these.

RECENT SEDIMENTS POTENTIALLY COMPARABLE TO ELLENBURGER ROCKS

Factors Limiting Analogy

Inasmuch as carbonate sediments capable of forming dolomites without the addition of magnesium are not known to be forming anywhere in the world today, the probable origin of the limestones of the Ellenburger group is here primarily considered. The dolomites are reserved for discussion under "Genesis of the lithic constituents."

The typical limestone of the Ellenburger group is a calcite rock so extremely fine grained that it is described as sublithographic. It is apt to contain minor irregular argillaceous films, patches of limestone pellets, and local small patches or veinlets of calcite. Above the Tanyard formation it locally contains scattered sand grains, and chert is intermittently abundant above the lower part of the Tanyard formation. Glauconite is extremely rare and, for practical purposes, the rock is essentially non-glauconitic. Where it does not break along the minor

argillaceous films its fracture is smooth and almost conchoidal. Terrigenous materials are scarce in limestones of the Ellenburger group.

Slight stratigraphic and regional variations are noticeable. The occasional occurrences of sand grains in the known outcrops are, with rare and very inconspicuous exceptions, restricted to beds younger than the Tanyard formation; and the limestones of the Threadgill member of the Tanyard formation contain a greater proportion of silty material in the western part of the region than they do in the east.

Now, although calcium carbonate occurs very widely in recent marine sediments, even accounting for about 32 per cent of deep sea sediments (Vaughan, 1924a, pp. 312–313), places where it is being formed in sufficient purity to comprise a potential limestone are areally restricted. Biogenic and clastic accumulations, such as coral and algal assemblages and their associated clastic debris, colonies of other sessile benthos, coquinas or shell-breccias, limesands, and *Globigerina*- or pteropod-ooze, account for most modern accumulations of relatively pure calcium carbonate. Obviously, the sublithographic limestones of the Ellenburger group do not belong with any of these, although algae may have played a part in their deposition. In fact, the field of the chemically precipitated calcium carbonate sediments must be searched to find similarities with limestones of the Ellenburger group. Inasmuch as the Ellenburger fossils demonstrate an essentially marine origin, only sediments formed in or in close association with marine waters are here considered.

It is generally recognized that chemical precipitation of calcium carbonate may occur through the agency of either physical (physicochemical) or biologic (biochemical) processes that disturb the equilibrium of sea-waters that are saturated or supersaturated with calcium carbonate. The organic factors have been stressed by some and the physical factors by others, but experimental work shows that both physicochemical and biochemical precipitation can occur. Johnston and Williamson (1916, p. 733) point out that "in order to decide definitely if a natural water is saturated with respect to calcite one must know: (a) the concentration of free CO_2 in the water, (b) the temperature, (c) the concentrations of the other constituents present"; and that "of these the third is the only one which has in general been satisfactorily ascertained." However, most investigators now "agree that the surface layers of the ocean water in tropical and subtropical regions are saturated or even supersaturated with reference to $CaCO_3$" (Vaughan, 1924a, p. 325. *See* also Johnston and Williamson, 1916, p. 735; and Black, 1933a, p. 457). Moberg and others (1934, p. 272) indicate the possibility of relatively heavy supersaturation for the warm surface waters, although they questioned as excessively high, supersaturation ratios such as were derived from data similar to theirs by Wattenberg and other German workers. C. L. Smith (1940, p. 171) says, "It is well known that the surface water of the Atlantic Ocean is heavily supersaturated with calcium carbonate." Revelle (1934, p. 1) states that "Although the experimental results obtained by various authors for the solubility product are not in agreement, it is at least certain that surface sea water at a temperature of 30° C. is saturated with calcium carbonate."

Calcium carbonate in solution is commonly said to occur as the bicarbonate, $Ca(HCO_3)_2$, although, of course, what is actually present in other than negligible amounts is Ca^{++} ions and HCO_3^- ions. The status of calcium carbonate as precipitate or solute is thought to be related primarily to the concentration of CO_2, the pH, and interconnected factors. $CaCO_3$ precipitated from the saturated surface waters of the oceans is subject to resolution where it sinks into cooler waters capable of holding more CO_2, and therefore likely to be undersaturated with respect to $CaCO_3$. A natural environment of chemically precipitated calcium carbonate sediments in the sea is seen to be one of shallow waters in a tropical or semitropical region, where the circulation of the waters is restricted, yet sufficient to allow replenishment or replacement from time to time by waters rich

in Ca^{++} and HCO_3^- ions. The precipitation of $CaCO_3$ through interactions of other soluble compounds with $CaSO_4$ is noted on page 85.

The present known sites of the undoubted occurrence in the sea of chemically precipitated $CaCO_3$, identified by the occurrence of aragonite needles, are the Bahama Banks (many references), "some of the flats behind the Florida Keys" (Vaughan, 1924a, p. 321), and "within an inclosed lagoon at Maiao, in the South Pacific" (Thorp, 1936, p. 92). The environment in all instances is one of shallow, warm, relatively sluggish waters; but from what is known of the sediments being formed at these places, those of the Bahama Banks most nearly recall the limestones of the Ellenburger group.

Temporarily reserving comment on the mineralogic composition of the calcium carbonate muds on the Bahama Banks, we may note remarks, inspired by one (Maurice Black) who was intimately acquainted with them, on their probable lithification features: "Aragonite mud behaves, in many respects like a clay sediment. . . . On lithification, the aragonite recrystallises as a dense and tightly welded mass of calcite granules . . . and . . . shrinkage cracks are formed. These spaces later become filled with (relatively) coarsely crystalline calcite deposited slowly from solution." (Hatch, Rastall, and Black, 1938, p. 174.) Black also believed that "Amongst the older limestones, the calcite mudstones are the lithified representatives of the modern aragonite muds. . . . The purer calcite mudstones are pale grey in colour, and have a smooth, almost conchoidal fracture. . . . Thin sections show that these rocks consist of extremely minute crystals of calcite, the individuals being so small that they render the slice semi-opaque. Running through this fine-grained rock are irregularly branching little veins of clear calcite, in comparatively coarse crystals." (Hatch, Rastall, and Black, 1938, pp. 173–174.) The similarities to the limestones of the Ellenburger group are apparent.

An environment of origin for the limestones of the Ellenburger group similar to that on the present Bahama Banks is indicated. Needless to say, an isolated "bank" is not required; although the Ellenburger sediments could have been formed in an area relatively elevated with respect to the surrounding sea floor. It has been pointed out that the reduced circulation and other conditions on wide shoal-water shelves and banks "resemble in some respects the conditions in isolated lagoons" (Hatch, Rastall, and Black, 1938, p. 171); and the protected bank areas are, in a sense, evaporating pans. Similar conditions may well have been, and probably at times were, widespread in epicontinental seas in shallow areas not receiving quantities of terrigenous sediments; such as might be found far from shore, adjacent to land approaching base level, or separated from the shore by relatively deep, current-swept channels.

Geographic, Sedimentary, and Biologic Features of the Bahama Banks

It may be profitable to examine more closely the geography and sedimentary features of the Bahama Banks to see what sorts of conditions are there displayed. A map of the entire area involved is given in a report by Drew (1914, Chart A) and some additional maps of interest are given by Drew (1914, Chart B); Field (1928, p. 122); Field and others (1931, fig. 1); Bavendamm (1932, figs. 1–2); Black (1933a, fig. 1; 1933b, fig. 1); Thorp (1936, fig. 3); and C. L. Smith (1940, figs. 44–52).

From these maps it may be seen that the complex of shoaly banks, islands, and intersecting channels of the Bahama Banks comprises a general shoaly area southeast of Florida and north of the east end of Cuba. The banks themselves extend to within 60 miles of Florida and 50 miles of Cuba, but are separated from both by deep channels. The general area involved is kidney shaped, convex at the southwest, and elongated in a north-northwest to south-southeast direction. It is about 450 miles long and 170 miles wide at the middle, tapering bluntly to either end. Within the general area outlined about 30,000 square miles consist of "banks"

which are today receiving or have recently received precipitated calcium carbonate muds. Those parts of the bank areas that are swept by currents tend to be surfaced by limesands (Black, 1933a, p. 462), but below the seasonably stagnant waters in the lee of (west of) Andros Island an area of about 4500 square miles (up to 70 miles wide and 90 miles long) is known to be floored with deposits that contain a large proportion of aragonite needles (Black, 1933a, p. 461, fig. 1; Field *et al.*, 1931, fig. 1). This area of known aragonite muds is itself about as large as the surface expression of the Llano uplift (approximately 4400 square miles), and the total area of potential calcium carbonate precipitation is about the size of Maine or one-ninth as large as Texas.

Great Bahama Bank, to the south, is separated from Little Bahama Bank, to the north, by a deep channel. It is divided into a smaller eastern and a larger western lobe by a tongue of the ocean. This tongue of the ocean is 120 miles long, averages 25 miles wide, and ranges in depth from 1200 fathoms at its north end to 795 fathoms at its south end. It is a deep *cul-de-sac* in a shallow bank. Great Bahama Bank itself is mostly less than 3 fathoms deep, and apparently does not exceed 5 fathoms in depth except on its shelving margins. On the west side of the tongue of the ocean lies Andros Island, 140 miles long in a north-south direction, protecting a large part of the western lobe of Great Bahama Bank from current sweeping and encouraging conditions favorable to the precipitation of calcium carbonate muds. Little Bahama Bank, on the north side of Providence Channel from Great Bahama Bank, is bounded at the south by Bahama Island and at the east by Great Abaco Island. Theoretically the sheltered bank area west of Great Abaco Island should constitute an evaporating pan similar to that west of Andros Island and likewise favoring the accumulation of calcium carbonate muds. The entire shoal area is sharply delimited, dropping abruptly, "at a gradient of one in three for the upper part of the slope, to depths varying between 2,500 and 6,000 feet" (Black, 1933a, p. 455).

"According to gravity data the Bahama Block is not underlain by igneous rocks, . . . is approximately in isostatic equilibrium, and has undergone recent oscillation in relation to sealevel. Structural phenomena on the margins of the block indicate long and persistent fault-zones; the block has risen or is rising on the east and is sinking or has sunk on the west" (Field and others, 1931, p. 783).

Of the sediments Black says (1933b, p. 167): "The rocks which form the islands are very pure limestones of Pleistocene Age, and the modern sediments on the banks are also entirely of calcite and aragonite, without any admixture of siliceous or argillaceous material (Thorp, 1936, p. 82 says—no appreciable terrigenous material). . . . Andros Island . . . is the largest island in the Bahamas. Along the east coast there is a well developed barrier reef backed by a narrow ridge of limestone hills. . . . Low-lying marshy plains, interspersed with shallow lakes and outcrops of limestone are found in the interior, whilst in the westernmost part of the island . . . the country consists of white, unconsolidated limestone-mud . . . with bare white drewite[6] flats, . . . (and) an intricate system of tidal creeks and mangrove swamps, which render it liable to heavy flooding under favorable circumstances." Drew (1914, p. 33) continues this description as follows: "Towards the west of the island (Andros) the land is remarkably flat, and near the coast consists of white chalky mud, which has partially dried, and in places has formed a harder crust on the surface. These half-dried mud-flats slope almost imperceptibly into the sea, and are continuous with the submarine flats which extend some sixty miles off the coast with an average depth of two to three fathoms. The mud forming these submerged flats is very soft, and near the coast it was easily possible to push a

[6]Vaughan (1924, p. 316) pointed out that the term "drewite," as originally described by Field (1920, Carnegie Inst. Washington, Yearbook 18, p. 197) was applied to fine grained, mostly detrital muds in Tortugas lagoon, and that it is not similar to the mainly chemically precipitated calcium carbonate muds to which Kindle (1923) applied it (Thorp, 1936, pp. 80-81) and for which Black here uses it.

twelve-foot sponge pole down to its full length into it without touching any harder material. The surface layer of the mud for a depth of about 6 inches is of a creamy white color, but below that it is of a grayish tinge and has a slight odor of sulphureted hydrogen."

According to Field and others (1931, p. 774) "the bulk of the fine-grain mud . . . is composed of crystalline grains of calcite and aragonite, 0.05 to 0.01 millimeters, and fine needles of aragonite 0.003 to 0.005 millimeters in diameter." Black states (1933a, p. 461) that "In the centre of the shoals west of North Andros Island, Aragonite needles make up about 20 per cent of the sediment, the other constituents being shells of foraminifera, chips of mollusc shells, and some limestone grains." References to mud cracks and ripple marks in the submerged muds were not noted, but dessication cracking of the muds on Andros Island is remarked by Black (1933b, p. 183).

"It would appear . . . that an appreciable quantity of the fine-grained calcium carbonate muds in the Bahamas, no matter what their present location, might have originated under fresh or brackish-water conditions" (Field *et al.*, 1931, p. 777). Bavendamm (1932) shows, on the basis of bacterial counts and other data, that the most favorable areas for the bacterial precipitation of $CaCO_3$ are not in the open sea, but in the marshes, inlets, or mangrove swamps on Andros Island. The inadequacy of a bacterial mechanism to account for the bulk of the lime-muds of the bank area proper is now generally conceded, however.

It would also seem that sediments of marine or complex origin may come finally to rest under essentially subaerial conditions. Black (1933b) describes how colonies of sediment-binding algae on the marl flats at the west side of Andros Island trap the calcium carbonate sediments from suspension in waters that are swept over them from the banks to the west during storms. Sediment-binding algae also grow under the shoal waters of the Great Bahama Bank, but "no complex algal heads were observed, and . . . it was only above low-water mark . . . that alga-controlled lamination and algal heads with characteristic internal structures were found" (Black, 1933b, p. 169). Black (1933b) further shows that the structures made by these colonies of sediment-binding algae resemble certain Paleozoic stromatolites (*see* Cloud, 1942); that different geographic and salinity belts support different growth-forms; that they are produced by *communities of organisms;* that, whereas they may be in part precipitated, they result in large part from mechanical entrapment; and that they originate normally as a surface modification of unconsolidated sediments, with well-developed algal sediments passing laterally and downwards into ordinary bedded sediments. "They mark a borderline facies between land and water—and, indeed, they often occupy territory which the cartographer hesitates to assign to either. Their structure depends upon several rhythmic processes, foremost amongst which is the alternate flooding and draining of the areas in which the algae grow" (Black, 1933b, p. 182).

Ambiguity between what is marine and what terrestrial seems inevitable in the interpretation of ancient sediments deposited under similar conditions, and the most that can be said is that if the rocks generally contain marine fossils their environment of deposition was essentially marine. On the other hand, even a dominance of nonmarine fossils would not establish a nonmarine depositional environment under such circumstances, as will be seen below.

The life of the Bahama Banks is described by Field and others (1931, pp. 769, 773) as follows: "The first and lasting impression of the entire region was that of an area in which but few kinds and small numbers of animals and plants could live (p. 769) . . . Eelgrass[6a] . . . is found on the bottom and at nearly all points from low water mark to the edge of the bank. Another organism that indicates a bottom surface varying only within a range of several inches is a burrowing crab whose inch-wide burrows are found in abundance wherever

[6a]Dr. Paul Galtsoff (personal communication to Cloud, 8/11/47) states that he saw no eelgrass on the Bahama Banks during an extended visit to the region in 1937. C. L. Smith (1940, p. 149) also reports eelgrass, however.

the water is more than 4 feet deep. . . . farther from shore, in only slightly deeper water a few other forms appear, chitinous(?) sponges, hydroids, crustaceans, and calcareous algae becoming more prominent. . . . The . . . sponge colonies tend to change their position from year to year, and especially after long and severe storms.[6b] Few live mollusks were found, and these only in the deeper areas or holes" (p. 773). Black (1933a, p. 463 notes that "Bottom samples of sediment sometimes consist largely of the shells of benthonic foraminifera and molluscs, but these are mostly decayed or broken, and living specimens are comparatively rare. Bottom living organisms appear to be abundant only where there is an outcrop of bare rock on the sea floor. Such outcrops are not frequent and are of small area; where they do occur, they are reported to be colonized by alcyonarians, sponges, and calcareous algae, and to support a fairly rich molluscan fauna. It is probable that much of the dead shell material which is spread over the rest of the bank has been derived from these comparatively well-colonized areas." However, Field and others (1931, pp. 773–774) state that "the bulk of the gastropod shells in the marine sediments are either terrestrial, fresh water, or brackish types, and have either been blown into the sea from Andros Island or derived by the reworking of the fossiliferous band of unconsolidated calcium carbonate mud along the east coast of the island." Twenty to 50 miles east, on the eastern shore of Andros Island, "where there is practically no calcium carbonate mud, extremely abundant and diversified life exists" (Field *et al.*, 1931, p. 777).

The Chemical Precipitation of Calcium Carbonate from Saline Waters[6c]

In 1892 Dall (*in* Dall and Harris, p. 101) suggested that much of the calcium carbonate mud in the shoal waters of the Florida keys "is probably the result of deposition of lime originally in solution and precipitated by chemical action." Subsequent authors, apparently with the exception of Correns (1939), have accepted chemical precipitation of calcium carbonate in the sea as a fact, although disagreeing on the relative importance of various processes in bringing it about. A good account is given by Black (1933a); a brief summary account by Hatch, Rastall, and Black (1938, pp. 170–173); a more extensive summary by Twenhofel and others (1932, pp. 311–328); and a theory of physicochemical precipitation is outlined by C. L. Smith (1940).

A large amount of experimental and empirical evidence has been brought to bear on the problem of solubility of $CaCO_3$, $CaSO_4$, and $MgCO_3$ in the presence of one another in sea-water, yet their solubility limits under varied conditions are not clearly understood. Empirical data suggest that calcium carbonate is the more insoluble of the three salts under ordinary conditions in sea-water. Wallace (1927, p. 65) states that "$CaCO_3$ is relatively insoluble, (and) $MgCO_3$ relatively soluble" in saline waters, and the general rarity of gypsum in normal marine sediments indicates indicates that its solubility limit is seldom exceeded in normal marine environments. "The large difference between the solubility product constants of calcium carbonate in sea-water and in pure water is explained as being partly caused by the low activity coefficient of the carbonate ion in sea-water" (Moberg *et al.*, 1934, p. 273).

The general opinion seems to be that under ordinary conditions calcium carbonate is the more insoluble of the common salts of sea-water, and that warm sea-water is likely to be saturated or supersaturated with it. Explanations involving the breakdown of theoretical $Ca(HCO_3)_2$, by various means, are thus in vogue to account for precipitation of $CaCO_3$. Other suggestions involve interaction between $CaSO_4$ and $CaCl_2$ with other compounds found in marine waters or produced by bacterial action.

[6b] C. L. Smith (1940, p. 150) notes that "Many sponges break off from their original attachment and become 'rollers,' when they occur wherever the currents drift them."

[6c] Attention is invited to the fact that a modified discussion of portions of the material included in this section of the present paper will be presented as a chapter of the "Treatise on marine ecology and paleoecology" being prepared for publication by the National Research Council.

There follows a systematic tabulation of some of the factors that have been advanced to account for chemical precipitation of calcium carbonate from sea-waters. In so far as it does not involve displacement from a logical sequence, these factors are listed in the approximate order of their frequency of publication. Direct references are given only for the less commonly expressed or more complicated ideas cited. Naturally some overlap is involved in both theory and probable application.

I. Physicochemical factors
  A. Removal of CO_2 from sea-waters saturated with theoretical $Ca(HCO_3)_2$ in the form of Ca^{++} and HCO_3^- ions.
    (1) By rise in temperature of the water, decreasing the solubility of CO_2.
      (a) Through warming of waters upwelled from the depths, by mixing with surface waters, and by insolation.
      (b) Through rise in temperature of superjacent air currents.
    (2) By agitation of the water.
    (3) By escape to air currents low in CO_2.
    (4) By lowering of pressure.
  B. Evaporation; resulting in increased salinity and loss of CO_2.
  C. Variations in hydrogen ion concentration; interconnected with other physicochemical factors and representing changes in CO_2 tension and variation in concentration of the CO_3^{--} and Ca^{++} ions. The exact effects of direction of displacement of equilibria are not agreed upon. (Irving, 1926; Wallace, 1927; Moberg *et al.*, 1934; Smith, 1940.)
  D. Disturbance of equilibrium by differences in the partial pressure of CO_2 in the sea and in the air above it, resulting in overbalancing or piling up of the Ca^{++} ion and precipitation of $CaCO_3$ (Lipman, 1924, p. 190; Gee *et al.*, 1932).
  E. Addition of a strong alkaline carbonate or bicarbonate to solutions saturated with $CaSO_4$ or $CaCl_2$. For example $(NH_4)_2CO_3$, K_2CO_3, or Na_2CO_3 may combine with $CaSO_4$ according to the equation $R_2CO_3 + CaSO_4 = CaCO_3 + R_2SO_4$; R being a monovalent alkaline base (Vaughan, 1924a, p. 314).

II. Biochemical factors
  A. Removal of CO_2 from sea-water by normal life processes of plants.
  B. Bacterial activity.
    (1) By ammonifying or nitrate-reducing bacteria.

$$NH_3 + H_2O = NH_4OH$$
$$2NH_4OH + Ca(HCO_3)_2 = CaCO_3 + (NH_4)_2CO_3 + 2H_2O$$
$$(NH_4)_2CO_3 + CaSO_4 \cdot 2H_2O = CaCO_3 + (NH_4)_2SO_4 + 2H_2O$$
$$(NH_4)_2CO_3 + CaCl_2 = CaCO_3 + 2NH_4Cl$$
$$2NH_3 + Ca(HCO_3)_2 = CaCO_3 + (NH_4)_2CO_3$$

(2) By sulphate reducing bacteria

$$CaSO_4 + 8H = CaS + 4H_2O$$
$$CaS + CO_2 + H_2O = CaCO_3 + H_2S$$

Drew's hypothesis of precipitation by a single bacterial agent (1913, 1914) is now generally discredited, and it has been shown by Lipman (1924) that bacteria probably do not precipitate any significant quantity of calcium carbonate in the open sea. The stimulus of Drew's work, however, led to investigations by Bavendamm (1932) that established the importance of bacteria in the precipitation of calcium carbonate from saline waters under certain conditions. Bavendamm's work shows that forms of bacteria well known from soils and estuarine muds in other parts of the world are effective precipitants of calcium carbonate at places in the special environment of the mangrove swamps, marshes, and inlets of Andros Island. This is probably due to their great abundance and high rate of metabolism in those places. The data on which C. L. Smith's criticism of the hypothesis of bacterial precipitation was based came mainly from two stations on coastal swamps (Smith, 1940, pp. 179, 184, fig. 152) and are insufficient to warrant its abandonment as a possibly contributing factor. Hatch, Rastall, and Black (1938, pp. 172–173) give equations for bacterial precipitation of calcium carbonate and point out the importance of $CaSO_4$ as a source compound, where bacterial reactions are involved. Although the waters of the Gulf Stream are undersaturated in gypsum, they contain over 20 times as much calcium sulphate as calcium carbonate, and this may be an important source of $CaCO_3$ in the presence of $(NH_4)_2CO_3$.

"Calcium carbonate has been produced aseptically (in the absence of bacteria) from sea water under tropical conditions by reducing the total carbon dioxide content of the water" (Gee, *in* Gee *et al.*,

1932, p. 187), and Johnston and Williamson (1916, pp. 743–744) believe that "chemical precipitation would take place wherever, and so long as, a current of water saturated with calcium carbonate was being warmed."

Stumper (1935, pp. 207–208) believes that the speed of decomposition of theoretical $Ca(HCO_3)_2$ in aqueous solution depends not only on the physical conditions of the reaction (pressure, temperature, etc.), and on the initial concentration of $Ca(HCO_3)_2$ and CO_2, but also in some measure on foreign substances dissolved or suspended in the water.

The importance of hydrogen ion concentration in the chemistry of carbonate compounds is receiving increasing attention. The complex of physical and chemical factors that relate to pH are analytically considered by Moberg and others (1934). These authors have developed generalized mass-law equations for the quantitative study of these variable factors, which they refer to as "the buffer mechanism of sea water." Factors which they consider interconnected in this buffer mechanism are pH, total CO_2, CO_2 tension, dissolved free CO_2, solubility of CO_2 in sea-water, HCO_3^- ion content, CO_3^{--} ion content, vapor pressure of sea-water, hydrostatic pressure, temperature, salinity, and alkalinity, referred to by them as "titratable base." Revelle (1934, p. 104) defines titratable base as "the equivalent concentration in milliequivalents per liter of strong bases balanced against weak acid radicals," and he further states that "In normal surface sea water at a temperature of 20° (C.) the calcium concentration and the titratable base generally bear constant ratios to chlorinity." With reference to the solubility of calcium carbonate in sea-water, Moberg and others (1934, p. 272) state that although, on the basis of figures given by others, "surface sea-water is apparently supersaturated with calcium carbonate to the extent of 470 fold . . ., (if) the value for the activity coefficient of carbonate ion . . . is taken into consideration . . . the apparent supersaturation is reduced to less than a sevenfold value." Variables such as $B_4O_7^{--}$ tend to reduce the apparent supersaturation even more (Revelle, 1934), but, in any event, large quantities of $CaCO_3$ are available for precipitation from the sea, and the amount of precipitation apparently is limited mainly by other factors.

The published record seems to warrant the following assumptions: (1) in general, warm waters of the modern sea are saturated or supersaturated with calcium carbonate; (2) under normal conditions, in recent seas, calcium carbonate is less soluble than magnesium carbonate, and the solubility limit of calcium sulphate is seldom if ever exceeded; (3) factors affecting the concentration of CO_2 in a given volume of sea-water are of primary importance in the chemical precipitation of calcium carbonate; (4) under special conditions not ordinarily found in open sea-water, bacteria can and probably do precipitate calcium carbonate; (5) the exact role of hydrogen ion concentration, other than as an index to the concentration of CO_2 and the CO_3^{--} ion, is not clear; (6) chemically precipitated calcium carbonate, in order to be preserved as a potential rock-forming sediment, must come to rest at a place where it is not subject to resolution or mechanical removal; (7) considering these factors, the most favorable environment for the accumulation of deposits of chemically precipitated calcium carbonate is one of warm, shallow, relatively sluggish waters.

As Vaughan (1924a, p. 328) aptly puts it: "The purest limestone is a very shallow water deposit. . . . Whether a shoal-water deposit is a pure limestone or not (however) is determined not by depth of water but by outwash from the land." The normal organic and detrital limestones are recognized by most as relatively shallow neritic or even littoral deposits, and the deep-sea oozes are in a special and stratigraphically insignificant category.

Qualitatively the data cited can be applied inferentially to the interpretation of ancient calcite-mudstones. On the other hand, it seems likely that there may have been considerable variation in the relative proportions of various salts in the epicontinental seas at any given time in the past, as well as in the total

quantity of carbon dioxide in the sea and air; not to mention physical variants. Thus quantitative interpretations, on the basis of statistical data from the modern sea and atmosphere, of rate of sedimentation (Johnston and Williamson, 1916, p. 744; Black, 1933a, pp. 458–461) or possible total calcium carbonate sedimentation (Johnston and Williamson, 1916, p. 748), have little meaning when applied to ancient sediments. For similar reasons, no particular order of precipitation of the several important marine salts can be assumed as an invariable rule for all times and environments.

Mineral Character of Chemically Precipitated Calcium Carbonate in Recent Seas

It is of interest whether calcium carbonate that is chemically precipitated from sea-water comes out of solution as the metastable mineral aragonite or as the stable mineral calcite; and, if the former, how long it may persist in that state under various conditions.

Vaughan (1914, p. 54) was apparently the first to note the occurrence of aragonite in the calcium carbonate muds of the Bahamas, and in 1917 (his Pl. 47, fig. 6) he figured aragonite needles from mud on the west side of Andros Island.

In 1916 Johnston, Merwin, and Williamson exhaustively considered the several forms of calcium carbonate and concluded (pp. 511–512) that: "Of established forms, calcite is, at ordinary pressure, the stable one at all temperatures from 0° (or lower) up to 970°. . . . Under all ordinary circumstances . . . pure aragonite tends to go over into calcite. . . . Natural aragonite is formed (among other ways) . . . in salt waters containing sulphate even at ordinary temperatures. Pure aragonite can persist as such only when dry; but aragonite containing other substances in solid solution may thereby be enabled to persist."

Johnston, Merwin, and Williamson (1916, pp. 508–509) further note that "*Natural aragonite* is usually not pure." They "identified, separated, and analyzed about a gram of the minute separate needles of aragonite occurring in the muds of the shoal waters of the Bahamas, and found that they contain about 0.7 per cent of sulphate reckoned as $CaSO_4$—a quantity of precisely the same order as . . . in samples of aragonite precipitated from solutions containing sulphate at ordinary temperature." It is noted by them that "The fact of the solid solution is significant for two reasons: that it probably determined (1) the precipitation as aragonite; (2) the preservation of aragonite as such." Johnston and Williamson (1916, p. 749) point out that even though "such impure aragonite may persist in contact with sea-water under ordinary circumstances, . . . when exposed to the action of meteoric waters it would soon transform to calcite."

Vaughan's discovery, and the inferences of Johnston, Merwin, and Williamson, were experimentally confirmed by Gee who precipitated calcium carbonate "aseptically from sea water under tropical conditions by reducing the total carbon dioxide content of the water" (*in* Gee *et al.*, 1932, p. 187). This artificial precipitate consisted "of crystals of aragonite which are closely similar in form, size, and optical properties to crystals of natural aragonite from the calcareous bottom muds of the Bahamas" (Revelle, *in* Gee *et al.*, 1932, p. 190). Revelle (*op. cit.*, p. 188) describes the individual needles of this aragonite as having dimensions averaging about 0.001 mm. by 0.003 mm., the largest being 0.002 mm. by 0.01 mm. and the smallest 0.0005 mm. by 0.002 mm. Thorp (1936, p. 74) states that artificial precipitation of aragonite needles was subsequently "produced on a number of occasions by Revelle and Fleming . . . by passing air free of CO_2 through sea water."

C. L. Smith (1940) describes the precipitation of aragonite and suggests that the process is facilitated by seeding with minute aragonite crystals stirred up from the bottom.

Vaughan (1924, pp. 317–321) described the naturally precipitated aragonite needles (identified by H. E. Merwin) from the Bahamas as being particles so minute as to be visible only with a very high power of the microscope or the ultramicroscope." The smaller aragonite needles are said to

exhibit vigorous Brownian movement and probably to consist of particles of colloidal size. Chemically precipitated calcium carbonate sediments are identified chiefly by the presence of aragonite needles. Samples from the Florida Keys also contain aragonite needles, but they are much fewer; and many of the small particles from the Floridian muds "appear to be rhombs and are probably calcite."

Between 1914 and 1942 no less than 12 different authors or groups of authors have called attention to the natural occurrence of aragonite in marine calcium carbonate muds, and its occurrence has been independently confirmed by at least 7 of these authors. Moreover, aragonite needles have been reported from calcium carbonate sediments at Maiao in the South Pacific (Thorp, 1936, p. 92), as well as at several localities in the Floridian and Bahaman regions. It may thus be regarded as well established that aragonite is precipitated from marine waters without the intervention of processes unusual in themselves. However, the oceanographic conditions under which aragonite muds may form and accumulate in quantities sufficient to be potentially rock-forming appear to be rare today and to have been so in the past. Comparison of results of bottom sampling with data on the rate of sedimentation (Black, 1933a, pp. 458–461) suggests that the aragonite needles in the modern calcium carbonate muds retain their mineralogic character for a reasonably long period of time. (At Funafuti, aragonite was found up to a depth of 220 feet.) That is, this aragonite does not go over to calcite in a matter of days or hours as does pure aragonite in the presence of fresh water (Johnston, Merwin, and Williamson, 1916, p. 511), but retains its mineral identity for an unknown but perhaps geologically significant length of time. Bøggild (1930, pp. 244, 238) writes that "In the Alpine Triassic we may find shells (of molluscs) possessng a perfectly unaltered aragonite," but that "the aragonite of all paleozoic and many younger shells has been changed entirely into calcite." Comparable data on the relative span of persistence of aragonite needles in calcareous muds would be of particular interest in connection with the problem of dolomitization. In any event no reliable report of pre-Triassic aragonite is known to the present writers.[6e]

The actual proportion of aragonite to calcite in these muds is not clear from the published record. Evidently aragonite is not an abundant mineral in calcium carbonate sediments except in parts of the Bahaman region. It is also not clear whether any of the calcium carbonate is actually precipitated as calcite or whether all the calcite in these sediments is detrital or secondary. As early as 1903, according to Grabau (1924, p. 337), G. Linck concluded from experimental data that if the solubility limit of calcium carbonate in sea water is exceeded, "deposition of $CaCO_3$ occurs, in the form of calcite in temperate climates and of aragonite in tropical climes." The present authors do not know of a critical reconsideration of Link's inference.

In 1914 (p. 54) Vaughan maintained that the calcium carbonate muds of the Bahamas were "precipitated mostly as aragonite," and Twenhofel and others (1932, p. 314) cite Vaughan as authority for the statement that "the calcium carbonate precipitated is mainly, if not wholly, in the form of aragonite." Black (1933a, fig. 1; *see also* Field *et al.*, 1931, fig.1) found the bottom deposits that "contain a high proportion of Aragonite mud" to be localized in an area of about 4500 square miles in the lee (on the west side) of Andros Island. Black (1933a, pp. 460–461) describes this as "an area where the sea is floored by a deposit consisting largely of aragonite mud," but goes on to say that "In the centre of the shoals west of North Andros Island, Aragonite needles make up about 20 per cent of the sediment." Then Hatch, Rastall, and Black (1938, p. 171) say that "a considerable area of the sea floor west of Andros Island is covered with a white deposit of precipitated aragonite," which they proceed to describe as aragonite mud. Thorp (1936,

[6e] A reported occurrence of original aragonite in a middle Pennsylvanian pelecypod (Newell, N.D., Late Paleozoic pelecypods; Pectinacea: Kansas Geol. Surv., vol. 10, pp. 26, 70, 1938) was based on a staining technique considered unreliable by mineralogists. The nacreous layer of orthoceroid cephalopods from the Upper Ordovician near Dubuque, Iowa, gives the x-ray powder pattern and optical properties of a carbonate apatite. (Dr. Clifford Frondel, personal communication to Cloud.)

p. 94) states that "aragonite needles are distributed over most of the area studied (Bahama Banks), but it appears that they have been washed from one or two local regions of precipitation." It is, thus, not clear whether these sediments at places do consist predominantly of aragonite, or whether they are called aragonite muds because of the large proportion of aragonite in them. In any event 20 per cent of any sediment is a considerable proportion, and even if that proportion is not actually exceeded on the Bahama Banks, there is no evident reason why sediments comprised largely of aragonite could not have been important in the past.

GENESIS OF THE LITHIC CONSTITUENTS OF ELLENBURGER ROCKS

Limestone

The limestones of the Ellenburger group are remarkably free of terrigenous materials, and where they are not dolomitic or cherty they are essentially pure calcite rocks. Material of terrigenous origin in the limestones of the Tanyard formation is virtually limited to minor argillaceous material, increasing westward, and to very minor amounts of angular silt particles, especially in the most westerly outcrops. With rare and very inconspicuous exceptions sand is absent from the Tanyard. The argillaceous material occurs as irregular films and not as well-defined layers. The limestones of the Gorman and, less commonly, the Honeycut formation are intermittently and sparingly arenaceous. The well-rounded and evenly frosted quartz-sand grains which they contain are ordinarily scattered through thin zones in the carbonate rock and seldom make well-defined sand beds. It is argued on page 96 that they were probably brought to their present position by the wind, and that their source was probably to the east and south of the present outcrops in the Llano uplift.

Except where they have been pelleted by mud-ingesting organisms, where they contain irregular veinlets of clear crystalline calcite, or where they are dolomitic, the texture of these limestones is that of the finest lithographic stone. Where they do not break along the irregular argillaceous films their fracture is subconchoidal. They consist of crystals of calcite so minute that thin sections appear semi-opaque. In fact their average diameter of 0.002 to 0.005 mm. (p. 123) is startlingly close to the 0.003 to 0.005 mm. range in diameter of aragonite needles from the Bahama Banks (p. 83).

It can hardly be doubted that the bulk of the limestones of the Ellenburger group were originally chemical precipitates. In fact they may have been purer chemical precipitates than the calcium carbonate muds of the Great Bahama Bank itself, where, in the center of the shoals west of North Andros Island aragonite needles make up only 20 per cent of the sediment, with "other constituents being shells of foraminifera, chips of mollusc shells, and some limestone grains" (Black, 1933a, p. 461).

Comparison of the lithic features of Ellenburger limestones with the inferred potential lithic features of recent marine sediments suggests their origin through alteration, probably at or near the sea floor, of sediments chemically precipitated as aragonite. They might thus be thought of as primary calcium carbonate muds but penecontemporaneous or diagenetic calcite rocks. The precipitated muds were worked over by mud-ingesting organisms (Moore, 1933, 1939), patches of whose ovoid faecal pellets resemble structureless oöids. In some of the more fossiliferous strata fragments of shells are locally conspicuous, but nowhere are the Ellenburger limestones known to be truly detrital. The occasional occurrence of polygonal contraction patterns suggests very shallow water and probably actual temporary exposure to the atmosphere. Ripple-marks were also observed at a number of places.

Dolomite

The only recent dolomitic sediments known to exist in rock-forming quantities are the clearly secondary dolomites of various coral islands in the Pacific and Indian oceans, such as the now classic Funafuti Atoll in the south Pacific (*see* Hatch, Rastall, and Black, 1938, pp. 195–197; Twenhofel *et al.*, 1932, pp. 342–

344). To state a generally held conclusion in the words of Twenhofel and others (1932, p. 339), "no examples of primary deposition of dolomite are known and . . . primary deposition of this sediment lies entirely within the realm of theory."

H. E. Merwin points out (*in* Twenhofel *et al.*, 1932, p. 339) that "Very little to assist in the interpretation or guidance of field studies has been found out by experimentation concerning the chemical relations of dolomite." He states that "although dolomite has been reported as a laboratory product . . . The geological significance of the experiments is slight because geological conditions have not been met." Virtually the same conclusion was reached by Wallace (1927, p. 67).

Irving (1926, p. 441) states that "The molar concentration of Mg in (modern) sea water is about five times that of Ca," and the work of W. Dittmar long ago showed that there is approximately four times as much MgO (6.24%) as CaO (1.67%) in ordinary sea water of modern times (Lyman and Fleming, 1940, p. 136). Although magnesium carbonate appears to be considerably more soluble than calcium carbonate in saline waters, Thorp (1939, p. 291) believes that the sea water of the Floridian and Bahaman region "is near or at the saturation point" for magnesium carbonate as well as calcium carbonate. He believes *(loc. cit.)* that "It is reasonable to expect that the conditions favorable to the precipitation of *(both of)* these salts are sometimes present." Steidtmann (1911, p. 427), impressed with the decrease in volume of dolomite in the geologic column with time, argued that "the decrease in the dolomite content of the sediments in going up the geologic column is mainly due to a decrease in the proportion of dolomite developed in the sea with time," due to selective processes in rock alteration on the lands resulting in a higher percentage loss of calcium than of magnesium through geologic time.

If primary precipitation of either $MgCO_3$ or $MgCa(CO_3)_2$ did or does occur in waters saturated or supersaturated with magnesium carbonate, such precipitation would presumably follow rules similar to those that govern the precipitation of calcium carbonate. The suggestion that the relative proportion of calcium carbonate and magnesium carbonate in the sea may have varied in geologic time is an entirely logical one; and very likely pressure, temperature, and general composition of the hydrosphere and atmosphere have also varied. There is, thus, no certain reason to doubt that primary dolomite may have formed in the geologic past. It is, unfortunately, probably not possible to distinguish primary dolomites from dolomites formed by penecontemporaneous alteration of calcium carbonate sediments at the sea floor.

In the past there were many advocates of the several theories of primary origin of dolomite (*see* Van Tuyl, 1916a, pp. 264–274), but since 1900 these theories have fallen into disfavor.

Sander (1937), however, recently concluded from studies of depositional fabric (Anlagerungsgefüge) that many of the Alpine Triassic dolomites are probably primary in origin, although he acknowledges that "Rein chemische Anlagerung von Dolomit wurde bisher nur in einem einzelnen Falle nachgenweisen" (*op. cit.*, p. 184). Mrs. E. B. Knopf (personal communication to Cloud) believes that what Sander really means is that "as far as he had studied he had only one instance in which he had definite proof that a considerable thickness of dolomite is a chemical precipitate," but that in many instances he had evidence favoring the direct settling of dolomite from suspension in sea water. Sander (*op. cit.*, p. 177) defined primary dolomite as "das in der Frühzeit der Gesteinsbildung Dolomite an eine Stelle im Gefüge kommt, an welcher nicht vorher Calcit war." As he evidently intended the word primary to connote any dolomite derived from ordinary consolidation of sediments which, whatever their previous history, were $CaMg(CO_3)_2$ at the time of their last settling down, it is difficult to argue on ponderable grounds that primary dolomite in Sander's sense might not be a common thing. Certainly all clastic dolomite and perhaps much of the dolomite here called penecontemporaneous might be primary in this sense.

The attempt to reconcile their observations of carbonate rocks in the field with

published chemical and sedimentary data brought the present writers to conclusions essentially in accord with those expressed by Van Tuyl in 1916 and arrived at along similar lines of reasoning. Examination of thin sections and chip samples of Ellenburger rocks in the laboratory yielded no evidence that would require a retreat from these conclusions, provided they are expressed in a form sufficiently elastic to admit new evidence.

Van Tuyl's classic report (Van Tuyl, 1916a) is the most comprehensive and definitive work on dolomite known to the present authors. Two summary condensations of this monograph were published by its author (1916b, 1916c). Additional important views and summaries of information on dolomite are given by Blackwelder (1913), Steidtmann (1911, 1917), Wallace (1927), Murray (1930), Twenhofel *et al.* (1932, pp. 330–351), and Hatch, Rastall, and Black (1938, pp. 175, 183–197).

With such a work as that of Van Tuyl available, and with its published summaries and the summaries of Twenhofel *et al.* and of Hatch, Rastall, and Black available and in essential agreement with one another and the views of the present writers, more extended discussion of the dolomite problem does not seem necessary at this place. Certain points, however, deserve emphasis or reiteration:

1. Dolomite is known to be formed secondarily along joints, faults, or other zones of weakness in the earth's crust by either ground-water leaching or replacement, or by hydrothermal or pneumatolytic action. Dolomitization may extend laterally from such channels, along the bedding, and become locally conspicuous, but known occurrences of such dolomite are volumetrically unimportant in the geologic column, and hydrothermal or pneumatolytic action cannot account for volumetrically important dolomitization away from other evidences of such activity.
2. The only adequate source of magnesium for most laterally extensive, nonclastic, bedded dolomites is the sea.
3. No examples of primary deposition of dolomite are known among recent sediments, and the chemical precipitation of dolomite muds in the geologic past lies entirely within the realm of theory.
4. Most well-bedded, laterally persistent dolomite between beds of unaltered limestone can be accounted for only by penecontemporaneous alteration of calcium carbonate sediments at the sea-floor or by primary deposition of the dolomite. However, means of surely distinguishing primary from penecontemporaneous dolomites are not known. It is known from Steidtmann's work (1917, p. 439) that "The replacement of aragonite and calcite by dolomite has been effected experimentally at ordinary temperatures by solutions comparable to seawater." Irving (1926, p. 441) points out that "Magnesium hydroxide is precipitated from seawater by addition of small amounts of alkali," and that "both magnesium and calcium are in delicate equilibrium where slight changes in alkalinity and carbon dioxide tension may cause precipitation." In a personal communication to Wallace (Wallace, 1927, p. 65), Irving states that if increase in alkalinity "results from free base alone, the magnesium is rapidly precipitated as the pH rises above 10," and that "there is a possibility of salt waters naturally approaching a pH value of 10, permitting the precipitation of both calcium and magnesium." He also remarks (*in* Wallace, *loc. cit.*) that, whereas $CaCO_3$ is relatively insoluble and $MgCO_3$ relatively soluble (in saline waters), "$Ca(OH)_2$ on the contrary is quite soluble as compared with the insoluble $Mg(OH)_2$."
   From these data it would seem that there is little chance of actual precipitation of $CaMg(CO_3)_2$ except through interaction between $Mg(OH)_2$ and $CaCO_3$ in suspension,

and less chance of precipitation of pure $MgCO_3$. The published information on the relative solubilities of the various salts of calcium and magnesium found in sea waters at present appears to favor the deduction that penecontemporaneous alteration of calcium carbonate sediments by magnesium salts acting at the sea-floor is a more important dolomitization process than primary precipitation. In view of this the writers hold that it is not advisable to assume a primary origin for a dolomite that can otherwise be explained as well as the result of penecontemporaneous alteration.

5. It has been known since 1848 (Van Tuyl, 1914, p. 361) and is now well established that dolomite may grade laterally to limestone with great abruptness.

   As a rule such dolomite is coarse to fine grained, and it is commonly vuggy or porous. Such dolomites may be underlain and overlain by limestone, but the lateral contacts between limestone and dolomite are likely to be gradational. Commonly they are without relationship to apparent fractures or zones of permeability such as would be followed by dolomitizing meteoric waters. It is thought that most such dolomites were formed below the sea, but probably at greater depth and at a later stage in diagenesis than the penecontemporaneous dolomites. Dolomites so formed would be truly secondary dolomite, but secondary within the diagenetic cycle and not as a result of ground-water leaching. Both penecontemporaneous and later diagenetic dolomites are, of course, authigenic.

6. A scatter-diagram by Steidtmann (1917, p. 437, fig. 1) based on "1,148 analyses of specimens from all over the United States . . . shows that nearly pure limestones and dolomites are more common than mixtures of the two."

   Of course, these data cannot be regarded as a fair average representation of carbonate rocks in the geologic column for the reason that the source of recorded analyses is normally from economic studies and clearly hybrid carbonate rocks are not ordinarily analyzed. Van Tuyl (1914, pp. 260, 262) shows that all gradations are known, and even the chemical analyses of selected parts of the section in the present report include several between Pfaff's theoretically rare limits of 7 to 11 per cent $MgCO_3$. Doubtless analyses across transitional zones would show a transitional character, although they might not affect the conclusion drawn from Steidtmann's data by Twenhofel and others that "conditions which favor dolomitization in the sea appear to be rather sharply distinct from those which do not permit it." Dr. P. B. King (written communication to Cloud, July 2, 1946) questions Steidtmann's statistical summary on the basis of "a large number of analyses of carbonate rocks . . . from the Permian of the Guadalupe Mountains," where "The only rocks that approached true dolomites were those in the 'back reef' 'shelf' area, and were probably evaporites."

7. Inasmuch as "aragonite and other metastable forms of $CaCO_3$ react much more readily with chemicals than does calcite," and a rock that consisted mainly of metastable $CaCO_3$ "would be in a very favorable condition to be dolomitized" (Van Tuyl, 1914, p. 401; *see also* Hatch, Rastall, and Black, 1938, p. 191), it is of special interest that aragonite is volumetrically important in recent chemically precipitated calcium carbonate muds west of Andros Island in the Bahamas. Aragonite muds were probably volumetrically important among the source elements of sublithographic limestones in the past, and distribution of aragonite in the original sediments may be related to irregular dolomitization of the rocks and to lateral gradations not related to

apparent zones of vertical circulation.

8. The porosity of many of the coarser grained dolomites is probably related to the greater potential permeability offered leaching solutions by their coarser fabric and to minor irregularities of initial dolomitization.

Inspection of analyses given in Part 3 of the present report will show the reader that there is a general tendency for the finer grained dolomites of the Gorman and Honeycut formations to average slightly higher in $CaCO_3$ than those of the Tanyard formation. It is suggestive that the dolomites with the higher calcite ratio are also those of finer grain and lower porosity, but more extended observations are needed on this matter before a conclusion may be reached about this relationship. The presence of coatings of well-formed dolomite crystals in some of the vugs suggests recrystallization from leaching solutions. The observations of the present writers lead them to view favorably the suggestion of Murray (1930, p. 463) that dissolution of included calcite from dolomites by percolating waters is important in developing porosity.

Lindgren pointed out in 1912 that metasomatic replacement was on a volume for volume and not a molecule for molecule basis. Under his "law of equal volumes," if porosity results from metasomatism it is likely to be due to solution ducts (*loc. cit.*, p. 535). Basing his calculations on the theory of molecular replacement, however, Elie de Beaumont had concluded in 1836 that the alteration of limestone to dolomite should be accompanied by a 12.1 per cent decrease in volume (*see* Van Tuyl, 1916b, p. 249), and geologic literature contains many references to the theoretical "12 per cent porosity" of secondary dolomites. The attack on the theory of cavity development through molecular replacement was taken up by Murray in 1930 and more recently by Landes (1946). If Landes' inference that the porosity of dolomites is related to replacement of limestones by ground waters is intended as a general conclusion, however, the present writers find no support for it in their studies of field relationships and thin sections (p. 124). Nor can they follow his argument (Landes, 1946, p. 317) that, in spite of the fact that "the voids in the dolomite have all the characteristics of solution cavities . . . yet they can not have been formed by ground water leaching or the neighboring limestone would be similarly honeycombed." Solution in granular dolomitic rocks of irregular composition is naturally more diffused than in compact limestones, where it tends to follow definite channels related to zones of weakness. The writers favor, rather, Murray's conclusion that porosity results from leaching of calcitic inclusions from rocks predominantly dolomite. The present work does not consider continuous or interconnected porosity a necessary consequence of ground water leaching. Extremely slow percolation might effect solution of calcite areas without essentially "spreading" the fabric of the dolomite grains, and interstitial reprecipitation might seal off the minute solution channels, preventing the development of effective porosity.

Although the coarser grained dolomites seem ordinarily to be more porous than the fine grained ones, effective porosity at least is not directly related to granularity. For instance, the distribution of springs in the dolomites of the Ellenburger group of the Llano region (p. 127) suggests that the finer grained dolomites of the Staendebach member of the Tanyard formation have a greater degree of permeability to meteoric waters than do the coarser grained dolomites of the Threadgill member of the Tanyard formation. It is of theoretical interest, in connection with the porosity problem, that Johnston, Merwin, and William-

son (1916, p. 510) point out that molecular replacement would demand a 10 per cent increase of volume on transformation of aragonite to calcite. One is tempted to speculate what relation to dolomite porosity the initial mineralogic state of the altered rock might have if replacement were on a molecular basis.

9. It has been observed by many geologists, including Hatch, Rastall, and Black (1938, p. 192), P. B. King (written communication to Cloud, July 2, 1946), and the present writers, that rocks that are dolomites near ancient lands are prone to grade to limestones away from the old shorelines.
   The explanation for this is not clear, but it is probably to be found in the fact that experimental evidence shows that dolomitization is favored by elevated temperatures and that, other conditions being equal, "dolomitization goes on most favorably in those regions where the waters are warmest" (Van Tuyl, 1914, p. 402). Dolomitization should, therefore, be encouraged by shallowness of water and thus nearness to shore or shoal areas (*see also* Twenhofel *et al.*, 1932, p. 346).
10. Direct precipitation of dolomites possibly may result from evaporation of inclosed hypersaline waters (P. B. King, written communication, July 2, 1946). However, such deposits are typically associated with gypsum and other evaporites that clearly represent a special type of sedimentation.

Proceeding from the foregoing remarks the following genesis is suggested as probable for the dolomites of the Ellenburger group.

The dolomites that show abrupt lateral transitions to limestone through considerable stratigraphic intervals, including all of the medium and coarse grained dolomites and some of the fine grained ones, are secondary or replacement dolomites. They were formed from calcium carbonate sediments below the sea floor at a stage in diagenesis sufficiently advanced for some compaction of the sediments to have taken place. Some of their abrupt lateral transitions to limestone may be related to zones of transition between calcite and aragonite in the sediments being altered, but others are possibly related to zones of permeability subsequently eradicated by continued diagenesis. Partial dolomitization resulted in limestones with an irregular internal meshwork of dolomite, or the reverse, and patches and grains of calcite remained locally in almost completely dolomitized sediments. The porosity now visible in these dolomites resulted largely from leaching, mainly of calcitic inclusions, by slowly percolating meteoric waters at some date subsequent to their lithification.

The dolomites that are laterally persistent, especially where they alternate with limestone, were formed penecontemporaneously at the sea floor, if they were not primarily precipitated as $CaMg(CO_3)_2$. Penecontemporaneous origin involves reaction between original calcium carbonate muds at the sea floor and magnesium salts in solution or suspension in the basal layer of sea water. The dolomite beds that are laterally continuous include nearly all the microgranular to very fine grained dolomites and some of the fine grained ones. Because of the relative solubilities of the carbonates and hydroxides of calcium and magnesium (p. 91) and because even some of the microgranular to very fine grained dolomites do grade abruptly to limestone at a few places, the writers tend to think of them as penecontemporaneous. It is conceivable, however, that a current from which carbonate minerals were being precipitated might locally be sufficiently depleted of $CaCO_3$ to permit the precipitation of $CaMg(CO_3)_2$, while $CaCO_3$ continued to precipitate in adjacent parts. In any event it cannot positively be said that the dolomites here called penecontemporaneous are not primary, and to that extent a sense of query is implicit in the use of the adjective "penecontemporaneous." Ideas similar to those of the present writers have previously been suggested by Daly (1909, p. 170), Blackwelder (1913, p. 622), and Hatch, Rastall, and Black (1938, p. 175).

The scattered euhedral dolomite rhombs seen in many of the limestones of the Ellenburger group probably resulted from reactions at the sea floor with waters not having a sufficient excess of magnesium for more extensive dolomitization.

No dolomites of clastic origin are known among the rocks of the Ellenburger group in the Llano region.

Chert

It is difficult to escape the inference that much, if not all, of the chalcedonic to porcelaneous (Pl. 23, figs. C and F; Pl. 21, fig. C) chert of the Ellenburger group was penecontemporaneous or primary in origin, and that the interstitial chert results primarily from diagenetic redistribution of gelatinous silica in the sediments.

Observations by the authors in the field and laboratory indicate that the dolomoldic cherts, which are so commonly regarded as true epigenetic cherts, result from intense leaching of dolomites that contain quantities of interstitial chert. Such cherts are commonly laced with crystalline quartz druse (Pl. 23, figs. A and B), resulting from redistribution of disseminated silica by meteoric waters, and making the total weathered mass more compact and bulky than one finds among residues prepared from fresh, relatively unleached rock. Their origin is therefore complex. The concentrated growth of quartz druse on jointing and bedding surfaces, in vugs, and in the cavernous or vuggy dolomoldic cherts clearly betrays its secondary origin. It is ordinarily localized in the dolomitic rocks, suggesting a relation to permeability. Its origin by redistribution of disseminated silica is confirmed by studies of insoluble residues from Upper Cambrian limestones and dolomites (San Saba limestone and Pedernales dolomite members of the Wilberns formation) that are equivalent to one another. These show a minimum of crystalline quartz particles and a maximum of disseminated silt or dust particles in the limestones, whereas the reverse is true in the dolomites.

Silicification of fossil shells is an open problem. It seems unlikely that this could occur within sublithographic limestones through weathering, but silicified shells are not known from Ellenburger rocks of the subsurface.

The chertification of pellet limestones, oölites (Pl. 23, fig. E), and stromatolites (Pl. 23, fig. I) is clearly post-depositional, but may have been penecontemporaneous and not long after sedimentation.

The occurrence of well-formed dolomolds and dolomite rhombs in many of the nodules, lenses, and beds of compact cherts suggests their origin through aggregation of gelatinous silica at the sea floor, concomitantly with the dolomitization process. The fact that chert-textures can be used at all in stratigraphic studies suggests their relation to sedimentary or early diagenetic processes, or both. Tarr and Twenhofel (*in* Twenhofel *et al.*, 1932, p. 545) contend that the volume of silica carried in solution by rivers to the sea is sufficient to account for "nodules, lenses, and beds . . . deposited directly from sea water," as well as some "silica replacement of the calcium carbonate surrounding the soft nodules as they rested on the sea floor."

An origin as semi-gelatinous silico-calcareous mud-balls is suggested for the so-called "cannonball cherts" of the present report (p. 16). Their features suggest origin by rolling about at the sea floor of plastic material that incorporated and bonded lime-mud and fragments of loose shells in a matrix of gelatinous silica, much as a snowball may be built up by rolling on the snow-covered ground.

It is perfectly conceivable that such mud-balls might be rolled by intermittent current or wave action insufficient to disturb significantly the sticky impalpable lime-muds that probably comprised the floor of the Ellenburger sea over most of central Texas. The drifting by currents of sponge "rollers" on the Bahama Banks has been described by Smith (1940, p. 150), and it is certain that the wide spread of pieces of *Archaeoscyphia* at certain levels in the Ellenburger was attained in a similar manner. *Archaeoscyphia* "rollers" and cannonball chert are common associates in the upper Ellenburger (Pl. 23, fig. H). Moreover, evidences of intermittently turbulent conditions are found sporadically through the Ellenburger sequence, and especially above the

Tanyard formation in the form of local thin intraformational granule-breccias and conglomerates. Differences in density of sponge and mud-ball, and the "rubbery" nature of silica gels, are objections to the idea outlined. The first is inconsequential if one has subspherical mud-balls and motion of any significance in the waters above. The second it is hoped will be minimized by mixing a lot of calcium in with the silica.

The various stages of apparent chertification of these cannonball cherts is probably related to varying original silica content, with possibly some redistribution of silica related to areas already partially siliceous. The concentration of fossils in these cannonballs, in general contrast to the surrounding limestones, tends to confirm the origin suggested and to negate the counter-hypothesis that they may be concretionary. Some of them apparently were compressed to lobate masses while yet plastic, if the sublenticular material of this texture did not result from accumulation and binding of drifting material in depressions originally present, but many retain a subspheroidal form (Pl. 23, fig. H).

Quartz-Sand

Quartz-sand, ordinarily referred to simply as sand, is found in Ellenburger rocks younger than the Tanyard formation. It occurs typically as scattered grains in carbonate rocks and seldom comprises well-defined sand beds. In the Llano region the rocks of the Gorman formation are more commonly and more abundantly arenaceous than those of the Honeycut, and the lower 50 feet of the latter are more commonly arenaceous than the overlying beds. The sands become more numerous and volumetrically more important from west to east and from north to south in the Llano region. The most prominent sand known to occur in Ellenburger rocks is a 21-inch zone that outcrops in the old Lake Victor quarry, about 13 miles north of Burnet and 0.5 mile east of U.S. highway 281. At this place 8 to 8.5 inches of slightly dolomitic sandstone is overlain by 12.5 to 13 inches of dolomite with half-inch layers of dolomitic sandstone like the lower 8 inches. In the lower 4.5 inches of this 21-inch zone are subrounded to rounded dolomite pebbles as much as 2.5 inches long and 0.8 inch thick.

The individual grains of sand are typically well rounded, evenly frosted, small, and poorly sorted within their small size limits. Grains that barely exceed the size limit of silt are commonly quite as well rounded and smoothly frosted as larger grains.

The writers believe that most, if not all, of this sand was brought to its present position by the wind. Evidence supporting this view is:

1. The generally well-rounded, smoothly frosted character of even the very small grains, some as small as 0.06 mm. being recorded from the lower Gorman strata in the Warren Springs section, indicates that they were shaped if not transported by wind action.
2. The scattered and poorly sorted character of the sand grains in most of the arenaceous zones, and the thin and widely intermittent character of the arenaceous intervals.
3. The general scarcity of terrigenous sediments in the Ellenburger rocks, posing obvious difficulties to the transportation of water-borne sands from the land.
4. The common association of sand zones with evidence of locally turbulent water conditions, suggesting an association with windstorms. This is exhibited by the occurrence noted at the Lake Victor quarry (above), where sizeable pebbles of dolomite occur in the lower part of a prominent sand zone. These pebbles were probably little more than compacted muds when they were torn loose from the sea-bottom, which accounts for their subrounded to rounded character.
5. The demonstrated competency of winds to carry sand, and the fact that wind-borne sands are well known in recent marine sediments. Hatch, Rastall, and Black (1938, p. 26) describe an area lying southwest of the coast of Africa between Cape Verde and the Canary Islands, where

> "During the spring and winter months a surprisingly large area of sea floor . . . receives a considerable amount of wind-transported material . . . (that) consists principally of well-rounded grains of quartz and is accompanied by much fine dust." One of the present writers (Cloud) has been at sea off the coast of southern California during a sandstorm of quite respectable proportions and duration.

A comparison of the probably windborne sands of the Ellenburger group in the Llano region, with the probably waterborne sands of the Upper Cambrian rocks is given on page 23.

Glauconite

Although glauconite is common in many of the Upper Cambrian rocks of central Texas, it is an exceedingly rare mineral in rocks of the Ellenburger group (p. 35) and its occurrences in the Ellenburger are probably not authigenic. Being a mobile mineral, however, it has locally attained an interstitial relationship with dolomite. Glauconite is recorded locally from the lime-muds of the Bahama Banks by Thorp (1936, p. 83), who states that "the very few grains in these deposits appeared to be old, eroded, and definitely not of authigenic origin." The distribution of probably authigenic glauconite in the lower Paleozoic rocks of the Llano region bears significant geologic implications. Some data relating to its identification and interpretation are therefore given below.

Glauconite is a complex hydrous silicate of potassium and ferric iron which occurs as ovoid or lobate globules and is found in some parts of the world in deposits of almost every age from Cambrian to Recent. The color of fresh glauconite is generally some shade of green, but it weathers yellow or brown, and some of the English Paleozoic glauconites are almost colorless (Hadding, 1932, p. 114). Its properties are summarily described by Schneider (1927, p. 289) as follows: "The composition of glauconite can be expressed . . . as . . . $K\ Mg\ Fe_3\ Si_6O_{18} \cdot 3H_2O$. The ferric iron content varies from 16 to 30 per cent and the alumina from 10 per cent down to less than 2 per cent. Glauconite is optically negative and biaxial with a small optic angle. Both the indices of refraction and the birefringence vary with the ferric iron content. Modern glauconite is essentially the same as the glauconite of the older formations both optically and chemically. The X-ray patterns of the samples of glauconite studied show that glauconite is a definite mineral, and not a mixture of various substances."

It is generally maintained that glauconite is a member of the mica group (Gruner, *in* Galliher, 1937, p. 698; various papers by Galliher; Hadding, 1932, p. 128); but the question is mooted whether it originates through alteration of preexisting biotite at the sea floor (various papers by Galliher), from alteration of "a number of mother materials" (Takahashi, 1939), or as a flocculent precipitate on the sea-floor and not by alteration of other minerals (Hadding, 1932). Regardless of its initial origin it seems more often than not to have been pelleted by bottom-feeding organisms, resulting in its polished and ovoid to lobate form. Glauconite may be confused with the chemically similar earthy mineral celadonite (Hatch, Rastall, and Black, 1938, p. 141), or with certain nonpotassic, low-silica, high alumina, high iron silicates known as chamosites (Hadding, 1932, p. 161). The chamosites, however, contrast with glauconite by occurring typically as oöids that have a radial structure (Hadding, *loc. cit.*).

Some environmental implications that have been attributed to glauconite are as follows:

1. "Glauconite is essentially a mineral of marine environments, and although it may find its way as a detrital mineral into terrestrial and fresh-water deposits, there is no satisfactorily confirmed case on record of its having been actually formed in a non-marine environment" (Hatch, Rastall, and Black, 1938, p. 141; and similar statements in most references listed).
2. Glauconite originates typically in neritic environments (permanently submerged sea bottom less than 100 fathoms deep), and it probably does

not form in littoral environments (shore zone between tides). Hatch, Rastall, and Black (1938, p. 142) say that "Greensands and green muds in modern oceans are found near the edge of the continental shelf, though the mineral glauconite occurs in both deeper and shallower water." They think (*op. cit.*, p. 143) that, where evidence of deposition in very shallow waters is found, "it seems probable that in many of these instances the glauconite was not formed contemporaneously, but was deposited in the form of a secondary concentrate." Hadding (1932, p. 54) thinks that, "beds of glauconite were deposited at a depth of probably less than 100 m., and the formation of glauconite took place at the same slight depth." In Monterey Bay, on the coast of California, Galliher (1935a, p. 1353) found that "Glauconite begins to occur in the sediments together with biotite at depths as little as five or ten fathoms; and . . . finally, at about fifty fathoms, glauconite becomes very abundant and gives the sediments a dark greenish cast."

3. Hadding (1932, pp. 54, 159) supposed that glauconite formed in "relatively cold water," basing his supposition on, among other things, the fact that it "neither occurs nor has been formed . . . with the coral reefs, nor in bryozoan beds." Takahashi (1939, p. 504) points out that "A summer temperature of not lower than 15° C. . . . seem(s) necessary for glauconitization." Galliher (1935b, fig. 16) shows recent glauconite in all climatic zones.
4. On stratigraphic evidence Hadding (1932, pp. 54, 84, 160) suggested that "beds of glauconite were deposited and the glauconite formed in agitated open water."
5. Hadding (1932, pp. 54, 160) believed that "The formation of glauconite was favored by a slightly reducing milieu," and that it "never formed in highly oxygenous water."
6. Galliher (1935a, p. 1361) states that "Recent occurrences of glauconite, as recorded by several writers (5 publications cited), always lie adjacent to land masses where plutonic or metamorphic complexes are exposed to erosion." Figure 16 of Galliher, 1935b, shows "Glauconite in present ocean basins," indicating its general proximity to igneous or metamorphic rocks. However, most of the coast line of the world, except in the arctic regions, is shown to be of or near igneous or metamorphic rocks and the validity of Galliher's implication is not unequivocably substantiated.

ECOLOGIC IMPLICATIONS OF ELLENBURGER LIFE

Except locally the fossil assemblages in rocks of the Ellenburger group are few in number of species and individuals. The faunas are dominantly molluscan, with gastropods and cephalopods relatively well represented. Brachiopods are few in number, only 7 genera and 13 or more species being known from the entire 1800 feet of rocks that comprise the Ellenburger group. Trilobites are uncommon, but better represented than the brachiopods. Two genera of archaeostracan crustaceans and two of sponges are known, and the primitive coral *Lichenaria* (identified by R. S. Bassler) occurs near the top of the Tanyard formation. Representatives of other zoologic groups are rare or absent.

Evidence of plant life is limited to stromatolites (*see* Cloud, 1942), possibly related to the activities of sediment-binding algae (*see* Black, 1933b), and abundant remains of the dasycladacean alga *Rhabdoporella* (identified by J. H. Johnson). The latter is known only from the upper 90 to 100 feet of the Tanyard formation. The ecologic implications of the algal structures are discussed in the papers cited and summarized in the section that follows.

In their dominantly molluscan aspect the Ellenburger faunas recall those of correlative carbonate rocks in the Ozark uplift and the southern Appalachian region and differ from those of the Arbuckle and Wichita Mountains, the Marathon basin, and to a lesser extent the Franklin Mountains. They are, of course, markedly different from those of

the black shale facies in the Lower Ordovician.

The Ellenburger fossils have not been studied in sufficient detail to say whether or not they occur in definite zones separated by unfossiliferous rock as Cullison (1945, pp. 47, 52) found the Lower Ordovician fossils in the Ozark uplift to do. Some species and genera certainly mark particular zones, but it is the impression of the writers, based on mapping, that the fossils in general are erratically and sparingly distributed through much of the section. The impression is gained that, although conditions were in general not favorable to the shell-bearing bottom-dwellers, there were local areas at most times where benthonic shells could and did survive. At some times these conditions were more widespread and relatively abundant life developed, but it is believed that in most instances this more abundant life was an outgrowth from forms that held on through the unfavorable periods. An analogy is found with conditions on the Bahama Banks today, where a generally soft bottom and waters periodically muddied with flocculent calcium carbonate are unfavorable to most forms of life, but where local patches of solid bottom support a rich molluscan fauna, as well as sponges, corals, and calcareous algae (Black, 1933a, p. 463).

Mud-ingesting organisms were active through most of Ellenburger time, as is shown by the commonly pelleted limestones (*see* Moore, 1933, 1939). These apparently were mostly soft bodied organisms, for preserved shelly remains are insufficient to account for the numbers of animals that must have engaged in the pelleting process. Probably many of them simply plowed up and ingested the surface muds, but others actually bored into the muds and left well-defined burrows (p. 35). Moore (1933, p. 25) believes that the simple ovoid pellets, such as are most common in the Ellenburger rocks, "are those of either polychaetes (worms) or molluscs." Thus, if the inference is correct that the pellets in the Ellenburger rocks were mostly made by soft bodied organisms, worms may have been responsible for them.

Tracks of fossils are common in the relatively thinly bedded limestones of the Threadgill member of the Tanyard formation in the western part of the Llano region. Most of these are discontinuous, selectively dolomitized welts (Pl. 20, fig. D) which average about as broad as the apertural diameter of the common snails of the same beds *(Lytospira gyrocera, Ophileta polygyrata)*. They are restricted to the surface of the rock and thus are not borings. Commonly they seem to anastomose because of overlapping. Their discontinuous nature suggests that they were made by some buoyant benthonic organism that from time to time lost contact with the sea bottom due to surging of the waves. This, in connection with their size and their association with the common snails of the time (Pl. 20, fig. D), strongly suggests that they are the trails of *Lytospira* and *Ophileta*. The ancient snails, like the modern ones, doubtless secreted an agglutinating substance along the paths they followed, and this would serve to bind and localize the drifting coarser sediments of the time and encourage the selective dolomitization seen. The interruption of the trails suggests that they were made within reach of the surging action of the waves and probably indicates reasonably shallow waters.

At one place, in the same beds that display the common type of trail, a corrugated trail about one-third of an inch wide and 12 inches long suggests trails that have been attributed to trilobites. This trail was seen 174 feet above the base of the Tanyard formation in the Pete Hollow section, and a trilobite was obtained from the same bed (TF–430). Several broader bifurcating trails that occur in the same beds are more difficult to assign. They could have been made by cephalopods, resting suspended but in contact with the sea-floor and washing back and forth with the surging of the waves.

Evidence of possible nektonic organisms in Ellenburger rocks is limited to a few conodonts from the lower strata of the Tanyard formation of the Threadgill Creek section (Barnes, Cloud, and Warren, 1945, p. 176).

PROBABLE OCEANOGRAPHY AND ECOGRAPHY OF THE ELLENBURGER SEA

Evidence relating to the probable lithogeny of Ellenburger rocks, the character of Ellenburger life, and the relations of both to the environment of Ellenburger time has been presented above. This is now brought to bear on a summary of the probable oceanography and ecography of Ellenburger waters:

1. Ellenburger waters were marine. They supported many forms of life unknown except from marine environments and none that are known to be limited to fresh waters.
2. The Ellenburger province of the mid-Continent sea was shallow. Its bottom was less than 100 fathoms deep, probably at most times and places less than 15 and possibly less than 5 fathoms deep, and perhaps locally awash. The environment was thus wholly neritic and possibly at times and places littoral, the terms neritic and littoral as here used referring to depth of water without implying any particular relationship to the principal shore-areas of the times.

   The intermittent presence of structures formed through the agency of algae (stromatolites) suggests a maximum possible depth of about 100 fathoms and their local good development favors a depth of less than 15 fathoms (Cloud, 1942, pp. 370–371). However, the depth of optimum photosynthesis was probably reduced by intermittent turbidity, resulting from the stirring up of calcium carbonate. Therefore, beds containing large and abundant stromatolites (Pl. 25, fig. B) may have been deposited in waters considerably less than 15 fathoms deep.

   Black (1933b; *see also* Hatch, Rastall, and Black, 1938, p. 166) shows that colonies of sediment-binding algae that are now building structures comparable to the common stromatolites of the Ellenburger group actually have their optimum development in tidal flats, or above normal high tide, on near-shore flats that are periodically inundated by marine waters.

   Evidence that the sea bottom was affected by the surging action of waves is indicated by interrupted gastropod trails in the lower Tanyard rocks and the occasional development of ripple-marks throughout the section. However, Sheppard and Emory (1945) report having observed ripple-marked sand at depths as great as 70 fathoms off portions of the California coast. In fact any bottom that is sandy is likely to be current swept at times and therefore prone to be ripple-marked. The local occurrence of polygonally cracked limestones suggests temporary subaerial exposure. which may have occurred in mud-flats of the littoral zone between tides or even at higher levels. The local development of intraformational breccias or conglomerates, commonly in association with sands thought to be windborne, suggests waters sufficiently shallow to develop strong bottom turbulence during periods of storm.

   The great development of chemically precipitated carbonate muds from which the Ellenburger rocks were probably formed presupposes an environment of warm shallow waters; and the only known comparable sedimentary area in recent seas, the Bahama Banks, is mostly less than 3 fathoms deep, and apparently does not exceed 5 fathoms in depth except on its shelving margins (p. 82). If the temperatures of Ellenburger times were high enough and the circulation of the sea poor enough, the carbonate sediments might have settled undissolved through waters deeper than those in which flocculent carbonate minerals could survive in present seas. It is not possible to place an average depth shallower than the 15 fathoms thought to be required for optimum photosynthesis, and even depths this shallow cannot be proved for beds in which stromatolites do not thrive.

3. The water of the Ellenburger sea was warm, and so, probably, was the air above it. Tropical or semi-tropical conditions are strongly indicated by the great succession of chemically precipitated carbonate sediments from which the Ellenburger rocks were probably derived. The evidences of primarily chemical deposition, and the general absence of clastic fabrics, suggests that the lime-muds of Ellenburger time may have been much more rapidly and abundantly precipitated than those of the Bahama Banks. This might suggest that the waters that moved into the Ellenburger province of the mid-Continent sea were more highly supersaturated with calcium salts, and that conditions affecting the precipitation of $CaCO_3$ were more persistent or more accelerated than they are over the Bahama Banks today.

   Of course, continuing or intermittent relative subsidence of bottom with respect to wave base is prerequisite for the accumulation of any sequence of shallow-water sediments.

   The known representatives of Ellenburger life do not furnish critical evidence on the temperature of the waters of Ellenburger time. Although lime-secreting algae seem generally to grow better in warm water than in cold water, they actually have a wide thermal range and do not of themselves furnish direct information about the temperatures under which they lived (Cloud, 1932, pp. 369–370). On the basis of numbers and variety alone the Ellenburger fauna does not compare at all well with the warm-water fauna of the present seas, except those found in unusual environmental circumstances such as occur on the Bahama Banks (pp. 83, 84).

4. Ellenburger waters were probably well oxygenated.

   Their dominant faunal elements are relatively large and thick-shelled gastropods and cephalopods. Intraformational conglomerates and breccias associated with probably wind-borne sands, and the surging indicated by ripple marks and interrupted gastropod trails, suggest intermittently turbulent conditions extending to the shallow sea-floor. Chemical analyses of Ellenburger rocks show them to be persistently low in iron away from places where it could have been secondarily introduced.

5. The Ellenburger sea was intermittently turbulent and at such times was probably "milky" with flocculent lime-muds stirred up from the bottom.

   The opacity of the waters at such times doubtless inhibited the formation of structures dependent for their origin on photosynthetic activity (stromatolites), and probably was unfavorable to the shell-bearing benthos as well.

6. At most times and places the bottom of the Ellenburger sea was soft.

   The patchy and intermittent occurrence of fossils in the Ellenburger, except in the lower beds at the west side of the Llano region, suggests a generally soft bottom, inhibiting the development of the shell-bearing benthos except at the few places where firm bottom conditions prevailed. The probable nature of the original sediments, comparable with those of the Bahama Banks, suggests a similar conclusion.

7. The sea in which the lower Tanyard sediments accumulated probably had a firmer bottom on the west side of the Llano region than it did to the east.

   The abundance of large gastropods in the limestones of the Threadgill member on the west side of the Llano uplift suggests this. The evidence of wave surging indicated by ripple marks and interrupted gastropod trails shows that the water here was still fairly shallow, but the probably firmer conditions indicated suggest that it was marginal to the areas of most active sedimentation. This point is supported by the fact that the Tanyard formation is thin-

ner on the western side of the Llano uplift than it is at the east.

8. In Ellenburger time land lay to the east and south of the Llano region. This land was either nearly level, relatively far removed, or separated from the Llano region by a channel. The sea-floor was probably shallowest at the east and south sides of the Llano region and deepened gradually to the northwest.

   Land to the east and south is indicated by the fact that the probably wind-borne sands of the post-Tanyard strata become more numerous and volumetrically more important to the east and south. That it was either nearly flat, relatively far distant, or separated from the Llano region by a channelway is indicated by the absence from the Ellenburger of recognizable water-borne detritus, and the first alternative as the primary controlling factor is probably eliminated for Tanyard and most of Honeycut time by the distribution of wind-borne detritus. Deepening of the sea westward and northward is indicated by a general decrease in dolomite in this direction, well shown on Plate 14. It has been noted (p. 94) that rocks that are dolomites in or towards the ancient shoal waters tend to grade seaward to limestones, concomitantly with increase in depth and thus decrease in temperature of the bottom waters.

9. If the land that lay to the east and south of the Llano region was not nearer to the present margins of the Llano region in Gorman time than it was in Tanyard time and much of Honeycut time, then atmospheric turbulence was at its peak in Gorman time.

   This assumption is based on the virtual absence of sand from the outcropping Tanyard rocks and the fact that it is commoner and more abundant in the Gorman formation than in the Honeycut. In the southeastern part of the region (Johnson City area) evidence of marine (thus atmospheric) turbulence was observed by Barnes to be commoner in the Gorman formation than in the beds above and below it. Evidence on this point from other parts of the Llano uplift is more equivocal, but either in support of (*e.g.*, Lake Victor quarry, p. 96) or at least not in conflict with observations from the southeastern part of the region.

10. Variations in the depth and temperature of the Ellenburger sea were probably slight, but such surely occurred.

    Inasmuch as dolomitization is probably favored by elevated temperatures, and because water temperatures ordinarily decrease with depth, penecontemporaneous dolomites may indicate shallower, warmer waters at the time of their formation than do limestones. The later diagenetic dolomites suggest warming of the bottom somewhat after deposition and at least partial compaction of their source sediments. There is probably every gradation between penecontemporaneous and late diagenetic dolomites. The geologic evidence suggests that coarseness of grain is related to slowness and irregularity of dolomitization, which in turn is related to permeability, or degree of compaction, and hence to the thickness of sediments above those being dolomitized. The coarser the grain, therefore, the later in diagenesis did dolomitization probably occur, and the greater was the lag between deposition of the source sediments and warming of the sea bottom. Lateral irregularity of dolomitization is doubtless in part controlled by the relative permeability of the sediments. Very likely it is also related to the mineralogic character of the carbonate sediments being transformed, metastable aragonite being more readily dolomitized than the stable mineral calcite. Application of these suggestions to the distribution of dolomites shown on Plate 14 will indicate to the reader in a general way where and when the seas of Ellenburger time in the Llano region may have attained their highest temperatures and shallowest

depths. A marked feature of this chart is the thinly alternating sequence of limestones and dolomites that characterizes the lower part of the Honeycut formation. These suggest the inception of fluctuating disequilibrium in the sea after a long period of relative stability of relationships in late Gorman time.

This condition of instability may have taken the form of simple fluctuations in depth and temperature. It may equally well have been related to more complex conditions related to the physical chemistry of sea water (such as pH and ionic interactions) and favoring either penecontemporaneous or primary(?) dolomitization through the rythmic depletion in $CaCO_3$ of successively invading currents supersaturated with salts of both calcium and magnesium, and with an excess of the CO_3^{--} ion. In any event variations in temperature and depth probably had some effect on the dolomitization process, in the direction indicated.

It should be mentioned that A. E. Parr (oral communication to Cloud, Nov. 1, 1938) has described how inclosed saline waters under certain conditions may be flooded and covered with fresh waters from the land and heated up much in the manner that the air in a greenhouse is warmed by the sun. According to Parr, data from one such inclosed area on the coast of Norway showed a temperature of 16° C. higher at 2 meters below the surface than at the surface, and at some places along the coast of Norway the growth of oysters is fostered by such "hothouse effects."

Periodic repetition of some such mechanism acting on sluggish waters could explain rythmic dolomitization as well as variations in depth of water alone. But, again, shallowness of water would probably facilitate the process, and the prolonged overspread of a fresh-water cover on shallow saline waters would probably produce optimum conditions for elevated temperatures and penecontemporaneous or later diagenetic dolomitization.

11. Although variations in the general types of life that dwelt in the Ellenburger sea are not marked, stratigraphically significant faunal variations in the Ellenburger rocks are apparent. The stratigraphically significant faunal changes that can be correlated with similar changes in distant regions are held to be most logically related to eustatic or epeirogenic movements.

At most places fossils are markedly more abundant in the Tanyard and Honeycut formations than they are in the Gorman formation. The most conspicuous difference in general faunal aspect is the relative abundance of sponges and trilobites and the dominance of heavily operculated gastropods *(Ceratopea)* in the Honeycut formation. However, the Honeycut fauna is still predominantly molluscan. The actual taxonomic representation of the faunas is not of critical interest at this place and is discussed elsewhere. The general aspect of the faunas cannot be judged from the index fossils listed on Plate 14, as named elements of particular correlative value are there emphasized.

The stratigraphically marked faunal changes at the Tanyard-Gorman and Gorman-Honeycut boundaries correlate with faunal changes that are widespread in North America. They, therefore, must mark some widespread change. Eustatic changes, that is, changes in the volume of the oceans, or movements of the ocean bottom itself, affecting the volume of water on the continents and the depth of water in entire epicontinental seas (*see* Grabau, 1924, p. 3), appeal to the authors as a more logical vehicle for accomplishing changes so widespread than hypotheses relating to barriers or other factors equally logical for changes of lesser extent. Epeirogenic movements of the proper scope could produce similar results. Shrinking

of the epicontinental seas doubtless affected climatic conditions, and this, plus concomitant changes in depth and salinity could affect extermination of the faunas from the regions occupied by shallow seas without requiring prolonged subaerial exposure, and perhaps without subaerial exposure at all. Repopulation would follow marine reinvasion, and if environmental conditions were similar to those previously existing, faunas of generally similar but taxonomically different aspect should result. Other factors capable of producing results so widespread (*e.g.*, climatic, salinity, mass evolution) would doubtless themselves relate to changes of eustatic or epeirogenic nature. In the Llano region, the Ellenburger sea was probably so shallow that it was actually exposed to the atmosphere at the time of marine recessions, that is, at the Tanyard-Gorman and Gorman-Honeycut boundaries. Perceptible truncation was not accomplished because atmospheric agencies were not adequate to affect the wide low-lying mudflats, and because the waters of the shallow reinvading epeiric sea were probably sluggish except at times of strong atmospheric disturbance.

12. Although conditions in general, during Ellenburger time, were not favorable to the shell-bearing bottom-dwellers, there were probably at most times local areas where benthonic shells could and did survive. At some times favorable conditions were more widespread in the region and relatively abundant life developed, but it is believed that in most instances this was an outgrowth from forms that held on through the unfavorable periods. Analogy with conditions on the Bahama Banks suggests that survival was in large part related to firmness of the bottom.
A different conclusion is reached by Cullison (1945, p. 52) to account for the apparently intermittent character of the Lower Ordovician faunas of the Ozark uplift. He reasons that successive faunal invasions from somewhere beyond the Ozark region were perhaps related to eustatic changes. However, the eustatic changes postulated do not appear to have been closely reflected in other regions except in a few instances (the major faunal boundaries).
13. Even though the shell-bearing benthos may have been rare during much of Ellenburger time, the abundant presence of soft-bodied organisms is indicated by the abundance of pelleted areas in the limestones (Moore, 1933, 1939). This bears directly on the potentialities of the carbonate rocks of the Ellenburger group as source sediments of petroleum.
The almost self-evident conclusion that "the more organic matter a recent marine deposit contains the greater are its chances of being a potential future source of petroleum" was reaffirmed by Trask as a result of extensive studies by himself, Hammar, and Wu (1932, p. 239). In view of the probably extensive mud-ingesting fauna of the Ellenburger strata, it is no longer safe to regard these strata as an unlikely source of petroleum where they are not in a position to receive leakage from above.
14. The only known area of recent sediments that can be compared closely with those from which the Ellenburger rocks were theoretically derived is the Bahama Bank region. If the Llanoria channel of the Ouachita trough (*see* Sellards, 1931, 1932; Miser, 1934; DeFord and others, 1940) extended to the east and south of the Llano region as early as the beginning of Ordovician time, the Ellenburger sediments may actually have been separated from the mainland by a relatively deep channel. In that event the Llano region would have formed a submarine bank, deepening gradually to the west, and with shoals and perhaps tidal flats or even local island areas at the south and east margins, as Andros Island lies on the bank of the tongue of the ocean (p. 82).

Whatever happened at the south and east, it is doubtful if the sea-bottom dropped off steeply to the west and north, or to great depths on any side. That the Llano region could have been a structural as well as a sedimentational counterpart of the Bahama Banks in Ellenburger time is suggested by its positive structural history, but the known sedimentary evidence from the surface and from the subsurface to the north reveals no features in this direction that could be interpreted as the margins of an abrupt bank. However, thinning and increasing proportion of limestone along the west side of the southern end of the Bend arch suggests that there may have been a westward steepening in pitch of the bottom profile essentially coincident with the crest of the present-day Bend arch.

The writers have misgivings about what actually lay immediately adjacent to the Llano region at the south and east. Were the Llanoria channel of the Ouachita trough not a well-documented feature of later times, and were it not indicated to be so suggestively like the narrow channels that separate the Bahama Banks from Florida and Cuba (Drew, 1914, Chart A), they might have guessed that the Ellenburger sea graded directly to a peneplained hinterland in these directions. Even a flat and distant hinterland, however, does not explain the remarkable scarcity of terrigenous debris in the Ellenburger so well as would the presence of a current swept channel between the Ellenburger shoals at the north and west and land to the south and east.

COMPARISON OF THE ELLENBURGER SEA WITH OTHER ANCIENT MARINE PROVINCES

Older Seas

Paleogeographic maps of late Cambrian and early Ordovician time (Schuchert, *in* Schuchert and Dunbar, 1941, figs. 70, 84) show the epicontinental seas and channelways of those two times to have had very similar patterns. It seems unlikely that Schuchert's "Ouachita trough" extended west as far as it is shown in late Cambrian time, but in central Texas the general position of the shore lines was probably close to that shown by Schuchert.

Principal interest, at this place, lies in evidence that may bear inferentially on actual differences between the environment of the Cambrian waters and those of the Ellenburger sea. In contrast to those of the Ellenburger, the Upper Cambrian faunas are dominated by trilobites, with brachiopods locally abundant and with gastropods rare except at places in the higher carbonate rocks. The Cambrian rocks are dominated by sandstone, detrital limestone, and shale. Stromatolitic limestones are locally well developed, and the upper carbonate rocks are finer grained and more typically dolomitic in the eastern part of the Llano uplift than in the west. The stromatolitic limestones are commonly microgranular to sublithographic, and ordinary limestones of the San Saba limestone member of the Wilberns formation are not uncommonly sublithographic in the more easterly exposures. Glauconite occurs abundantly to sporadically in the granular limestones of the Upper Cambrian strata; but macroscopically visible glauconite is apt to be absent or much reduced in quantity in the microgranular to sublithographic limestones, the noncalcareous sandstones, and the shales.

Application to these facts of the inferences that have been made on previous pages results in the conclusion that the environment of the late Cambrian seas differed from that of the Ellenburger sea in several important respects.

Of course the fossils and the presence of glauconite show that the Cambrian sea was definitely saline, except possibly at the time lower Hickory sediments were being deposited. The general presence of glauconite (pp. 97–98) suggests that, for the most part, the bottom of the sea in which the Upper Cambrian sediments accumulated was deeper and perhaps colder and less well oxygenated than that in which the Ellenburger beds were formed. If the inferences of Galliher (1935a, 1935b, 1937) are valid, it also suggests the presence of

igneous or micaceous metamorphic rocks on near-by coasts or islands. Such islands, incidentally, are known (Bridge, Barnes, and Cloud, 1947, p. 113) to have been present at least as late as Cap Mountain time. The continued or intermittent presence of a large island or other land mass directly west of the Llano region, almost if not quite to the end of Cambrian time, is indicated by the locally thick water-borne sands of the San Saba limestone member of the Wilberns formation in the western areas (pp. 156, 179–182, 344). The waters adjacent to this land mass were probably deeper than those to the east and it may not have been a principal or persistent shore region.

That the waters of the late Cambrian sea were intermittently shallow and probably warmer after the deposition of the Morgan Creek limestone member of the Wilberns formation is indicated by the intermittent occurrence of prominent stromatolitic bioherms and biostromes. The highest Cambrian strata show a rising proportion of sublithographic, sparingly glauconitic to nonglauconitic limestones as they are traced eastward. This suggestion of increasing chemical precipitation combines with the increased dolomitization eastward to indicate that the principal shoal-area of the times, at least of latest Cambrian time, lay to the east of the present Llano region. A general shoaling of the Cambrian seas toward the end of Cambrian time is suggested. The eastern part of the Llano region was above wave base, and possibly above water, for a long enough time at the end of the Cambrian to permit considerable truncation of Cambrian sediments in the southeastern part of the region (Pl. 14) and lesser truncation elsewhere (Pl. 20, figs. A–B). In the western part of the region sedimentation was probably continuous across the Cambrian-Ordovician boundary (Pl. 19, fig. D); and eustatic effects or minor epeirogenic deleveling, with subsequent environmental changes, may be called upon to explain the faunal break at this place.

Coeval Provinces of the Mid-Continent Sea

Of the equivalent outcropping Lower Ordovician rocks of the mid-Continent region, those of the Ozark uplift most nearly resemble the Ellenburger deposits in faunal aspects, types and volume of chert, and probable lithogeny. Even these, however, differ from the Ellenburger in the fact that they are almost wholly dolomitic, and especially in the large amount of terrigenous material that is to be found in many of them (Cullison, 1945). In fact no sequence of Lower Ordovician rocks known to the writers is so persistently low in materials of terrigenous derivation as is the Ellenburger group. The upper Gasconade dolomite of the Ozark sequence and, at places, the Newala limestone of the Appalachian sequence make the nearest approach to it.

In the Arbuckle and Wichita mountains the rocks equivalent to the Ellenburger group of Texas are much thicker, contain much terrigenous material, and are almost wholly calcitic. Those of the Marathon basin are thinner, contain much terrigenous material, and are almost wholly calcitic. Those of the Sierra Diablo, Franklin Mountains, and the Rocky Mountain Front all differ in their content of terrigenous material and in other features described in Part 3, those of the southeastern part of the Sierra Diablo region (Beach Mountain section) being most similar to the Ellenburger.

To forestall confusion in the ensuing resumé, attention is invited to the fact that relative thickness of sediments in itself bears no necessary relationship to the depths of the waters in which they accumulated. It is a matter of common knowledge that to accumulate a thick series of sediments in shallow waters requires progressive relative depression of the sea floor; but that actual thicknesses of sediments accumulated, granting an adequate receptacle for them, depends on the source of supply and the competency of the transporting agents.

Bridge (1930, p. 156) considered the sediments of the Ozark province of the mid-Continent sea to have been "quite

similar to the lime sediments now accumulating on the Great Bahama Bank." Cullison, in his helpful summary of conditions in the Ozark region (1945, p. 52), "believed that the lower Ordovician sediments were deposited in seas which were commonly muddy, shallow, and hypersaline." He points out (Cullison, 1945) that the faunas are found in zones between which are appreciable thicknesses of unfossiliferous dolomite; and he infers that this is to be explained by successive faunal invasions induced by better marine circulation and decrease of detritus, "due perhaps to eustatic changes." Schuchert (*in* Schuchert and Dunbar, 1941, fig. 54) shows that the Ozark region proper lay far from land almost in the middle of a great epicontinental sea. On a structural basis, therefore, the Ozark region of early Ordovician time may have been similar to the Bahama Banks except in degree of submarine relief. However, in some manner terrigenous materials were much more abundantly supplied to it, and from a sedimentational point of view the Ellenburger province more nearly resembled the Bahaman region. Bridge (1930, pp. 138–147) shows that portions of the Ozark uplift were emergent at various times during the deposition of the Lower Ordovician sediments, and these emergent areas doubtless furnished the detrital material. The fact that the carbonate rocks equivalent to the Ellenburger in the Ozark region are all dolomitic suggests that the seawaters retained more uniformly elevated temperatures and shallow depths than did those of the Ellenburger province. These observations are in line with the descriptions and most of the inferences made by Cullison (1945). The present writers, however, question the advisability of invoking eustatic changes to account for the successive faunal invasions noted by Cullison (1945). If these were related to movements of the ocean bottom or to changes in the total volume of water in the oceans that fact should be reflected by correlative features in other regions, and only those faunal changes which are so reflected should be explained by other than local mechanisms.

Along the Rocky Mountain Front the Manitou formation at places overlaps the Sawatch quartzite (Cambrian) and pinches out against the pre-Cambrian rocks. The shore line was evidently irregular and the carbonate sediments were deposited in varying depths of water receiving varying and commonly large quantities of fine detritus.

In the region of the Diablo Plateau (Pl. 16) and the Franklin Mountains (Pl. 16) of west Texas the earliest established invasion of the Paleozoic seas occurred in Lower Ordovician (Tanyard) time. The true Bliss sandstone of the Franklin Mountains can be correlated with the Tanyard formation only tentatively and by analogy with the so-called Bliss sandstone of the Sierra Diablo. The latter is known to be of Tanyard age, the former may yet prove to be Cambrian. In any event, the sea of Tanyard time in the Sierra Diablo region, and probably in the vicinity of the present Hueco and Franklin mountains received copious quantities of quartz-sand. The shore was thus near by and probably of relatively marked relief. The depth and temperature of the sea are more highly speculative matters to which the interested reader may apply the ecologic inferences suggested earlier. The sea of Gorman time received much water-borne sand in the Sierra Diablo region and considerably less in the vicinity of the Franklin Mountains. At the former locality, therefore, it was either nearer land or adjacent to land of more marked relief or more deeply mantled with clastic debris than at the latter. Reasonably warm temperatures and shallow depths for the sea of Gorman time are suggested by the relatively common dolomitization of rocks of Gorman age in both the Sierra Diablo and the Franklin Mountains (Pl. 16). Strata of Honeycut age are largely dolomite at the southeast corner of the Sierra Diablo region (Beach Mountain section) and largely limestone between here and the Franklin Mountains. Terrigenous materials are relatively uncommon throughout rocks equivalent to the Honeycut formation, being represented by minor silt and argillaceous material and rarely sand. The sea of Honeycut time thus may have been warmer and shallower at the southeast corner of the Sierra Diablo region than it was northwest from here, but the

land to the south was furnishing little terrigenous debris. The implications of the post-Honeycut strata are not pertinent to this discussion.

The Marathon limestone, which is partially equivalent to the Ellenburger group, consists of flaggy argillaceous limestone "with much interbedded shale and occasional layers of conglomerate and sandstone" (King, 1937, p. 27). Fossils are uncommon and at most places the fauna is dominated by graptolites. Near its middle is a thin zone of thickly bedded, siliceous and in minor part dolomitic limestone, more nearly resembling the Ellenburger than other rocks in the sequence, and containing cephalopods, gastropods, and articulate brachiopods. Conditions markedly different from those of the Llano region are indicated for the early Ordovician sea of the Marathon basin and the Big Bend in Trans-Pecos Texas. The absence of dolomite suggests that the Marathon limestone accumulated in relatively deeper, cooler waters than did the equivalent sediments of the Llano province. Much fine argillaceous material and organic matter was contributed to them. It discolored the limestones and locally made shale beds. The limestones are commonly sublithographic, suggesting that they may be the undissolved remnants of chemically precipitated calcium carbonate that drifted into the region and mixed with the argillaceous matter. Although deep and cool in contrast to the Llano province of the early Ordovician sea, neither excessive depths nor truly low temperatures are indicated. Stromatolites in the siliceous limestone near the middle of the Marathon limestone indicate temporarily shallow waters. According to the concepts of the present writers, as previously stated, mere thickness of sediments bears no finite relationship to depths of the waters in which they accumulated and the conclusions of Barton (1945) regarding Marathon sedimentation do not necessarily follow from the evidence presented by him.

The Lower Ordovician rocks of the Arbuckle and Wichita Mountains are largely limestones that are dark in color from contained argillaceous material and are locally arenaceous. They are much thicker than equivalent carbonate rocks in other parts of the mid-Continent. The absence of dolomite suggests that they accumulated in deeper, cooler waters than those of the Llano province. However, the intermittent occurrence of stromatolitic structures indicates that the waters were, nevertheless, relatively shallow much of the time, and much of the limestone may have been chemically precipitated. The relation of these rocks to the well-known Ouachita belt of clastic rocks (Miser, 1934) indicates that, whereas the province of the sea wherein their sediments accumulated lay to the northwest of the Ouachita trough, the distinction between trough and shelf was not as great as it was farther to the south, and subsidiary currents were enabled to carry to the Arbuckle-Wichita province such clastic sediments as they were competent to handle.

The early Ordovician sea in which the Ellenburger sediments were deposited is seen to have been a great epicontinental sea with a variety of shore line features, shoals, islands (*see also* Walters, 1946), and channels. It is doubtful if at any place or time its depth greatly exceeded 100 fathoms, and extensive banks and offshore flats of carbonate muds were probably at times awash. At the same time, progressive subsidence is called for to permit the accumulation of the sediments. The principal channelway of the larger region here considered was the Ouachita trough, which, with its subsidiary Llanoria channel, appears to have lain between land to the southeast and shoal waters to the northwest. The Llanoria channel probably extended as far southwest as the Big Bend province of Texas, but whether it extended beyond, ended as a *cul-de-sac* like the tongue of the ocean in the Bahaman region (p. 82), or simply faded out is not known. Presumably the Llanoria channel was narrower, and the recipient of less and mostly finer sediment than was the Ouachita trough proper. Thus the lands that bounded it to the east and south may have been lower, and the clastic sediments largely current-borne from the northeast. The boundary between it and the dominantly shoaly banks to the north may have been fairly well defined, and the relative thicknesses and character of

sediments accumulated are to be taken as representative of supply, rate of subsidence, and nearness to shore or effective current action. Interpretation of features of the mid-Continent sea beyond the bank-regions to the northwest requires evidence not at present available to the writers.

GEOLOGIC HISTORY

THE POST-ELLENBURGER UNCONFORMITY

At least seven historically significant erosional unconformities are represented by the stratigraphic juxtaposition of rocks of varying age upon the Lower Ordovician rocks of the Llano region, and the major unconformity at the upper surface of the Ellenburger rocks is compound in the degree to which various lesser unconformities have coalesced. Some of these unconformities are graphically portrayed in figures 2 and 3.

Of the eight unconformities described below, all except the disconformity between the Ives breccia and the Chappel limestone (no. 3) represent periods of emergence from the sea of the positive area called the Llano uplift, followed by subaerial erosion and marine reinvasion and sedimentation. Truncation of the upper beds of the Ellenburger group has totally removed the Honeycut formation from a point about 10 miles east of McCulloch County, and about 0.7 mile south of Maxwell Crossing of San Saba River, and the studies on which this report is based have revealed no strata younger than the Gorman formation west of this locality. The ensuing summary discussion is in large part based on data presented under the heading "Beds that overlap the Ellenburger."

1. The first recorded and probably most significant truncation following the deposition of Ellenburger sediments was that of pre-Devonian time. In addition to rocks of probable Middle Ordovician age, represented only by reworked conodonts (Barnes, Cloud, and Warren, 1945, p. 176; 1947, pp. 126, 140) and by such other post-Ellenburger and pre-Devonian rocks as may have been deposited in the Llano region, pre-Devonian erosion removed 680 or more feet of beds from the top of the Ellenburger between the southeastern (Johnson City area) and southwestern (Bear Spring area) parts of the Llano region. As it is approximately 65 airline miles west-northwest from the top of the measured sequence of Ellenburger rocks at Honeycut Bend in the Johnson City area to the top of the measured sequence on Rattlesnake Hill in the Bear Spring area, the truncation would appear to have been at the rate of approximately 10.5 feet per mile in a west-northwesterly direction. Data from the north side of the uplift, between the Cherokee area and the Lost Creek area, indicate about a 13-foot per mile westward truncation with evidence at King Creek, about halfway between, essentially confirmatory of this figure (p. 347). The structural history of the Llano uplift suggests the validity of these figures, granting local fluctuations, as an approximate expression of the actual truncation. Presumably, a marked eastward tilting of the region occurred either before or during the Devonian invasion, if not both. At Honeycut Bend high Lower or low Middle Devonian rocks (Stribling formation) rest on the youngest known beds of the Honeycut formation, and a mile northeast of Rattlesnake Hill rocks of lower Middle Devonian (Bear Spring formation) and Middle or Upper Devonian age (Zesch formation) are preserved in a structural sink in the upper beds of the Gorman formation. Ellenburger strata have suffered deeper Paleozoic truncation in the extreme southwestern part of the Llano region, normal truncation extending to about 140 feet above and collapse to 70 feet above the zone of *Archaeoscyphia* in the Gorman formation opposite the mouth of Big Saline Creek in eastern Kimble County. They have been still more deeply truncated in McCulloch County, with normal truncation to about 80 feet above the zone of *Archaeoscyphia* in the Gorman formation at the mouth of Joe Davis Hollow and in the Bald Ridge area, and with local collapse to as much as 25 feet below the same zone of *Archaeoscyphia*. Although total truncation at these places cannot be positively dated more closely than pre-Mississippian, unnamed rocks of probable Middle or Upper De-

vonian age that occur in a joint filling about at the horizen of the zone of *Archaeoscyphia* of the Gorman formation in the Bald Ridge area (TF–233) indicate it to have been largely pre-Devonian.

Evidence that the Devonian marine overlap progressed roughly from east to west across the Llano region is furnished by the fact that the Devonian rocks are older in the east and younger in the west, whereas truncation of the underlying Ellenburger rocks is greatest in the west. That younger Ellenburger rocks were once present in the western part of the uplift is proved by the occurrence of Honeycut fossils *(Ceratopea)* as pebbles in the strata that overlap the upper limestones of the Gorman formation at locality TF–158 in the Bear Spring area. Irregularities in the Devonian overlap and temporary withdrawals of the sea are suggested by the occurrence of rocks probably assignable to the Pillar Bluff limestone as pocket- and crack-fillings below the Stribling formation (Barnes, Cloud, and Warren, 1945, p. 169). It is conceivable, however, that the Helderberg sea was so shallow that its sediments were totally by-passed, except for those that washed into open pockets and cracks in the sea floor.

2. While Upper Devonian sediments were being deposited elsewhere, truncation in the Llano region effectively removed most of the Devonian rocks whose once widespread character is testified to by the widely isolated remnants so far discovered. It is probable that this truncation also significantly affected the Ellenburger strata. Except in the southeastern part of the region (Johnson City area) beds of established Devonian age have been found only in ancient structural sinks or as crack- or cave-fillings where they were protected from erosion. That this erosion was subaerial and prolonged, is proved by the fact that at locality TF–158 in the Bear Spring area Devonian strata are preserved only in a deeply collapsed structural sink whose margins are overlapped by lower Mississippian beds which have themselves been subjected to shallow collapse. That it occurred in pre-Ives time is indicated by the relatively wide distribution of the uniformly thin Ives breccia, which is nearly coextensive with the Chappel limestone. That the erosion surface developed was one of little relief is proved by the failure of the coarsely clastic Ives sediments to be preserved as lenses of widely varying thickness such as would inversely reflect the relief of the underlying surface.

3. Unconformable relationships between the Ives breccia and the Chappel limestone are suggested by the fact that at many localities the Ives is absent and the Chappel rests directly on Ellenburger rocks, as well as by the abrupt lithologic break between the two units. The Ives breccia is so thin, however, that its distribution could be explained by expectable irregularities in deposition; and in any event physical evidence does not indicate an historically significant unconformity between it and the Chappel limestone. Moreover, reworked clastic material from the Ives, which should be very resistant and persistent, is rare or absent in the Chappel, and the break between the two units may well represent simply an interruption in or change in conditions of sedimentation. Where the two formations are normally juxtaposed the contact is probably most accurately defined as a disconformity.

4. The unconformity between the Chappel limestone and the Barnett formation seems important on the basis of physical evidence, and the stratigraphic gap may be considerable at some places. Although collapse during the period of erosion represented by this unconformity has locally dropped the Chappel strata well below the Ellenburger surface of that time, the Ellenburger strata appear not to have been significantly truncated.

The unconformity between the Chappel and Barnett formations is not shown to best advantage in figure 3, due to the use of the base of the Barnett formation as a datum, but one significant feature is brought out. Where the Chappel limestone overlaps the highly soluble limestone of the Gorman formation it is preserved in structural sinks whose margins are commonly directly overlapped by strata of the Barnett formation. It is possible that, where the roofs of caves collapsed to form the structural sinks in

which the Chappel strata are preserved, these caves could have formed before Chappel time. However, it seems likely that most of these features are of post-Chappel origin, for none are known to contain strata in their original position of deposition. In some instances the strata are let down with little disturbance, suggesting essentially concomitant solution and slump. In any event it seems to have been post-Chappel and pre-Barnett solution that led to the final collapse or gradual slump, whichever it was, and the entrapment of the Chappel limestone. Such activity is presumptive evidence in support of the subaerial exposure which is indicated by the truncation, and locally the complete removal, in pre-Barnett time of the Chappel limestone not so preserved.

5. Widespread truncation and locally complete removal of Barnett strata were accomplished in pre-Pennsylvanian time as shown by figure 3. This truncation is somewhat exaggerated because the use of the base of the Barnett formation as a datum fails to account for variations in its thickness due to nondeposition. As was first pointed out by Goldman (1921) a prominent zone of glauconite and phosphatic pellets is widespread at this unconformity. In part the phosphatic material attains the size of pebbles and is associated with pebbles of Barnett lithology. This glauconite-phosphate-pebble zone is well displayed on the east side of Texas highway 16 about 5.5 miles by speedometer south of the courthouse at San Saba and 0.6 mile farther south in the wall of a shale pit. It has been found on search at many places in the eastern part of the Llano uplift. The glauconite and phosphate globules are tiny lobate or ovoid pellets resembling the fecal pellets of mud-ingesting organisms. The glauconite globules are much darker and smaller than the Cambrian glauconite of the Llano region and must commonly be washed from their silty matrix before they can be identified with confidence. This glauconite-phosphate zone probably represents concentration in the shore zone of material reworked from offshore deposits, for it has been pointed out that the process of glauconitization is not ordinarily a littoral phenomenon. In the western part of the Llano region, in the Bear Spring area, a zone of highly colored, angular to subangular, small chert pebbles occurs at the base of the Marble Falls limestone.

6. Attention has been called by Moore and others (1944, p. 697) to the unconformity between strata of Morrow age and higher Pennsylvanian beds within the Marble Falls limestone (unrestricted). This erosional unconformity has completely removed the beds of Morrow age at many localities and locally has brought beds of post-Morrow age into direct stratigraphic contact with Ellenburger rocks. The mapping by Barnes and Warren in Honeycut Bend (Johnson City area) shows the nature of this overlap.

7. Beds of Canyon age overlap older Pennsylvanian formations, and, at at least one locality in western McCulloch County (Blockhouse ranch, south of Camp Creek settlement), rest in direct unconformable contact on faulted Ellenburger rocks. A significant erosional unconformity preceded by a period of active faulting is evident.

Other Pennsylvanian unconformities undoubtedly occur, but they are not known to affect Ellenburger strata.

8. Permian, Triassic, and Jurassic time in the Llano region are represented only by profound erosion, doubtless accompanied by epirogenic movements. All previously formed rocks were exposed to the atmosphere, and the Lower Cretaceous seas invaded the surface so denuded to deposit their sediments on pre-Cambrian, Cambrian, Ordovician, and Carboniferous rocks.

RESUMÉ OF INFERRED PALEOZOIC EVENTS IN THE LLANO REGION

As it did in the Ozark uplift (Bridge, 1930, pp. 136–139) and probably almost at the same time (Bridge, 1936, Table 1), the first Paleozoic sea to invade central Texas entered a region of considerable local relief. It reworked sands of eolian origin (Barnes and Parkinson, 1940) into the base of the Hickory sandstone member of the Riley formation, but whether a part of the Hickory actually represents eolian sedimentation is not known. To be sure, it is essentially nonglauconitic, in contrast to the higher Cambrian strata,

but Hadding (1932) has shown that the true, primary basal beds in the marine series of strata are typically nonglauconitic. Hills, several hundred feet high, projected above the initial sea floor; and some buried hills are known to extend stratigraphically into the Cap Mountain limestone member of the Riley formation (Bridge, Barnes, and Cloud, 1947, p. 113).

The lands were largely denuded of quartzose detritus or reduced in elevation by the middle of Riley time; and the Cap Mountain limestone member is composed of granular, essentially detrital, glauconitic limestones that are locally trilobite shell-breccias and probably originated in a shallow and yet perhaps a relatively cool neritic environment. During the changes in relationship of land to sea that occurred in late Riley and early Wilberns time, the lands again supplied abundant sand to compose the regressive-transgressive sand zone in the midst of which the Riley-Wilberns formational boundary is drawn.

The Welge sandstone member of the Wilberns formation includes minor detrital glauconite and grades upward into reddish and locally earthy granular limestones at the base of the glauconitic Morgan Creek limestone member. Detritus of terrestrial origin decreases upwards and the granular limestones of the Morgan Creek limestone member suggest a neritic and perhaps cool environment, like that of later Riley time. During middle Wilberns time quantities of argillaceous material were contributed to the sea from a westward direction to comprise the Point Peak shale member. This shale is displaced by dolomitized and rather pure carbonate rocks to the east, indicating that in that direction lay warm shoal waters barred or far removed from an effective source of terrigenous debris. The transposition of the San Saba limestone member into the Pedernales dolomite member eastward indicates that these easterly shoals were persistent to the end of Wilberns time. The continued or intermittent presence of a large island or other land mass to the west, almost if not quite to the end of Cambrian time, is indicated by (a) the locally thick water-borne sands of the San Saba limestone member of the Wilberns formation in the western part of the region (pp. 156, 179, 344) and (b) the decrease toward the eastern margin of the Llano uplift in the amount of terrigenous detritus representing the Point Peak shale member. The waters adjacent to this land mass were probably deeper than those to the east, and the land may not have been a principal or persistent shore region. However, local shoaling in its vicinity is suggested by the abnormal occurrence of dolomite of the Pedernales type 130 feet below the top of the Wilberns formation of the Calf Creek area (p. 345).

Intermittent shoaling and warming of the waters in which the post-Morgan Creek sediments were deposited is indicated by the local conspicuous development of stromatolitic limestones. The increasing proportion of sublithographic limestone and dolomite eastward in latest Cambrian time indicates a general shoaling of the region in that direction. The gradient of the sea floor was to the northwest and either depression of sea level or tilting in a northwesterly direction resulted in emergence of the southeastern part of the Llano region and truncation of highest Cambrian strata (Pl. 14). Marine conditions probably persisted to the west, with sedimentation being continuous across the Cambrian-Ordovician boundary (Pl. 19, fig. D).

At the beginning of Ordovician time either the Ouachita trough was in existence or the hinterland to the south and east had been reduced to a peneplain—perhaps both. Any islands that might have contributed terrigenous sediments were buried; and the floor of the shallow, tropical or subtropical sea sloped gently to the northwest, away from shoals at the south and east. The region was repopulated with a dominantly molluscan fauna, unlike the dominantly arthropodan fauna of the Cambrian.

During early Ordovician time the Llano region remained relatively stable, with minor fluctuations in depth and temperature of water, condition of the bottom, and nearness of land. The marine waters of the region were primarily warm, intermittently turbulent, and relatively well oxygenated shoal waters, deepening to the northwest. Sedimentationally and ecologi-

cally the region was like the Bahama Banks off the southeast coast of Florida. Its generally soft bottom of pure carbonate muds and the intermittently muddy nature of its waters inhibited the development of shell-bearing bottom dwellers except in local areas where firm bottom-conditions occurred. Where and when favorable bottom-conditions prevailed, these local colonies were enabled to coalesce and extend more widely through the region. The faunal changes at the formational boundaries correlate with similar faunal changes in other regions and probably are related to eustatic or epeirogenic movements. Equilibrium conditions of the ancient waters at any particular time are suggested by the character, persistence, and frequency of penecontemporaneous dolomitization. The probable oceanography and ecography of the Ellenburger sea are summarized on pages 100–105.

What central Texas was like in Cotter, Powell, Smithville, Black Rock, Middle and Upper Ordovician, and Silurian time is not surely known, although generally emergent conditions are indicated. Rocks of these times have not been found. Which, if any, were deposited and subsequently removed, and which were never deposited has not been established. That Middle Ordovician seas may have reached the Llano region is suggested by the presence of the conodont *Chirognathus* in limestone of Glen Park (Mississippian) age at locality 16T–2–27A_1, in Blanco County (Barnes, Cloud, and Warren, 1945, p. 176; 1947, pp. 126, 140).

The greatest truncation of Ellenburger rocks and thus probably the longest period of Paleozoic emergence of the Llano region occurred before Devonian time. This truncation was at a maximum in the western part of the uplift, whereas the oldest Devonian strata known are in the east and the youngest in the west. From these data one may provisionally infer that the region was tilted to the east and largely truncated before Devonian time, followed by an east to west Devonian marine invasion and continuing truncation of the emergent areas. Additional eastward tilting may have accompanied and been partially causal to inundation. Irregularities in the Devonian overlap and temporary withdrawals of the sea are suggested by the occurrence of rocks probably assignable to the Pillar Bluff limestone as pocket- and crack-fillings below the Stribling formation (Barnes, Cloud, and Warren, 1945, p. 169; 1947, pp. 131–132). It is conceivable, however, that the Helderberg sea was so shallow that its sediments were totally by-passed, except for those that washed into open pockets and cracks in the sea floor. As yet outcrops of Devonian rocks are too uncommon and the probable general features of the Devonian sediments too little known to warrant more extensive speculations on the character of the Devonian sea.

It is known that marine invasions occurred at several times during Mississippian and Pennsylvanian time; but, aside from the character and ages of the sediments that these invasions more commonly brought to rest upon the Ellenburger strata (pp. 42–60), consideration of these seas is not pertinent to the present report.

The entire Llano region was emergent in latest Paleozoic time. It remained so until blanketed with a thick cover of Cretaceous rocks whose gentle doming and truncation now reveal the more ancient strata.

PALEONTOGRAPHY

INTRODUCTORY REMARKS

Numerous collections of fossils were made in the early phases of the mapping in central Texas and in the reconnaissance studies of regions peripheral to the mid-Continent basin. Concurrent studies of these served to delimit the various biotic divisions of the Ellenburger group and to indicate the possible use of various forms in correlation. Additional collecting from Ellenburger rocks led to some revision of concepts; but, as refinements were made and substantiated, and as clues to the field recognition of the key forms became systematized, collecting tapered off. In the later phases of the work, therefore, fossils were collected only occasionally for documentary purposes and where unusual or exceptionally good material was to be had. Altogether the writers and their

associates in the field work collected Ellenburger fossils from 478 localities. Besides these, 274 collections were made from rocks above and below the Ellenburger as well as from rocks correlative with the Ellenburger in other regions. The correlations suggested in Plates 14 and 15 are based upon these 752 collections of fossils, as well as on the published faunal information cited and fossils recorded in the field but not collected. The ranges of fossils shown at the left side of Plate 14 refer only to central Texas. It is known that *Tetralobula*, probably *Syntrophina*, *Lytospira*, *Helicotoma*, *Ophileta*, and *Jeffersonia* have longer ranges in other parts of the country and perhaps in central Texas, but the range lines on Plate 14 are recorded objectively from data for central Texas only. Probable ranges of regional index fossils are listed on pages 61–62.

The fossils collected were studied in a preliminary way and, pending monographic study of the Ellenburger faunas, some results of the preliminary studies are here briefly summarized.

Of the 478 collections of Ellenburger fossils, 182 are from Tanyard, 132 from Gorman, and 164 from Honeycut strata. The representation is not as even as it would appear from these figures, however. Collections from the Gorman formation are mostly small and display little variety, although Gorman strata are known at most localities where Ellenburger rocks occur in the Llano uplift. In contrast, rocks of the Honeycut formation, which thin and disappear westward in the uplift, are in a proportional sense far better represented faunally than are Gorman strata. Moreover, as a rule, the writers were more apt to make documentary collections from the Gorman than from other strata, because it is more difficult to produce fossils from the Gorman formation on demand. Most of the collections made by the writers were obtained as an adjunct to mapping, and are small. Additional collecting would be advisable in connection with monographic faunal studies.

Fossils similar to or identical with many of those herein considered are described in publications by Roemer (1852); Butts (1926); Ulrich, Foerste, and Bridge (1930); Dake and Bridge (1932); Powell (1935); Bridge (*in* Bridge and Girty, 1937); Ulrich and Cooper (1938); Knight (1941); Ulrich, Foerste, Miller, and Furnish (1942); Ulrich, Foerste, and Miller (1943); Ulrich, Foerste, Miller, and Unklesbay (1944); Cullison (1944); Shimer and Shrock (1944); Bridge and Cloud (1947); and Cloud (in press). The greatest gap in present knowledge of the Lower Ordovician faunas is in those from the Gorman formation and its equivalents.

In spite of all the works cited, many of the Ellenburger fossils are yet to be described. Moreover, it must be kept in mind that the following discussion is circumscribed not only by the lack of names for new forms, but by the fact that, in many instances, it has not been practicable to make direct comparison with authentic specimens of species provisionally identified. The concept of generic assemblages as the primary tool in correlation dominates the biostratigraphic portion of this report. Specific distinctions, other than *Ceratopea* and the brachiopods, are made as a matter of convenience to indicate certain groups of shells whose correlative value within a broadly conceived genus demands some closer designation. *Helicotoma uniangulata* is an example of such a group.

The ranges of some of the fossils useful in correlation are shown against a generalized column for the Llano uplift at the left side of Plate 14. Illustrations of some fossils from the Ellenburger group, as well as from beds above and below, are given on Plates 38 to 44. Special emphasis is placed on the brachiopods and ceratopeas because of their importance in correlating with the Lower Ordovician of west Texas and southern Oklahoma.

Obviously to describe 752 or even 478 fossil localities would unduly extend a report already bulky. It is hoped that in most instances approximate locality will be apparent from context, and that exact locality can then be found without great inconvenience by reference to the proper map or section. Complete and detailed lists of locality descriptions are on file with the Bureau of Economic Geology, the

U. S. Geological Survey, and the U. S. National Museum.

FOSSILS OF THE ELLENBURGER GROUP

The biota of the Tanyard formation is dominated by gastropods and cephalopods, many of them large. A dasycladacean alga, a primitive colonial coral, a few brachiopods, occasional trilobites, and an archaeostracan crustacean also occur.

Lytospira gyrocera (Roemer), *Ophileta polygyrata* (Roemer), and *Gasconadia* cf. *G. putilla* (Sardeson) dominate the relatively thinly bedded limestones of the Threadgill member of the Tanyard formation in the western part of the Llano region. The upper 90 to 100 feet of the Tanyard is characterized by *Rhabdoporella* (determined by Dr. J. Harlan Johnson, letter to Barnes, 10/29/45), the primitive colonial coral *Lichenaria* (determined by Dr. R. S. Bassler, oral communication), two species of *Paraplethopeltis*, two species of *Ribeiria*, several species of *Clarkoceras*, and an abundance of *Ozarkina*. The brachiopod *Tetralobula* is known only from about 40 to 50 feet above the base of the Tanyard formation in the western part of the uplift. The only other brachiopods known from the Tanyard formation are *Syntrophina* and *Finkelnburgia*, the former being rare, and the latter at some places common. A robust new species of *Finkelnburgia** holds a position about 260 to 285 feet above the base of the Tanyard formation in the Bear Spring area. The cephalopods *Dakeoceras*, *Burenoceras*, *Conocerina*, and *Levisoceras* make their first appearance near the middle of the Threadgill member; *Burenoceras* ranging to the middle of the Gorman formation and *Conocerina* ranging perhaps to the top of the Tanyard, but apparently not into the Gorman formation. *Dakeoceras* has not been recognized above the lower one-third to one-half of the Staendebach member. *Levisoceras* seems to range through much of the upper three-fourths of the Tanyard formation but not to its top. *Ectenoceras* ranges downward from the top of the Tanyard formation to some point well below its middle. *Oneotoceras* is rare but diagnostic of the Tanyard formation. It has been seen almost at the top of the formation and at points well toward or below the middle. *Lytospira*, although typically a fossil of the Threadgill member of the Tanyard formation in the western part of the uplift, ranges across the Tanyard-Gorman boundary and well into the Gorman formation. Although *Ophileta* ranges through the Tanyard and Gorman formations and into the Honeycut, the Tanyard species of *Ophileta* are commonly large and relatively depressed, both as to spire and cross section of the whorl. *Sinuopea* and *Schizopea* range through or almost through the Tanyard formation and downward into the top of the Cambrian, but an abundance of specimens suggests the Tanyard. *Ozarkina* and *Helicotoma* of the type of *H. uniangulata* (Hall) range from the top of the Tanyard formation to somewhere well below its middle, and *Gasconadia* ranges from its base to somewhere above the middle. *Chepultapecia* ranges through at least the upper half of the Tanyard and into the Gorman formation. Patelliform snails, and the so-called *"Pelagiella" paucivolvata* (Calvin), are locally abundant. The patellids range through the formation, but the range of *"P." paucivolvata* has not been determined. A *"Euconia"*-like snail has been seen at a few places. *Leiostegium* occurs in the lower part of the Tanyard formation at some localities. Cystid and chiton plates are locally common.

The Gorman formation is not only poorer in number and variety of fossils than the other formations of the Ellenburger group, but proportionately fewer of its fossils have been described. Its most striking faunal elements are the large gastropods *Rhombella* (formerly known as *"Roubidouxia"*) and *Lecanospira*, but a number of other gastropods and cephalopods, a few brachiopods and trilobites, and a sponge are known.

The name *Rhombella* applies to large widely phaneromphalous gastropods whose pleural angle ranges from about 90° to 105°, and which consist of about 5 very rapidly expanding whorls that are rhombic in cross section and tend to be flat at the top and base. Ordinarily only the two basal whorls are preserved; and parts of at least two whorls are required to dis-

*Being described by Cloud (in press) as *Finkelnburgia obesa*.

tinguish it surely from *Euconia,* which is a high-spired shell with 8 or 9 more slowly expanding whorls and a more acute pleural angle (65° to 75°). Small, high-spired, *Euconia*-like shells with a convex base are designated "*Euconia,*" pending systematic revision. *Rhombella* occurs from the base to the top of the Gorman formation and its sure identification probably constitutes proof of a Gorman age.

Lecanospira is known only from the Gorman formation. It ranges from the top of the formation probably to its base but is uncommon in the basal strata. *Lytospira* and *Ophileta* are known from the Gorman formation but are not characteristic of it. *Ophileta,* or *Ozarkispira,* of the type of *O. rotuliformis* or *O. leo,* however, suggest the Gorman formation; and in general the post-Tanyard ophiletas have higher spires and relatively deeper whorls than do the Tanyard species. Patelliform gastropods are locally common and some are provisionally assigned to *Proplina. Chepultapecia* is not uncommon in the lower part of the Gorman formation, although its presence tends to suggest the Tanyard. *Hormotoma* makes its first known appearance at the base of the Gorman and extends upward through the Honeycut formation. *Plethospira* also first appears in the Gorman formation, and perhaps *Raphistomina* and *Polhemia.* Two species of *Diaphelasma* mark the upper 90 feet of the Gorman formation and *Syntrophina* suggests the lower 120 feet of the Gorman, although one *Syntrophina* has been found about 200 feet below the Tanyard-Gorman boundary. *Syntrophinella* is known only from the vicinity of the *Archaeoscyphia* zone in the Gorman formation, the latter fossil being known below the Honeycut only from a restricted interval near the middle of the Gorman formation. A few cephalopods are known from the Gorman formation, but most of these have not been identified. The flat-ended siphuncle of *Mcqueenoceras* occurs locally in the upper half; a large *Clitendoceras*-like cephalopod occurs in the zone of *Archaeoscyphia;* and small, strongly curved brevicones having flaring apertures and ranging for some distance below the zone of *Archaeoscyphia* are assigned to *Burenoceras.* The piloceratids are represented only by a single specimen close to *Piloceras hornei* U. F. M., which was obtained 15 to 20 feet below the *Archaeoscyphia* zone of the Gorman formation near the Cherokee Creek section (TF–90). Of trilobites, species of *Hystricurus* are most common, but the genus ranges into the Tanyard formation also. An occasional cystid plate represents the pelmatozoans.

Many of the Honeycut fossils of central Texas appear to be specifically identical with fossils described from the Jefferson City strata of Missouri by Cullison (1944). The general assemblage is so similar that the slight variations are thought to be mostly geographic. The dominant faunal elements are the sponge *Archaeoscyphia annulata* Cullison, and species of *Ceratopea, Orospira, Hormotoma,* and other gastropods of many sizes and shapes. Species of the trilobites *Jeffersonia, Rananasus,* and *Bathyurellus* are common at places in the lower half of the formation, with *Rananasus* apparently having a fairly restricted range. The flat-ended siphuncles of the endoceratid cephalopod *Mcqueenoceras* are also locally common.

Except for its occurrence near the middle of the Gorman formation, *Archaeoscyphia* is known only from the lower half of the Honeycut, but it is there very abundant locally. No specimen has been seen in the position of growth, but occasional joined specimens and their local concentrations suggest that these sponges grew in colonies from a common substratum. The brachiopod *Xenelasma* is known from the lower 140 feet of the Honeycut formation and is common in the lower 70 feet. Mostly it occurs in chert, but it is very common as free silicified specimens at places on the top surface or in the top inch or two of the highest stratum of the Gorman formation. It is not known at a lower position, and the "Gorman specimens" probably grew at the sea-floor of earliest Honeycut time. *Finkelnburgia* of the type of *F. cullinsoni* Ulrich and Cooper has been found at a few places in the Honeycut formation, and, of course, the commoner "finkelnburgias" of the more generalized types have also been noted. Six "species" of *Ceratopea* have been recognized and found to characterize particular parts of the section. These are

at present designated by numbers, as indicated on Plate 14, pending description and naming of the new species. Species 5 and 6 (*C. "keithi"* Ulrich) each display several varieties, and the young of species 3 (*C. robusta* Oder) are so difficult to tell from species 2 (*C. capuliformis* Oder) that the two forms are regarded as subspecies of *C. capuliformis* in the broad sense (in practice they are briefly designated by subspecific name alone). In addition to the six species of *Ceratopea* indicated on Plate 14, *Ceratopea tennesseensis* Oder has been collected from the highest Honeycut stratum known in the Llano uplift, in the Honeycut Bend section, and a small horn-shaped species is known from the lower part of the formation. *Barnesella lecanospiroides* Bridge and Cloud (shown on Pl. 14 as "*Maclurites affinis*") has been found only from about 130 to 180 feet above the base of the Honeycut. This planispiral, hyperstrophic or pseudosinistral shell is easily confused with *Lecanospira* but a marked bulge on the inner surface of the whorl, toward the keel, is a distinguishing feature. *Raphistomina, Lesueurilla, Polhemia, Plethospira,* and patelliform gastropods occur locally, and a possible *Onychochilus* was seen at one place. *Tarphyceras* cf. *T. chadwickense* U.F.M.F. has been found between 280 and 400 feet above the base of the Honeycut formation, representing an extension of the genus *Tarphyceras* into older beds than it has previously been reported from. Piloceratid cephalopods are represented by the occurrence of *Allopiloceras* at three localities (TF–246, 16T–2–43D, 16T–2–33E) having a range of 460 to 580 feet above the base of the Honeycut formation. *Cotteroceras* or a laterally compressed *Cyptendoceras* was seen at a few places. *Aphetoceras* and *Moreauoceras* have been collected from the lower part of the Honeycut formation. The archaeostracan crustacean *Eopteria* has been found only from about 130 to 180 feet above the base of the Honeycut formation, holding essentially the same range as was observed for *Barnesella.*

FAUNAL DIFFERENTIATION OF THE ELLENBURGER FROM UNDERLYING AND OVERLYING ROCKS

The faunas of the Upper Cambrian rocks are dominated by trilobites, with a fair abundance of brachiopods in some parts of the section, and with snails locally common. Some of the fossils from the Cap Mountain limestone member of the Riley formation were described by Lochman in 1938, but except for a few species described by Bridge (*in* Bridge and Girty, 1936) and in scattered reports by others, the species from the Wilberns formation are mostly unnamed. Decker (1945) described many Wilberns graptolites from the Point Peak shale member about 380 feet (p. 156) below the top of the Wilberns formation in Mason County, but graptolites have not been found at other localities.

Cedaria, Tricrepicephalus, Aphelaspis, and certain inarticulate brachiopods mark the Riley formation, with *Aphelaspis* and *Lingulella arguta* (Walcott) marking its upper part. *Eoorthis* occurs approximately 70 feet above the base of the Wilberns formation, with the trilobites *Pterocephalia* and *Elvinia* immediately below it, and with the brachiopod *Huenella* ranging up to 50 feet above it. The lowest *Billingsella* known in central Texas appears at or just below the zone of *Eoorthis* and the genus ranges from here to within 135 feet of the top of the Wilberns formation. During field studies six species of *Billingsella* were recognized, and approximate stratigraphic separations could be made on the basis of the species present. *Plectotrophia* proved to be a very useful index to the middle Wilberns, occurring near the top of the Point Peak shale member at most places. The common species is *P. bridgei* Ulrich and Cooper, but *P. alata* (Walcott) is locally associated with it. Immediately south of the Bald Ridge area *Paleostrophia* occurs with *Plectotrophia,* and in the vicinity of the Bear Spring area the related huenellid brachiopod *Mesonomia* appears to supplant it. The primitive bellerophont *Owenella* and the peculiar sinistral gastropod *Scaevogyra* have limited ranges in the upper half of the Wilberns formation, as shown on Plate 14. In the Pedernales

dolomite member, and near the position of *Scaevogyra*, Barnes has found the rare brachiopod *Xenorthis*, the bellerophont gastropod *Anconochilus barnesi* Knight, and a peculiar limpet-like shell referred to *Matthevia* aff. *M. variabilis* Walcott by Dr. Bridge. Saukiinid trilobites of several closely related genera range from below the middle to within 115 feet of the top of the Wilberns formation, and *Stenopilus* apparently marks about the upper 220 feet of the formation. Trilobites such as *Platycolpus*, *Eurekia*, *Chariocephalus*, *Euptychaspis* and others also characterize Wilberns strata.

Few fossils cross the Cambrian-Ordovician boundary. The gastropod *Sinuopea* makes the deepest invasion and *Schizopea* transgresses it slightly. *Plethometopus*, normally a Cambrian fossil, appears to range into Ordovician strata in the vicinity of Burnet and may do so in the Threadgill Creek section. Even *Stenopilus* may range above the boundary northwest of Round Mountain, in Blanco County. The pygidia of *Plethometopus* and perhaps other trilobites high in the Cambrian are very like those of *Leiostegium* and perhaps other trilobites low in the Ordovician, and sure discrimination requires the cephalon.

The beds that overlie the Ellenburger rocks in central Texas are so far removed from them in time that no genera are found in both Ellenburger and younger strata and only the remotest faunal similarities exist. In the Devonian, *Parastrophinella* characterizes the Pillar Bluff limestone, *Leptocoelia* the Stribling formation, *Pentamerella* the Bear Spring formation and *Echinocoelia* the Zesch formation. Many of the Devonian fossils are listed by Barnes, Cloud, and Warren (1945, 1947). Pertinent information on the Carboniferous faunas is listed in the discussion of "Beds that overlap the Ellenburger."

INTERREGIONAL INDEX FOSSILS OF THE LOWER ORDOVICIAN CARBONATE ROCKS

Fossils that proved useful in the interregional correlations considered in the present report are listed under 15 itemized groups on pages 61–62, and the degree of reliability that may be placed upon them is there indicated. It is felt that the section on regional correlation is the proper place for this information, but that cross reference should be made here. The interested reader will find complete faunal documentation for all correlations made, either in Part 3 of the present report or in cited published references.

GEOLOGIC STRUCTURE

FAULTS

The faulting that disturbs the Paleozoic rocks of the Llano uplift is of a tensional type, and the faults are normal or nearly vertical, having a range of dip from about 60 to 90 degrees. There is evidence that during faulting, openings may have existed along some of the faults. For example, on Squaw Creek in Gillespie County, blocks of limestone several feet across that belong to the Threadgill member of the Tanyard formation rest between walls composed of the San Saba limestone member of the Wilberns formation.

Along several of the faults of the Llano region the rocks immediately adjacent to the faults dip in a direction opposite to that of the normally expectable drag. The reason for such "reversed" drag is not apparent from field observations, but it is conjectured to be caused either by a noncompensatory movement in a direction opposite to the original displacement, or possibly by slumping or pitching of the strata toward openings along the zone of displacement. The "reversed" drag seems to be mostly associated with the steeper faults.

The rocks of the Llano uplift are thought to have comprised a relatively resistant mass, around the eastern and southern sides of which developed the geosynclinal area (Llanoria geosyncline of Sellards, 1933) containing the Ouachita facies. The faulting in the Llano region probably accompanied the late Paleozoic folding that involved the sediments of the Llanoria geosyncline, movement in the geosynclinal areas to the east and to the south placing the Llano area under torque and causing it to fracture. The theoretical tensional couples developed by active compression from east and south would result in fractures aligned dominantly in the northeast quadrant, as fault-

ing in the Llano region is. Moreover, the theoretically expectable range of strike within the northeast quadrant of faults so formed is comparable to that actually found.

Special relationships of the fault zones are so readily visualized from inspection of areal data alone that structural cross sections are not given for the various maps.

Detection of Faulting

Detailed mapping was necessary in order to find unfaulted sections of Ellenburger rocks or, failing in this, to match sections across faults. Even with detailed work an occasional fault was detected only after discrepancies in the thickness of some portion of the section led to even closer scrutiny of the rocks. For all of the sections measured it was necessary to map an area sufficient to detect the various faults and fault zones that might be headed in the direction of the contemplated section. The various units of the Cambrian beneath the Ellenburger strata in the western part of the uplift are easy to identify as are also the various units of the Cambrian beneath the Pedernales dolomite in the eastern part of the uplift. The rocks above the Ellenburger are also distinctive. These distinctive units above and below the Ellenburger make detection of faulting at the Ellenburger boundaries simple, and faults heading toward contemplated sections across these boundaries are easy to detect. However, in the broad expanse of Ellenburger between its boundaries the detection of faulting is often difficult.

Mapping of the Ellenburger during the present project was ordinarily preceded by examination of aerial photographs to detect alignments and offsets in the vegetational pattern which might indicate faults. Some of the faulting in the Ellenburger scarcely affects the vegetational pattern, and the alignments may be faint or actually not visible under the stereoscope. For the detection of very faint alignments it has been found helpful to examine individual aerial photographs with the line of sight almost parallel to the surface. During such preliminary examinations all alignments detected were pencilled on the photographs for checking in the field, but many of them proved not to be significant, being caused either by joints or by faults having only a few inches or feet of displacement. The alignments that are significant, however, are detected in mapping member and formational boundaries, and with an inferred position already pencilled on the photograph, the verification or emendation of their actual position on the ground was simplified. The facies boundaries were mapped after member and formational boundaries, whose mapping revealed the presence of faults and also determined whether particular anomalies are due to faulting, slumping, or gradation. For general areal mapping the tracing of formation, member, and facies boundaries furnished sufficient data; but if a section were to be measured, key beds were traced in order to detect minor faults which may be situated between boundaries. Key beds identified by sand, chert, fossils, or grain size are common in the Gorman and Honeycut formations. In the Tanyard formation, however, only chert and grain size were useful in identifying beds for lateral tracing, and, in general, distinctions are difficult. However, trial-and-error tracing ordinarily revealed some bed or combination of beds that could be followed with reasonable accuracy.

The outcrop characteristics of faults in the Ellenburger group vary. Some are marked by fault breccias, but many of them show clean breaks with little disturbance to strike and dip and no appreciable brecciation. Many of the faults can thus not be followed except by the tracing of key beds to points where they are cut off. Along some faults the rate of dip and direction of strike of the beds change and make the detection of the faults relatively easy. Care must be taken not to confuse fault breccias with intraformational breccias or with pseudo-breccias such as are found at the contact of laterally gradational limestone and dolomite.

Major Fault Trends

The major faults of the Llano uplift mostly trend in the northeast-southwest quadrants with only a very few, such as the Little Llano River fault zone, which trend about N. 10° to 15° W. The north-

easterly trending faults include most of the faults of the Johnson City area, the Simpson Creek fault zone of the Cherokee area, the Honey Creek fault of the Bear Spring area, and the Roaring Spring fault of the Backbone Mountain area. The direction of next greatest importance seems to be in a north-northeast direction, as exemplified by the faults of the Gorman area and the Cherokee fault zone of the Cherokee area. Some of the prominent faults, such as the Riley Mountain fault of the Moore Hollow and Warren Springs areas and the Bluff Creek fault of the Bear Spring area, have a general north-south trend. The Bald Knob fault zone of the Backbone Mountain area trends about east-northeast. Rarely, however, does a fault of large displacement trend east-west, as does the approximately east-west fault shown in the map of the Tanyard area (Pl. 8). Although the major faults have a tendency to be straighter than the smaller ones, they are not straight for any great distance, and fault slivers and wedge-shaped blocks are common along them. Occasionally the displacement on a major fault will shift to a parallel or echelon fault, and the intervening beds are apt to be steeply tilted. An example of this may be seen along the Cherokee fault zone in the Cherokee area where all units of the Ellenburger group can be seen in a distance of half a mile in one of these steeply upturned zones, and another example, along the Simpson Creek fault zone, is shown stereoscopically in figure A of Plate 34.

The major faults influence the outcrop pattern of the Llano uplift. Because the boundary between the Paleozoic and pre-Cambrian rocks is marked by faults in many places, it consists of more or less straight fault lines interspersed with the curving normal contact lines. Some areas of Paleozoic rocks project into the pre-Cambrian areas. Examples of these are those that form Backbone Ridge and the ridge on which Lion Mountain is located in western Burnet County, the ridge on which Lone Oak Mountain is located in northern Llano County, and the Riley Mountain-Cedar Mountain-Bee Rock Mountain group of Llano and Gillespie counties. Some of these areas are grabens, whereas others have a major fault on one side and a normal contact or minor fault on the other. The Paleozoic rocks of the Riley Mountains are almost isolated in the pre-Cambrian terrane of southern Llano County, being separated from Cedar Mountain to the south by Sandy Creek with Cedar Mountain in turn separated by Cut Off Gap from Bee Rock Mountain, which is still farther south, in Gillespie County. Long Mountain in eastern Llano County is an isolated area of Paleozoic rocks that has been dropped into the pre-Cambrian. The Paleozoic rocks are more resistant to weathering than are the rocks of the pre-Cambrian; consequently the Paleozoic rocks stand high, forming a rim around the pre-Cambrian basin of the Llano region, and occurring as detached and topographically high areas of Paleozoic rocks in the basin.

Minor Fault Patterns

The distinction between the major and minor faults becomes, in some instances, a matter of judgment where the complete fault pattern has not been mapped. A major fault will in places fray into a number of smaller faults dissipating the throw over a wide area. In the Bear Spring area, the Bluff Creek fault seems to be fraying out at both ends, but what it does beyond the border of the map is unknown.

Other complicated fault patterns are connected with some of the major faults, as may be seen in the Moore Hollow area. Here faults take off westward from the Riley Mountain fault and merge into a very complicated and unpredictable maze of faults.

Minor faults trending northwest-southeast are occasionally encountered and are troublesome to map. These faults may occur in a series of parallel breaks, as mapped in the southern part of the Cherokee area and in the western part of the Bear Spring area, or as a lone fault, as mapped in the western part of the Gorman Falls area.

Age of Faulting

Faults involving the Smithwick shale have been mapped during the present work, and the writers have seen rocks of

the Strawn formation in fault contact with the Marble Falls limestone. In the western part of the Llano uplift, in the vicinity of Calf Creek, unfaulted beds of Canyon age overlap faulted rocks of Ellenburger age. The major late Paleozoic faulting is thus indicated to have taken place before Canyon time. The present authors do not know of evidence to indicate whether the faulting was in progress during Strawn time or was a post-Strawn and pre-Canyon event.

FOLDS

Folds in the Ellenburger strata seem to be chiefly incidental to faulting. They include large tilted basin-like structures of younger rocks that have sagged into older rocks along major faults such as in the Honey Creek basin of the Riley Mountains and in the Backbone Ridge area. These basin-like structures are mostly somewhat complicated by faulting. Much of the Ellenburger is in fault blocks having fairly uniform dip, and folding is not a very noticeable structural feature. Minor folding of these essentially uniformly dipping blocks is not readily detected unless individual beds are mapped with care.

Small pronounced folds were noticed in the Point Peak shale member of the Wilberns formation and superjacent rocks and in the shale of the Barnett formation and adjacent rocks. In the Cherokee area many small folds, some of which are quite sharp, are present in and above the Point Peak shale member and some of these persist upward to the contact of the San Saba limestone and Pedernales dolomite members of the Wilberns formation. The axes of many of these folds are aligned in a northwest-southeast direction, but alignments in other directions also occur. This type of folding was not mapped in other areas, but it has been noted. Not enough observations have been made on this type of folding over the uplift as a whole to determine whether these folds have a pattern showing a relationship to the major stresses affecting the Llano uplift or whether they are without pattern or have a different pattern for individual fault blocks. Similar folds, as well as small, sharp, doubly-plunging folds resembling certain Appalachian folds, affect the Marble Falls limestone and Mississippian formations along and parallel to the margins of the Simpson Creek and Cherokee fault zones of the Cherokee area. Doubly plunging minor synclines have also been noted and mapped along the northwest limb of the faulted Honey Creek syncline in the Bear Spring area.

COLLAPSE CONTACTS AND STRUCTURAL SINKS

Solution and collapse are common at several horizons and within several units of the Ellenburger group, as well as in the Upper Cambrian carbonate rocks. In the Bald Ridge area, solution along the boundary between the San Saba limestone member of the Wilberns formation and the overlying calcitic facies of the Threadgill member of the Tanyard formation has allowed the Threadgill rocks to collapse. In the Bear Spring area, dolomites of the Staendebach member of the Tanyard have collapsed into the limestone of the Threadgill member, as is well displayed along Bluff Creek. In the Cherokee area the dolomitic facies of the Gorman formation has collapsed into the calcitic facies of the Staendebach member of the Tanyard, and in the vicinity of the Victoria Gravel Company quarries it has collapsed into the dolomitic facies of the Staendebach. The Honeycut formation is collapsed into the limestone at the top of the Gorman formation for a short distance in the Cherokee area. In the Gorman Falls area a nearly circular collapse interrupts the contact between the Honeycut and the Gorman formations in the vicinity of a northwest trending fault. Collapsed areas were mapped within the calcitic facies of the Gorman formation in the Gorman Falls area and noted in other regions, and they may be common in other formations of the Ellenburger group. Where these collapsed features are basin-like, having the structure but not necessarily the topographic expression of a sink, they are referred to as structural sinks.

Solution at the top of the Ellenburger group has allowed younger rocks to settle into the Ellenburger in the basin-like structural sinks. Some of the most intriguing geologic history of the Llano

uplift is preserved in the structural sinks of the western areas. These sinks are mostly in the calcitic facies of the Gorman formation, which seems to be the most highly soluble unit of the Ellenburger. The section on geologic history enumerates the periods of submergence and emergence recorded by the formations found in the structural sinks.

The Devonian Bear Spring and Zesch formations of the Bear Spring area are entrapped in a small structural sink, and it is possible that rejuvenation of this sink is responsible for the presence at this place of the Ives breccia. The Ives breccia was seen in a structural sink east of the mouth of Joe Davis Hollow, McCulloch County, as were larger areas of Chappel limestone. In the Bald Ridge area a structural sink about one-half mile long and a thousand feet across contains Chappel limestone and the Barnett formation. This, however, appears to represent collapse in an area that was synclinal to begin with. Another structural sink at the mouth of Joe Davis Hollow contains a facies of the Barnett formation not seen in the near-by normal outcrop of the Barnett. In the northeastern part of the Llano uplift, in the Gorman Falls area, still another period of emergence is recorded, during which solution of the Ellenburger strata was sufficient to entrap rocks of Morrow age, none of which are in normal sequence between near-by outcrops of the Barnett and Marble Falls formations.

During the present investigation only a very small portion of the Ellenburger-Carboniferous contact has been mapped. With detailed mapping of this contact, additional geologic history should be revealed in the structural sinks at the top of the Ellenburger.

JOINTS

Joints in the Ellenburger rocks have not been studied during the present work, but their presence has been noted. Many of the joints, especially in the limestone, have been enlarged by solution, and very likely some of the more continuous of these, filled with soil and supporting a relatively luxuriant growth of vegetation, account for many of the alignments seen on aerial photographs of the Llano region.

A rather characteristic sphenoidal jointing (p. 18), Plate 25, figure E, perhaps related to the present surface, is common in the microgranular dolomites.

A striking joint pattern, while not seen in the Ellenburger rocks, is common in the Cap Mountain limestone member of the Riley formation. This joint pattern is visible on aerial photographs of many areas of the Llano uplift and is not unlike in pattern the Widmanstätten structure of meteorites. The pattern is not only visible in photographs of vegetated areas but is visible in photographs of fields barren of vegetation. The visibility of the joints is probably caused by a color difference in the soil, possibly accentuated at places by a difference in moisture content.

PETROGRAPHY

The petrography of the Ellenburger rocks is for the most part included in the field descriptions of the various stratigraphic sections described in Part 2. Some additional information beyond that which can be seen with a hand lens is obtainable from a thin-section examination and is recorded here. In addition to the examination of thin sections and of chip samples and insoluble residues under the stereoscopic binocular microscope, the insoluble residues of all of the sections should be examined under a petrographic microscope. A start on such an examination has been made by Dr. S. S. Goldich and Mr. Bruce Parmelee, using material from the Moore Hollow and Warren Springs sections. Their results are significant and should be extended to other surface sections of the Ellenburger group in the Llano uplift to see if the various elements identified by them have a correlative value.

The data recorded at this place represent a summarization of the data obtained from the examination of 131 thin sections from the Johnson City and Cherokee areas and give the characteristics and relationships of the common minerals composing the Ellenburger and adjacent rocks. The present writers have examined none of the insoluble residues with a petrographic microscope; consequently many of the

rarer constituents such as those noted by Goldich and Parmelee have not been found. Description of the individual thin sections is given in Part 3.

STUDIES OF THIN SECTIONS

Carbonate Rocks

Calcite and dolomite are the predominant carbonate minerals composing the Ellenburger rocks. Some of the iron found upon analysis is probably ferrodolomite replacing part of the magnesiodolomite (ordinary dolomite), as is indicated by absorption noted in some of the dolomite crystals.

Grain size distinctions between the limestones in the Ellenburger and those beneath are important. The Cambrian limestones are predominantly granular with the crystals of calcite being measured in tenths of millimeters, or even millimeters, in size. The average grain size of the various limestones of the Ellenburger group ranges between about 0.002 and 0.005 mm., being so small in size that the thin sections are several crystals thick, thus yielding poor definition of the various crystals. Most of the Ellenburger limestones examined have some variation of grain size, with the preponderance of grains near the sizes stated above. Many sections have, in addition, a network or display small irregular areas composed of a slightly coarser grained calcite, contrasting sharply with the cloudy finer grained areas.

The few thin sections of limestones above the Ellenburger that were examined, except those composed of limesand, do not vary markedly in grain size from the limestones in the Ellenburger. The limestone of the Stribling formation varies between about 0.01 and 0.02 mm. in grain size and is enough coarser than the Ellenburger that it has a definitely granular appearance when viewed by naked eye or with a hand lens. The only thin section of Marble Falls limestone examined has about the same grain size as that of the limestones in the Ellenburger, but it is crowded with Foraminifera. Probably a sequence of thin sections from the Marble Falls limestone would reveal a considerably coarser average grain size.

Pellet limestones are abundant throughout the Ellenburger group, the pellets varying widely in size, shape, and sorting. The pellets are mostly cloudy and finer grained than the surrounding somewhat clearer and coarser grained calcite. Some pellets have a sphericity which causes them to resemble oöids, and, in some instances, pellet limestones seem to grade into oölitic limestones, of which a few are present in the Ellenburger. The limestones of the various formations of the Ellenburger cannot be distinguished in thin section, even though as a group they are mostly distinct from the limestones above and below.

The dolomites of the Ellenburger group and the underlying Pedernales dolomite member of the Wilberns formation have a wide range in grain size, some grain sizes being fairly distinctive of certain members. The Pedernales dolomite is mostly very fine grained, but in the eastern part of the Llano uplift much coarse grained dolomite is present. Nine sections of the finer grained portion have a grain size averaging between 0.06 and 0.5 mm. Only two sections of the coarser grained Pedernales dolomite were examined, and these averaged 0.6 and 0.5 mm. in grain size with some grains ranging up to 1.5 mm. in size.

Four thin sections of the dolomite of the Threadgill member of the Tanyard formation average in grain size between 0.6 and 1.0 mm. with some grains up to about 2.5 mm. in size. The dolomite in the Staendebach member (9 sections) ranges from 0.075 to 0.75 mm. in size with most of the sections having a grain size of about a quarter of a millimeter. The coarser grained dolomite is in the top portion of the member. In the Gorman formation the grain size is noticeably smaller, ranging in 10 sections between 0.02 and 0.25 mm. in size, with one anomalous section averaging 0.6 mm. in grain size. Of 12 sections of dolomite examined in the Honeycut formation the grain size averaged between 0.04 and 0.3 mm. Somewhat coarser dolomite was noticed in the Honeycut formation where sections are composed of limestone-dolomite mixtures.

The average grain sizes given above are approximations based on the better

developed crystals within the thin sections, disregarding smaller pieces which are obviously corners or edges of crystals. The range in average size of grain noted under the petrographic microscope in thin sections was less than that noted during examination with the binocular microscope of chip samples from the several measured sections. It is upon the latter type of examination that the average sizes of grain given on pages 19 and 24 were derived, data from such examination being more comprehensive on this point.

The dolomite rhombs vary from practically clear to very cloudy, because of included particles, and light brown, owing probably to the presence of ferrodolomite. In some thin sections the impurities are evenly distributed throughout all the rhombs, in some the rhombs vary in cloudiness, and in others the impurities are zoned within the dolomite crystals. Inclusions in pellets and oölites are preserved in the dolomite, and for this reason the ghost outlines of the pellets and oölites can be seen in the dolomite rhombs. In some sections where the limestone is completely changed to dolomite, pellets and oölites can be recognized by the distribution of the impurities within the dolomite. It is evident that dolomite rhombs which include these objects were formed *in situ*.

It has been commonly suggested that upon the dolomitization of limestone there is a reduction in volume of about 12 per cent (p. 93). Many large dolomite rhombs, so far as can be seen, are completely surrounded by limestone and no visible porosity is present. This is clearly authigenic dolomite, and if porosity had formed, it would have been eliminated by compaction. The presence of undisturbed surfaces of oöids crossing dolomite rhombs, however, suggests that no volume change takes place upon dolomitization.

Only one of the thin sections examined gave information about the period of stylolite formation. In this section some rhombs have irregular edges at their contact with a stylolite, indicating that if solution to form the stylolite did not take place wholly after the dolomite rhombs had formed, it continued or was rejuvenated subsequent to their formation. In another section dolomite rhombs are included in the residue accumulating along stylolites, and in this section a stylolite partially surrounds a dolomite rhomb.

In resumé, the examination of thin sections indicates that some surely of the dolomites of the Ellenburger group were deposited as calcium carbonate and dolomitized at some later time. From the evidence noted in the field and under the microscope, it seems that dolomitization of the Ellenburger occurred mostly if not entirely at or near the sea floor during diagenesis, while the magnesium-charged waters of the ocean could still penetrate the calcareous muds. Why dolomitization is so erratic in some units of the Ellenburger has not been surely determined, but it is probably related in part to permeability and in part to the mineral status (whether aragonite or calcite) of the original calcium carbonate muds (pages 92–93).

Some thin sections of the limestones and dolomites of the Gorman formation and the bottom portion of the Honeycut formation contain sand. The sand grains are well rounded, are poorly sorted within their size range, and are composed predominantly of quartz, an occasional microcline grain, and rarely a grain of plagioclase. No sand was seen in the thin sections of the Tanyard formation, and only a limited amount is present in portions of the Pedernales dolomite member of the Wilberns formation.

Cherts

The preponderance of the chert in the Ellenburger group and in the Pedernales dolomite member of the Wilberns formation is made up of an extremely fine grained aggregate of quartz crystals having about the same grain size as the limestones in the Ellenburger. Much of the chert has a network of clear quartz crystals of somewhat larger size, surrounding the hazy, fine grained areas. This variation in grain size is also common in the limestones. No section was available in which chert and limestone are in juxtaposition, and it is thus not known whether the chert preserves the grain size of the limestone or not. However, a pellet limestone seen in thin section 43 of the Cherokee area

shows pellets of extremely fine grained calcite to be surrounded by a network of coarser grained chert. Another section, No. 17 of the Johnson City area, is composed of extremely fine grained chert pellets and spheres surrounded by a coarser grained chert.

The size of the quartz grains ranges progressively from the extremely minute ones composing some cherts to crystals sufficiently large for optical determination. The extremely small crystals appear no different than the larger ones except for a haziness caused by the thin sections being several crystals thick.

Chalcedony in fibrous and banded aggregates is common in many of the thin sections of chert. Although it appears to be most common in the Gorman and Honeycut formations, it is not confined to them.

Dolomolds and dolomite rhombs are common in many thin sections of the cherts. A truly dolocastic chert is represented by thin sections 70 and 70a collected in the Cherokee area. The casts are of quartz crystal mosaics, in which the size of some of the smaller crystals approaches that of some of the coarser grained cherts.

ECONOMIC RESOURCES

SUBSURFACE RESOURCES

Oil and Gas

In view of the importance of the Ellenburger rocks of the subsurface as a reservoir for oil and gas the following discussion may seem disproportionately small in contrast to that given for "Outcrop resources." However, the writers feel that the present discussion should be confined to features of potential significance as noted at the outcrop and to reasonable surmises about conditions that may exist in the subsurface.

The portions of the Ellenburger group from which petroleum is produced probably cannot at present be correlated with the divisions of the Ellenburger established at the surface in the Llano uplift. Conversely, zones at the surface which might seem to be potential producers in the subsurface probably cannot be definitely traced to any existing area of production on the basis of information at present available from the subsurface. If accumulations of petroleum exist anywhere near the Llano uplift, observations made at the surface may apply to their discovery and exploitation, but it should be emphasized that faulting and exposure to the atmosphere preclude the possibility of obtaining commercial oil or gas from the Ellenburger within its outcrop area.

At the surface in central Texas vuggy dolomites of the Tanyard formation comprise the most notable zone of porosity in the Ellenburger group, and in favorable subsurface areas equivalent rocks might be oil bearing. However, studies by Dr. S. S. Goldich and Mr. Bruce Parmelee on porosity and permeability of some of the Ellenburger rocks in the Moore Hollow and Warren Springs sections show little *effective* porosity. If, nevertheless, the porosity in the Tanyard in some areas is effective, then the impervious microgranular dolomites of the overlying Gorman formation could serve as a seal to upward migration. While mapping, it was noticed that in areas where microgranular dolomite alternates with other dolomites or limestone, water commonly comes to the surface along the top of a microgranular dolomite bed, flows across the bed, and disappears where more pervious rock is reached. The stratigraphic distribution of observed springs at the surface (p. 127) and the relative effectiveness of the several stratigraphic units to hold water under earth-damned storage tanks (p. 134) indicate that the greatest potential effective porosity in the Ellenburger group and immediately subjacent carbonate rocks is in the dolomitic facies of the Staendebach member of the Tanyard formation. Where dolomites of the Staendebach member are directly overlain by microgranular to very fine grained dolomites of the Gorman formation, therefore, selective leaching could produce conditions favorable for porosity traps.

Preliminary studies of subsurface data indicate that on the eastern side of the Bend arch the lower part of the Gorman

formation is chiefly microgranular dolomite, as it is at the surface, and that this microgranular dolomite could act as a confining member for any petroleum that might be contained in porosity in the Tanyard formation. To the west of the crest line of the Bend arch the grain size in the dolomite facies of the Gorman formation coarsens and the Gorman strata could well have porosity comparable to that of the underlying Tanyard formation. Because of known changes in the lithic characteristics of the Ellenburger group at the surface and the possibility of greater changes in the subsurface, it is not safe to predict the location of zones of porosity at any great distance from the Llano uplift.

Rocks equivalent to the Tanyard formation in the Beach Mountain section (pp. 67, 360; Pl. 16) are predominantly sandstone, whereas in the Llano uplift no sand has been found. In some intervening area the two facies should interfinger, and if source beds are available and structural conditions right, petroleum accumulations may be present at this place.

Ellenburger strata have been eroded at various times previous to the deposition of sediments ranging from Devonian to lower Pennsylvanian in age. These periods of exposure to erosion are recorded by the presence of remnants of formations in part preserved in structural sinks about the Llano uplift. Solution of the Ellenburger has been very prominent during these erosion intervals, with resultant collapse and brecciation of much of the Ellenburger. Much of the porosity so created is eliminated by recementation of the breccias, but considerable probably remains; and this, along with porosity contained in residual accumulations of soil and chert at the ancient surface of the Ellenburger might form an important place for the accumulation of petroleum. At the surface the calcitic facies of the Gorman formation shows the most evidence of large-scale solution, and where this portion of the Ellenburger group comes directly below the overlapping beds, conditions favor local petroleum accumulations in caverns, solution channels, or breccias. Production from such traps may be rich and short lived, as in other cavern or channel production. At the southwest edge of the Llano uplift (Kott well, Gillespie County), however, the calcitic facies of the Gorman has disappeared, and this condition may hold for much of the subsurface southwest from the uplift. Other prominent limestone facies in the Ellenburger are undoubtedly transected by erosion in the subsurface, and these may develop solution features similar to those in the calcitic facies of the Gorman formation and likewise favoring the local accumulation of petroleum in the unconformable zone. Probably the most consistently favorable conditions for unconformity production from the Ellenburger will be found where impervious younger beds overlap the dolomitic facies of the Staendebach member of the Tan- distribution of springs (p. 127) and the ability of "tanks" to hold water (p. 134) indicates the best probability of continuous or effective porosity.

Zones of dolomite porosity will also be transected in the subsurface, and where these zones are overlapped by impervious beds the chances for petroleum accumulations should be good, provided source beds are available and structural conditions right.

It appears to be a widely held belief that the ultimate source of petroleum now in Ellenburger rocks was in younger strata, and that the petroleum leaked downward into the Ellenburger. However, the observed petroliferous nature of some of the microgranular to very fine grained Cambrian and Ellenburger dolomites at the surface suggests that some petroleum, at least, was indigenous to these early Paleozoic rocks, being retained, on exposure to the atmosphere, in the finest grained and least permeable rocks. The Ellenburger and Upper Cambrian rocks are, therefore, themselves potential source beds.

Water

The Ellenburger strata in the subsurface contain some potable water where they fringe the Llano uplift. The ultimate depth and lateral extent of the potable waters has not been investigated and, be-

cause of insufficient wells, cannot be determined at this time. An indirect approach will be used to indicate the more favorable zones for water in the Ellenburger. Well records have not been reviewed, but in the areas which have been mapped in detail for this report 82 springs (clusters of several springs are counted as 1) have been mapped in the Ellenburger. Besides these, six springs have been mapped in the Upper Cambrian Pedernales dolomite member of the Wilberns formation, and an untabulated number, some of which (*e.g.*, Gunstock Springs in Mason County) are of large volume, in beds below the upper carbonate facies of the Cambrian. Of the springs or clusters of springs in the Ellenburger, 27, which is one-third of the total, come from the dolomitic facies of the Staendebach member of the Tanyard formation. The number of springs from the other units of the Ellenburger are as follows: Honeycut formation, 21; calcitic facies of the Threadgill member of the Tanyard formation, 12; calcitic facies of the Gorman formation, 7; dolomitic facies of the Threadgill member of the Tanyard formation, 7; dolomitic facies of the Gorman formation, 6; and calcitic facies of the Staendebach member of the Tanyard formation, 2. The magnitude of the numbers given is not an accurate expression of potential, for the areal representation of the various units is unequal and their thickness varies. The Tanyard, Honeycut, and Gorman formations are of about equal thickness, but because of truncation, the areal representation of the Honeycut is only about half as great for the uplift as a whole as is that of the other formations. In addition the Tanyard is split into 4 units and the Gorman is split into 2, so that on a formation basis the figures are 48 from the Tanyard, 21 from the Honeycut, and 13 from the Gorman. The dolomitic facies of the Threadgill member is not represented in the western part of the Llano region and has a generally restricted distribution as compared to other dolomite units of the Ellenburger. Another factor limiting the application of the above data is the fact that almost one-third of the springs counted are in the Bear Spring map area, and many of these are probably at or near the contact of the limestones of the Threadgill member and the dolomites in the Staendebach. From the statistics as furnished by the number of springs, it seems that a well would have a better chance of obtaining water in the dolomitic facies of the Staendebach member of the Tanyard formation, or at the base of a sequence of dolomites of the Tanyard that rest on limestone, than elsewhere in Ellenburger rocks.

Where not overlapped by younger rocks the Ellenburger contains water in all units, but not in definite horizons. Much of the water in the upper two formations of the Ellenburger is along joints and in solution openings, and it is almost impossible to predict the amount of water, if any, that will be obtained by drilling.

OUTCROP RESOURCES

From a commercial standpoint carbonate rocks can be roughly divided into two groups, namely, (1) those for which specifications are physical and (2) those for which specifications are chemical. There is a certain amount of overlapping of these two groups; for example, some fluxing stone must meet both chemical and physical requirements.

Stone Used Chiefly Because of Its Physical Properties

All formations and units of the Ellenburger group are usable for crushed stone, as there is little variation in strength or hardness throughout the Ellenburger group of rocks. The main requirements for a deposit of Ellenburger rock to be used chiefly for crushed stone is that it be along a railroad and be so situated topographically that it can be readily and cheaply quarried. These conditions are satisfied in the vicinity of Sudduth, Burnet County (fig. 7), where the Victoria Gravel Company operates a quarry for the production of crushed stone (Pl. 22). The quarry is in the lower part of the Staendebach member of the Tanyard formation. A subsequently opened quarry west of the railroad on the same property was operated for the production of dolomite for magnesium ore and is not at present used for crushed

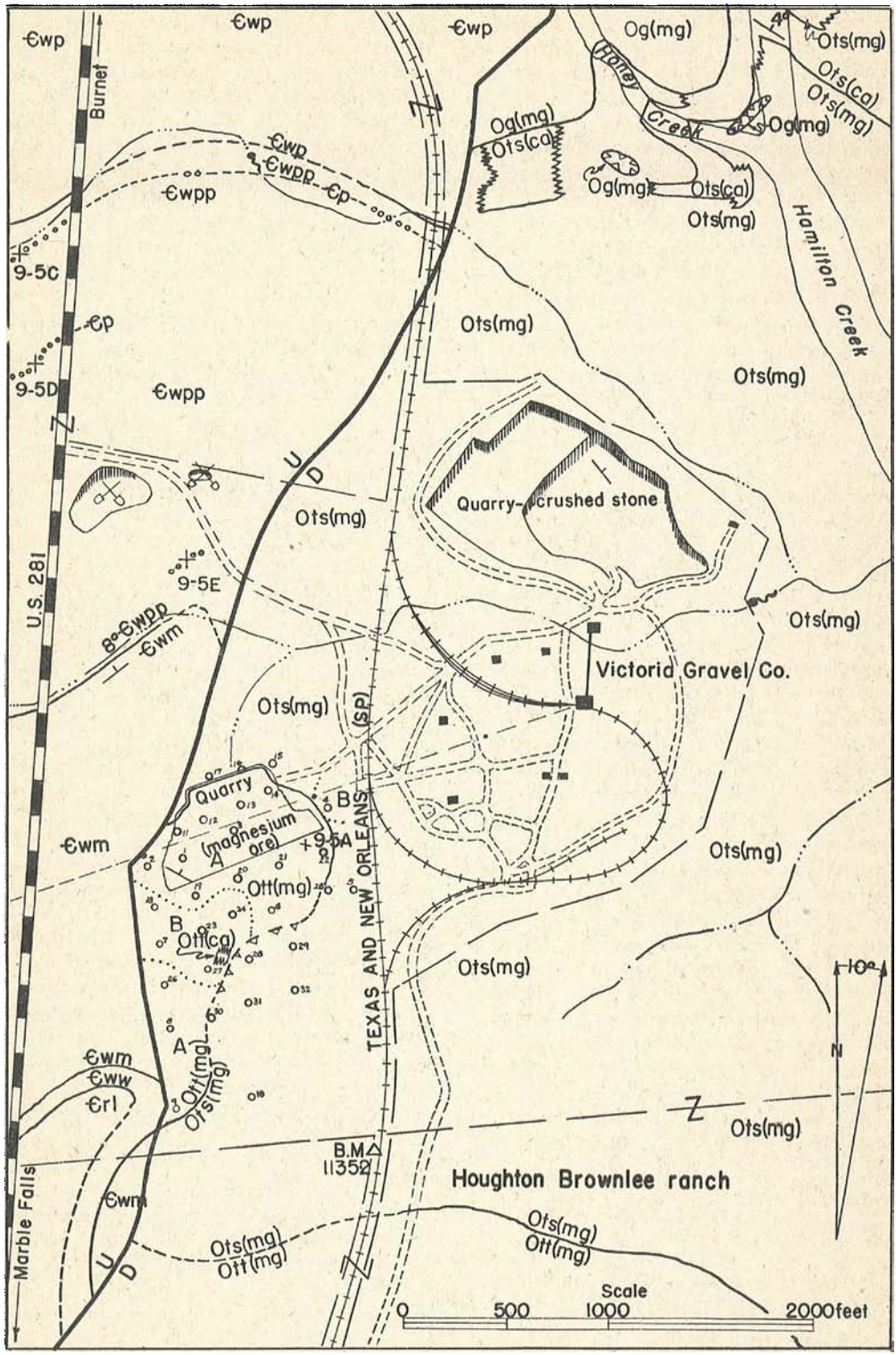

Fig. 7. Geologic map of an area in the vicinity of the Victoria Gravel Company quarries, Burnet County, Texas.

stone only because it is farther from the crushing plant. It is in the top of the Threadgill member of the Tanyard formation.

Adjacent ground both north and south from the present quarries is favorable so far as railroad transportation is concerned; but much of the surface in these areas is of low relief, making it difficult to start a quarry. The Backbone Mountain area of the present report (Pl. 11) is favorably situated for establishing quarries, and only short railroad spurs would be needed. In fact Backbone Ridge (Burnet County) in general is the most accessible portion of the Ellenburger outcrop area for location of quarries.

Long Mountain in Llano County is topped by Ellenburger rocks, beneath which is much Pedernales dolomite. The southwestern end of Long Mountain is along a railroad, offering a favorable site for quarry location even though the initial work would be difficult because of the steepness of this end of the mountain. A quarry from which crushed stone was produced for construction of Buchanan Dam is located at the northeastern end of Long Mountain. No effort has been made to determine whether this quarry is in the Pedernales dolomite member of the Wilberns formation or in the Tanyard formation. It has not operated since the completion of the dam.

Small inliers of the dolomitic facies of the Gorman formation are situated along Mesquite Creek a short distance both east and west of a railroad, north of Lake Victor, Burnet County. A small quarry in the western inlier opened for road material has long been abandoned. These inliers are in valley bottoms and, in general, are not favorably located for the establishment of large quarries, since stripping of the overlying Cretaceous rocks would soon become necessary. A small abandoned quarry, described under locality B1–2 in The University of Texas Publication 4246, is located 7.7 miles west of Johnson City and about 100 yards downstream from the highway crossing over Rocky Creek. The quarry is in the Pedernales dolomite member of the Wilberns formation and the stone was probably used for local road construction. The localities where Ellenburger and immediately subjacent Cambrian carbonate rocks are most accessible to railroad transportation have been enumerated. Another prominent group of Ellenburger outcrops runs roughly parallel to and about 4 miles south of the railroad between San Saba and Brady in the northern part of the Llano uplift. The Cherokee area includes the more easterly of these outcrops, and quarry sites could be located anywhere along the Simpson Creek fault zone.

The crushed stone now produced from the Ellenburger by the Victoria Gravel Company is used mostly for railroad ballast, road metal, and for concrete aggregate. Since the quarry opened in 1937 about 4 million tons of crushed stone has been produced. The quarry in the Staendebach member of the Tanyard formation contains an abundance of chert, which prohibits the use of this stone for any chemical use. The quarry in the Threadgill member of the Tanyard formation is low in impurities, and the stone may be used for practically any chemical use for which a high grade dolomite is needed. This rock is also of value for crushed stone and as stone chips to be used for stucco, roofing, and terrazzo.

Explanation of figure 7, illustration on opposite page.—Formations and members of the Ellenburger group of Ordovician age present are as follows: Og(mg), dolomitic facies of the Gorman formation (in part collapsed into the Tanyard formation); Ots(ca), calcitic facies and Ots(mg), dolomitic facies of the Staendebach member of the Tanyard formation; Ott(mg), dolomitic facies and Ott(ca), calcitic facies of the Threadgill member of the Tanyard formation. Cambrian formations and members present are as follows: Wilberns formation—ewp, Pedernales dolomite; ewpp, Point Peak shale; ewm, Morgan Creek limestone and eww, Welge sandstone members; Riley formation—erl, Lion Mountain sandstone member. In the vicinity of the quarry for magnesium ore, areas outlined by dots and labeled A indicate rock containing in excess of 30 per cent $MgCO_3$, and areas labeled B indicate rock containing less than 30 per cent $MgCO_3$. Symbols such as 9–5E indicate the locality of a fossil collection. Base from U. S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940. Geology by Virgil E. Barnes and Lincoln E. Warren, 1944–45.

In much of the eastern part of the Llano region, the microgranular dolomites of the Gorman formation are varicolored in yellowish, pinkish, and brownish tones such as beige, rose beige, rose pink, cinnamon pink, tan, old ivory, and nutria. Many of these colors are desirable for terrazzo chips, and the latter have been produced from several small pits (*see* Univ. Texas Pub. 4246, locality Bu–44), mostly about 3.5 miles south of Sudduth along the eastern side of U.S. highway 281. The most highly colored microgranular dolomite in this area is near the base of the Gorman formation where it is faulted against the Hickory sandstone member of the Riley formation. The stone is of a dark red color.

Another pit from which some chips for terrazzo, as well as crushed stone for highway surfacing and concrete aggregate, were taken is located near Sudduth at the intersection of the railroad and the highway. This pit is in coarse grained dolomite, probably of the Threadgill member of the Tanyard formation, but it could be in the coarse grained portion of the Pedernales dolomite member of the Wilberns formation. The stone is mottled pinkish gray to brownish gray and is described under locality number Bu–36 in The University of Texas Publication 4246.

Other localities from which terrazzo chips have been obtained are described under locality numbers Bu–20, Bu–33, and Bu–39. Locality Bu–20 is located along Hamilton Creek at the south city limits of Burnet where the dolomite is colored pink with breccia-like areas of ivory. This deposit is an inlier surrounded by Cretaceous rocks and probably formed as a weathering breccia or caliche on the pre-Cretaceous surface. An ivory colored limestone occurs at locality Bu–33, about 1.5 miles by road northwest of Burnet, along Hamilton Creek. Dolomite locality Bu–39 is east of the highway about 1 mile south of Burnet. The pits from which terrazzo chips are produced are mostly small, and, as their operation is mostly periodic, some may have been overlooked. Also other pits have probably been opened since the field work for Publication 4246 was completed.

The Ellenburger rock is good for filter stone, and the fines from crushing when properly screened can be used for stone sand.

The University of Texas Publication 4246 covers the use of the Ellenburger as a building stone and discusses 28 localities where deposits have been or might be of value for building and monumental stone. Five quarry sites of the Vermont Marble Company in San Saba County, all in limestone, are discussed under locality S–1. One of these, in the Threadgill member of the Tanyard formation (Pl. 20, fig. C), has stone of good quality. A small quarry in the Staendebach member of the Tanyard formation, in the southeast corner of the W. R. Payne ranch, contains much chert and the stylolites are rather open. Limestone in a pair of small quarries high in the Staendebach member, along State highway No. 16 on the H. C. Perry ranch, is also highly cherty. In a quarry in the calcitic facies of the Gorman formation, above McAnelly Canyon on the J. C. Creamer ranch, the stone is inferior in grade, the stylolites being open and the weathering of pyrite nodules causing unsightly stains. The two small quarries that comprise the fifth site of the group are also in the calcitic facies of the Gorman formation, along the San Saba-Chappel road one-fourth of a mile south of the Simpson Creek fault zone. In addition to those noted, two other small quarries in limestones of the Threadgill and Staendebach members of the Tanyard formation are shown on Plate 2. The only quarry containing promising stone is located in the Threadgill member of the Tanyard formation (Pl. 20, fig. C). Even here only a portion of the beds quarried is desirable; and were all beds in the sequence to be used, the quality of the product would be lowered. The field work for the building stone publication (Univ. Texas Pub. 4246) was done before any of the present detailed information on the Ellenburger was known; consequently the sampling of the Ellenburger was done in a hit-or-miss fashion. If the present information had been available, sampling would have been largely confined to the limestones of the Threadgill member of the Tanyard formation, the

uppermost portion of the calcitic facies of the Gorman formation, and the upper calcitic portion of the Honeycut formation. The upper calcitic portion of the Honeycut formation, being present only in a limited area of Blanco County and possibly in a small area in eastern Burnet County, was not sampled at all during the building stone work.

About 17 dolomite deposits are described in the building stone publication. Few of these contain stone which is of building or monumental grade, and most of the localities are recommended only as being suitable for crushed stone.

Stone Used Chiefly Because of Its Chemical Composition

Producing areas.—The only Ellenburger rock so far quarried because of its chemical composition was dolomite that served as an ore of magnesium in the plant operated by the International Minerals & Chemical Corporation near Austin, Texas. A small amount of the same "ore" was shipped to the Mathiesen Alkali Company, Lake Charles, Louisiana. The quarry from which this rock was obtained is about 6 miles south of the town of Burnet in Burnet County. It was operated by the Victoria Gravel Company and produced about one-quarter of a million tons of magnesium ore. The geology in the vicinity of Victoria Gravel Company property is shown in figure 7. The quarry for magnesium ore is located west of the railroad and is in the top of the Threadgill member of the Tanyard formation.

A fault divides the area shown in figure 7 into two parts. The western part contains Cambrian rocks that include from south to north the Lion Mountain sandstone member of the Riley formation and the Welge sandstone, Morgan Creek limestone, Point Peak shale, and Pedernales dolomite members of the Wilberns formation. The San Saba limestone member of the Wilberns is absent. East of the fault all of the rocks are Ordovician in age; the top portion of the Threadgill member of the Tanyard formation, the Staendebach member of the Tanyard formation, and the bottom portion of the Gorman formation are represented.

The Threadgill member of the Tanyard formation outcrops in two separate patches, the more northerly of which contains the quarry for magnesium ore. This outcrop is limited by normal overlap of the Staendebach member to the east and by faulting at the west. Rocks of the Threadgill member are brought to the surface at this place in a northeastward-plunging anticline. They belong mostly to the dolomitic facies of the Threadgill with only one small outcrop of limestone noted between drill holes 27 and 28. The outcrops southwest of drill hole number 25 are very poor, and the boundary between the Threadgill and Staendebach members in this area has been drawn on the basis of analytical data. The high silica content of holes 28, 29, and 31 (*see* "Chemical data," pp. 389–390), suggests that solution of the underlying Threadgill member has allowed cherty dolomite of the Staendebach member to collapse into the Threadgill member. Drill hole number 28 is in a dense clump of trees and underbrush between drill hole 6 and the one outcrop of limestone, and the relative density of vegetation suggests soil formation and water circulation such as is favored by collapsed areas. If this is a collapsed area it would not have to be much larger to include drill holes 29 and 31. On the basis of chemical data the Threadgill member has been divided into zones that are marked on figure 7 by dotted lines. The two zones labeled A have a content of $MgCO_3$ above 30 per cent, ranging up to 47.90 per cent in drill hole 31; and the two zones labeled B have a content of $MgCO_3$ below 30 per cent, the lowest recorded being 16.35 per cent for drill hole 27. The chemical data from drill holes on this property substantiate the lateral gradation so often mapped during the work on the Ellenburger problem. It also makes it evident that the only safe way to predict the chemical properties of rock in the Threadgill member is from analysed samples from holes drilled on a closely spaced grid. The only rock of chemical grade within the area covered by figure 7 is in the Threadgill member.

From the patch of the dolomitic facies of the Threadgill member of the Tan-

yard mapped in the southern part of figure 7 similar coarse grained dolomite extends almost 2 miles to the south and includes an unknown amount of coarse grained dolomite of the Pedernales dolomite member of the Wilberns formation. The coarse grained Pedernales dolomite is probably of about the same grade as the dolomite in the Threadgill if analyses of the two obtained in Blanco County are indicative. The length of outcrop in this fault block is about 1.2 miles, and the surface, except in the southeastern portion, is flat and not well suited for the location of a quarry.

The next fault to the east of the area shown in figure 7 drops the top of the Threadgill member to slightly more than one-half mile upstream from the falls on Hamilton Creek at Mormon Mill. Good quarry sites exist from 0.7 to 1.3 miles southeast of Sudduth station along the bluff of Hamilton Creek and along a side drain of Hamilton Creek. Drilling, of course, would be necessary to determine the grade of the dolomite.

The entire thickness of the Staendebach member of the Tanyard formation is exposed within the area mapped, and the quarry from which crushed stone is produced is located near the middle of the dolomitic facies of the member. The calcitic facies of the Staendebach member occurs at its top. It is laterally gradational to dolomite, with some sections devoid of limestone. The Gorman formation, composed mostly of microgranular dolomite and a few limestone beds, outcrops within the map area only in the vicinity of Honey Creek. The Tanyard-Gorman contact, especially in the area just east of figure 7, is in large part a collapse contact, with the Gorman at one place being dropped down many feet into the dolomite of the Staendebach. Two small areas of Gorman are collapsed into the Staendebach within the map area.

Areas of potential production.—Analyses were made by Mr. R. M. Wheeler of selected portions of the sections of limestone and dolomite in the Johnson City area and in the Cherokee area. Other sections measured contain stone of chemical grade for which it would be desirable to have analyses, but further analytical services were not available. The analyses are listed under "Chemical Data" on pages 377–381, and the position of each sample in the section is given so that it can be compared with the graphic and written descriptions.

In the Johnson City area analyses number 1 and 2 are of rocks within the Point Peak shale member of the Wilberns formation. Analyses 3 to 10, inclusive, are of the lower fine grained portion of the Pedernales dolomite member and are high in insoluble material and rather uniformly high in magnesia. Analyses 11 to 20 are of the upper coarse grained portion of the Pedernales dolomite and, except for samples 11 and 17, are low in insoluble material and uniformly high in magnesia. Analysis 21 is of high grade rock straddling the Cambrian-Ordovician boundary. Analyses 22 to 28 are of the bottom portion of the Threadgill member of the Tanyard formation and are similar to the coarse grained dolomites of the Pedernales except that they contain about half as much Fe_2O_3. Analyses 29 to 35 are of the lower portion of the Staendebach member of the Tanyard formation and are all high in insoluble material and uniformly high in magnesia. Analyses 36 to 49 are of the dolomitic facies of the Gorman formation and are rather uniformly high in insoluble material and are slightly low in magnesia. Analyses 50 to 66 are of the middle dolomitic facies of the Honeycut formation and are similar to the dolomites in the Gorman formation.

In the Cherokee area analyses 67 to 73, inclusive, are of the lower part of the Threadgill member of the Tanyard formation. They are uniformly low in insoluble material and, as compared with similar rocks in the Johnson City area, somewhat low in magnesia. Analyses 74 to 83, of the upper part of the Threadgill member, have a wide but not uniform variation in insoluble content and an erratic and slightly low magnesia content. Analyses 84 to 92, of limestones from the calcitic portion of the Staendebach member, are mostly very high in insoluble material and show an excessive amount of magnesia. Analyses 93 to 102, of the dolomitic facies of the Gorman formation, are

considerably higher in insoluble material than equivalent rocks in the Johnson City area and lower in magnesia content than the same rocks. Analyses 103 to 109 are of limestone from the calcitic facies of the Gorman formation. The bottom three samples are rather high in magnesia, and two of the samples are high in insoluble material. The top four samples are from the prominent massive limestone zone at the top of the Gorman formation and are exceptionally pure limestone so far as magnesia is concerned and only slightly high in insoluble material. Analyses 110 to 113 are of limestones in the calcitic facies of the Threadgill member of the Tanyard formation from the Kirk ranch section and are laterally equivalent to dolomites analysed in the Cherokee section. Sample 113 is a dolomitic limestone, and the other three are almost free of magnesia. The insoluble material is exceedingly high in these samples as compared with the equivalent samples from the Cherokee section. As the analyses were made from samples taken primarily for studies of insoluble residues, the chances are that the insoluble portion is abnormally high in most of them.

From the above analyses it appears that the purest dolomites are from the Threadgill member of the Tanyard formation and the coarse grained portion of the Pedernales dolomite member of the Wilberns formation. The purest limestone is probably in the topmost portion of the Gorman formation, and, where low in network dolomite, limestones in the Threadgill member of the Tanyard might also be pure. It is possible that the insoluble material in the upper part of the Gorman at other places may be lower than the perhaps "loaded" analyses indicate it to be in the Cherokee area. Additional analytical work should be done on the limestones both of the Threadgill and the top of the Gorman. Moreover, the upper limestone facies of the Honeycut formation in Honeycut Bend should be analysed.

Except for those mentioned under the section on "Producing Areas," above, few favorable occurrences of either the Threadgill member of the Tanyard formation or the Pedernales dolomite member of the Wilberns formation are near a railroad. The most accessible area is probably south of Post Mountain near Burnet. No area of limestone in the Gorman formation is known to be really close to a railroad, and the Mill Creek portion of the composite Backbone Ridge section is probably the nearest. The upper massive limestone of the Gorman formation is well exposed and appears to be exceptionally pure in the vicinity of Longhorn Cavern. Outcrops of this upper limestone of the Gorman formation are within a few miles of a railroad in the Cherokee area (Pl. 2), and other areas about equally distant from the same railroad are probably present between San Saba and Brady. All other known outcrops of this portion of the Gorman formation are far from railroad transportation.

The upper limestone zone of the Gorman formation and the dolomites of the Threadgill member of the Tanyard formation and the Pedernales dolomite member of the Wilberns formation are suitable for agricultural "limestone." These "limestones" are relatively hard and expensive to crush, and for this reason may not be able to compete with the softer Cretaceous limestones. For the production of sodium carbonate by the Solvay process the upper limestone of the Gorman in places might be low enough in silica, and if limestones of the Threadgill member of the Tanyard were investigated in detail some would undoubtedly be found to contain less than one per cent silica and be low in magnesia. About the same specifications as for the Solvay process are required for limestone to be used in the Bayer process for the production of aluminum oxide and in the manufacture of sugar. At many localities limestones and dolomites of the Ellenburger group are suitable for use in the production of calcium carbide, lime and carbon dioxide, dolomite refractories, filler for fertilizers, flux, glass, mineral feeds for stock, paper, poultry grit, technical carbonate, and probably for the production of many other commodities.

Water

The number of springs issuing from each unit of the Ellenburger group in the

areas mapped has been enumerated on page 127. Almost half of these issue from the dolomitic facies of the Staendebach member of the Tanyard formation, and almost a quarter of them issue from the Honeycut formation. The flatter areas are deficient in springs, most of them being located in areas of considerable relief or along faults. Surface water also is limited in most of the flatter areas and must be supplemented for stock raising by impounding water in earth dammed storage ponds locally known as tanks. Care must be taken in locating tanks on portions of the Ellenburger. Most of the microgranular dolomites are essentially impervious, and tanks situated on them, if the dam is constructed out of impervious materials, will ordinarily hold water. Experience shows that tanks are also likely to hold water if built on the Pedernales dolomite member of the Wilberns formation regardless of its grain size, on either dolomites or limestones of the Threadgill member, or on limestones of the Staendebach member of the Tanyard. Many tanks built on the dolomitic facies of the Staendebach member will not hold water and others will hold only a limited amount. Tank building in the calcitic portions of the Gorman and Honeycut formations can be successful if cavernous areas are avoided and the tanks are built on beds of microgranular dolomite which are locally common even in the calcitic portions of these formations.

The major springs for the areas mapped are shown on the geologic maps and some are mentioned in the text description of the areas. In general, springs shown on the geologic maps may be expected to flow or seep for a good part of the year, but few are truly perennial or of large volume. Many other springs exist in areas of Ellenburger outcrop not mapped for the present publication. The Texas State Board of Water Engineers in coöperation with the United States Geological Survey has issued mimeographed reports on the "Records of wells and springs, drillers' logs, water analyses, and maps showing locations of wells and springs" for Blanco County, 1932; Gillespie County, 1937; Mason County, 1940; and San Saba County, 1939. In these reports formations from which springs issue are not given, but in areas mapped the formation is known. The following information on the flow of springs at some specific date is taken from the above noted publications on San Saba and on Blanco counties.

Name of spring	*Gallons per minute*
San Saba County	
Gorman Falls area	
Gorman Spring	900 measured
Sulphur Spring	600–700 estimated
Clark Spring	50 estimated
Seven Springs	250 measured
Between Gorman and Tanyard areas	
Post Oak Spring	350 measured
Jennings Creek Spring	650 measured
South of Tanyard area along Fall Creek	
Boiling Spring	1900 measured
Cherokee area	
Rough Creek Spring	220 measured
Barnett Spring	405 measured
McAnelly Spring	300 estimated
Mud Spring	5 estimated
Two unnamed springs	2–3 estimated
Blanco County	
Johnson City area	
Unnamed (Crofts ranch)	60 measured
Unnamed (Hyatt ranch)	5–10 estimated
Salter Spring (Wier ranch)	10 estimated

A group of springs known by the name of Three Springs, along Pedernales River, not included in the issued report, probably flow several hundred gallons per minute. The only spring mentioned in the Ellenburger of the Bear Spring area in Mason County is Bear Spring and no estimate of its flow is given. By comparison with the springs noted, it is estimated that a number of the other springs mapped in the various areas probably flow several hundred gallons a minute.

PART 2

LOCAL STRATIGRAPHY

BALD RIDGE AREA, McCULLOCH COUNTY

INTRODUCTORY STATEMENT

In a logical succession of Ellenburger sections from northwest to southeast in the Llano uplift, the thinnest and most abnormal is that displayed in the Bald Ridge area, in southeastern McCulloch County. The irregular area mapped lies between the towns of Brady and Camp San Saba and is approximately bounded on the southwest by U.S. highway 87, on the south by San Saba River, on the east by a north-south power line, on the northeast by the Brady-Voca road, and on the north by an arbitrary line. About 11 square miles was mapped geologically between the latitudes of 31° 00′ to 31° 05′ north and longitudes of 99° 15′ to 99° 19′. Plate 4 shows the geology of the area at a scale of 1:10,000.

Control for the base map of the Bald Ridge area was taken from a Texas State Highway Department traverse of U.S. highway 87. The base was plotted and adjusted by L. E. Warren from data recorded by the authors on aerial photographs of the U.S. Department of Agriculture.

Rocks mapped within the Bald Ridge area include the Point Peak shale and San Saba limestone members of the Wilberns formation (Upper Cambrian), the Tanyard and Gorman formations of the Ellenburger group (Lower Ordovician), a small patch of Devonian rocks, and strata of Mississippian and Pennsylvanian age. All of the Honeycut formation and the upper 130 to 230 feet of the Gorman formation are missing as a result of pre-Devonian truncation.

The structure of the area is simple, a few very minor faults and occasional collapse structures being the principal complications. Dips are mostly quite low, and a few gentle rolls repeat beds in the northern part of the area. Because of the low dips, gentle topography, poor exposures, collapse structures, and structural rolls, stratigraphic measurements were difficult to make and the accuracy of those made is not guaranteed.

The Bald Ridge area is of special interest in the Ellenburger problem because it lies at the northwestern corner of the Llano region and displays facies changes in the lower part of the Gorman formation that are of significance in predicting what the Ellenburger rocks of the adjacent subsurface might be like.

Vegetal and topographic patterns as expressed on aerial photographs are helpful in mapping. The limestones of the Threadgill member of the Tanyard formation and the San Saba limestone member of the Wilberns formation merge in a topographically rough area of fairly abundant cedar in which bedding patterns are very evident. This pattern is distinct on the photographs from that of the Staendebach member of the Tanyard formation and the Gorman formation, which merge in an area of smooth and gently rolling topography with scattered clumps of live oak. Both live oak and cedar grow on the higher limestones of the Gorman formation and tree growth is mostly thicker than on the underlying dolomites. Depressed areas, fuzzy with mesquite, betray the occurrence of shales of the Barnett formation; whereas the interbedded limestones and marly zones of the Pennsylvanian show conspicuous vegetal banding of cedar and mesquite.

Several sections measured in and near the Bald Ridge area are described on pages 140–153 and diagrammatically represented on Plate 14.

UPPER CAMBRIAN

WILBERNS FORMATION

The Welge sandstone and Morgan Creek limestone members of the Wilberns formation are not present in the Bald Ridge map area but are well displayed between its southeast corner and the mouth of Katemcy Creek, along San Saba River. The Welge sandstone is brown to brownish yellow,

sparingly glauconitic, and about 24 feet thick. The Morgan Creek limestone is granular, glauconitic, red to pink in the lower part and gray to greenish gray above, and about 125 feet thick. *Eoorthis* is abundant 68 feet above the base of the Wilberns formation at Flatrock Crossing of San Saba River, northeast of Camp San Saba. *Elvinia, Pterocephalia,* and other trilobites occur just below it and thumbnail-shaped *Billingsella* is common from just below to several feet above it.

The lower 110 feet of the Point Peak shale member of the Wilberns formation consists of interbedded green shales; platy, crinkled, micaceous, green limestones; and granular, gray to grayish brown, glauconitic limestones. The upper 80 feet is a zone of sublithographic to microgranular, greenish to brownish gray to woodash gray, stromatolitic limestones locally interbedded with or laterally displaced by shale like that below. Local zones of fine grained dolomite occur near the top of this biohermal zone. On Plate 4, this upper 80-foot zone of almost continuous stromatolitic bioherms is erroneously included with the San Saba limestone member. Such an inflexible application of member lithologies, although defensible on some grounds, was shown by later study to obscure the actual stratigraphic relationships of the bioherms, but the map was already in the hands of the engraver.

Plectotrophia bridgei Ulrich and Cooper and a new species of *Paleostrophia* occur together about 20 feet below the principal zone of stromatolitic bioherms at the top of the Point Peak shale member. Stromatolitic limestone is also locally interbedded with shales at and below the zone of *Plectotrophia.*

The San Saba limestone member of the Wilberns formation in the Bald Ridge area consists of about 200 feet of mostly granular, intermittently glauconitic, brownish to greenish gray to grayish brown limestone that weathers gray to bluish and brownish gray to grayish brown. A conspicuous zone of yellowish limestone crowded with saukiinid trilobites marks the base of the member, and trilobites are locally abundant throughout it.

LOWER ORDOVICIAN

Ellenburger Group

Only about 830 feet of Ellenburger rocks are present in the Bald Ridge area, the Honeycut formation and the top beds of the Gorman formation being absent.

Tanyard formation, Threadgill member.—The boundary between the Threadgill and Staendebach members of the Tanyard formation in the Bald Ridge area is drawn at the line of chemical change from limestone below to dolomite above. Thus the Threadgill member corresponds to the original "Threadgill limestone" of Bridge and Barnes (*in* Barnes, 1944). The lowest semiporcelaneous to subchalcedonic white-weathering cherts occur in the general vicinity of the transition from limestone to dolomite, and the stratigraphic thickness involved in the transition is so slight that it serves very well in place of the more difficultly mappable chert boundary.

Limestone, with rare thin interbeds of dolomite, comprises the approximately 255 feet of the Threadgill member of the Bald Ridge area. It is predominantly sublithographic, essentially nonglauconitic, pearl gray and old ivory to light brownish gray, and weathers to medium to light bluish gray or woodash gray ledges separated by intervals of poor exposure.

Sections of *Lytospira* and *Ophileta* as well as dolomitized trails are locally abundant on bedding surfaces, but in general they are less abundant and the limestone beds mostly thicker than in the Threadgill member of the Bear Spring and Lange's Mill areas. *Gasconadia,* occasional breviconic cephalopods, and abundant silicified *Finkelnburgia* occur locally.

Quartz druse occurs on some beds as scattered rosettes and occasional incrustations. Near the top of the member at most places are thin plates and extensive lenslike inclusions of tan- to russet-weathering chert composed of silicified fragments of fossils and pelletlike debris. Locally semiporcelaneous to subchalcedonic, nodular chert occurs near the top of the member, and more rarely at lower positions.

Separation of the Threadgill member of the Tanyard formation from the San Saba limestone member of the Wilberns formation below is based on the change from the granular and glauconitic limestones of the latter to the sublithographic and essentially nonglauconitic limestones of the former, as well as on faunal distinctions.

Tanyard formation, Staendebach member.—Except for the local occurrence of meshwork dolomitic limestones near the base and at the top, the approximately 280 feet of beds included in the Staendebach member of the Bald Ridge area is wholly dolomite. The dolomite of the lower third is mostly very fine grained to fine grained and light to medium gray to yellowish and brownish gray. At places it contains plates and lenses of subchalcedonic to porcelaneous, locally oölitic, chert that weathers light tan to shiny white. The dolomite of the upper two-thirds of the member is fine to medium grained, in large part vuggy, and light gray to light brownish and yellowish gray. It yields much more chert than the lower third, and its chert is for the most part conspicuously dolomoldic and drusy, with local blocks and layers that are subchalcedonic to chalcedonic and weather shiny white. Much oölitic to crypto-oölitic chert was seen and oölitic laminar chert occurs locally in the upper beds. Subchalcedonic to chalcedonic, commonly oölitic, white-weathering cherts are locally conspicuous in the vicinity of the Tanyard-Gorman boundary.

The Tanyard-Gorman boundary is difficult to map in this area because of the relatively coarse grain size of the lower Gorman strata. It is placed below the lowest sand, the Tanyard formation being wholly nonarenaceous, and the local concentration of white-weathering smooth-fracturing cherts near the boundary is a considerable aid to its approximate location. Typical Tanyard fossils such as *Ozarkina, Helicotoma,* and the dasycladacean alga *Rhabdoporella* range to the top of the Staendebach member, and faunal distinction from the overlying Gorman formation is possible at most places where determined search is made.

Gorman formation.—Pre-Devonian truncation in the Bald Ridge area removed all Honeycut strata, as well as the upper beds of the Gorman formation; and Devonian and Carboniferous rocks rest directly on beds possibly as much as 230 feet and as little as 130 feet below the top of the Gorman formation.

The remaining strata of the Gorman formation differ from those in other parts of the Llano region in that the lower beds are principally fine to medium grained dolomites that grade laterally to limestone, whereas microgranular dolomite is a rarity. Because they are so unusual in this part of the section, the intertonguing limestones within the mainly dolomitic lower part of the formation are shown on Plate 4, but dolomites within the mainly calcitic zone are not separately mapped.

The failure of the criterion of grain size of dolomites to be applicable in selecting the Tanyard-Gorman boundary in the northwest part of the Llano region was disappointing and bodes difficulty in subsurface work northwest from the Llano country. Fortunately sand ranges to the base of the Gorman formation in this area, while sand in the Tanyard formation at the surface of the Llano uplift has so far been found only as extremely rare grains in the Moore Hollow area (p. 255). The concentration of porcelaneous to chalcedonic and locally oölitic white-weathering cherts in the vicinity of the Tanyard-Gorman contact is an aid to its location, and faunal evidence serves to limit it closely. As in other areas *Rhombella* ranges to the base of the Gorman formation, whereas *Lecanospira* first appears somewhat above the base.

The fine to medium grained dolomites of the Bald Ridge area are light gray, grading to brownish gray and grayish brown, and the limestones into which they grade commonly contain an internal dolomitic meshwork that weathers into reticulate relief. The uncommonly occurring very fine grained to microgranular dolomites display darker colors, and the upper limestones are purer and dominantly sublithographic.

Chert is intermittently abundant in the Gorman formation of the Bald Ridge area,

occurring as nodules, lenses, plates, and thin bands that are mostly chalcedonic to porcelaneous and locally oölitic. Centers of the oöids are not uncommonly sand grains. Of more local occurrence is quartz druse, dolomoldic chert, and at places oölitic laminar chert such as normally characterizes the upper beds of the Tanyard formation. Of local prominence in the float are stromatolitic structures of the archaeosolon type (parallel pipes) outlined or replaced by drusy and dolomoldic chert.

The principal zone of *Archaeoscyphia* in the Gorman formation occurs about 210 feet above its base and a second occurrence was noted locally about 15 feet higher. *Archaeoscyphia* was also noted in beds apparently above its principal zone east of the Devonian joint-filling at TF–233 (marked F). Structural sinks are common in the vicinity of the *Archaeoscyphia* zone and its inferred trace on Plate 4 at many places crosses such collapsed areas on a projected line, even though higher beds are actually known to be at the surface at such places. Its trace outlines well the gently synclinal structure of the area in which are the more prominent collapsed extensions of the Mississippian strata.

DEVONIAN

Medium yellowish brown, to olive gray, fine grained, slightly arenaceous, fossiliferous limestone of Devonian age (TF–233) is plastered into crannies and irregular surfaces of the Gorman formation and occurs as float for about 250 feet along an east-west line about midway between High Lonesome Mill and the May Brook Kothman ranch headquarters. This rock apparently represents a joint-filling in rocks that are probably little above the principal zone of *Archaeoscyphia* in the Gorman formation.

It is further described, referred with query to the Zesch formation, and its few fossils listed in a report by Barnes, Cloud, and Warren (1947, p. 139).

CARBONIFEROUS

Mississippian

Only the Chappel limestone and the Barnett formation are known to represent the Mississippian of the Bald Ridge area.

The Chappel limestone is well displayed at the northeast end of a large collapsed area on the May Brook Kothman ranch, between the ranch headquarters and the windmill known as High Lonesome. Exposures that extend north from fossil locality TF–406 display about 25 feet of granular, crinoidal, rose pink to olive gray and plain gray limestones that are spottily fossiliferous. Some of the fossiliferous pockets contain a rich, varied, and well preserved fauna of Chouteau age, including forms identified by Dr. G. A. Cooper as *Stenoscisma* sp., *Sedenticellula* sp., *Shumardella obsolens* (Hall), *Rhynchopora cooperensis* (Shumard), *Productella* sp., *Avonia* sp., *Plicatifera boonensis* (Branson), *Brachythyris chouteauensis* Weller, *B. girtyi* Branson, *Spirifer striatiformis* Meek, *S.* aff. *S. gregeri* Weller, *Pseudosyrinx*, n.sp., *Tylothyris* sp., *Cyrtina burlingtonensis* Rowley, *Plectospira sexplicata* (White and Whitfield), *Reticularia cooperensis* (Swallow), *Athyris lamellosa* (Leveille), and *Cranaena* aff. *C. occidentalis* (Miller).

From a maximum observed thickness of about 25 feet, the Chappel limestone of the Bald Ridge area thins to a feather edge, occurring erratically along the collapsed Ellenburger-Mississippian contact. It varies little in appearance from that displayed in the vicinity of locality TF–406, but is rarely so fossiliferous. Excellent collections of the fauna of Chouteau age may be obtained, however, at the margins of a caliche pit in a structural sink at the seventh culvert north of San Saba River along U.S. highway 87 about 6.7 miles south-southeast from the courthouse at Brady (TF–385 to 389c), as well as northwest from the locality.

The Barnett formation of the Bald Ridge area consists of thin limestone beds interspersed in covered and relatively depressed areas that support a thick growth of mesquite and are judged to be underlain by shale. Caliche is characteristic of such shale areas, and gray to olive gray

calcareous shale may be seen in the caliche pit mentioned above, in the structural sink on U.S. highway 87. The areas of mesquite concentration make fuzzy patches on the aerial photographs, offering a ready clue to the occurrence of outlying patches of the Mississippian strata.

The limestone that occurs in the Barnett formation of this area includes both medium gray to yellowish or brownish gray granular limestone and medium to rather light olive gray or mouse gray sublithographic limestone. They resemble some of the limestones found in the lower part of the Marble Falls limestone, and the poor exposures at many places cause difficulty in drawing the Barnett-Marble Falls boundary. This boundary was placed largely on a faunal basis, fusiform fusulines resembling *Fusiella* and locally a large bellerophont occurring to the base of the Marble Falls limestone, whereas the limestones of the Barnett formation contain species of *Aviculopecten, Bembexia,* rarely *Goniatites,* a small *Linoproductus,* a small *Pustula,* and a large *Orbiculoidea* such as were seen in known Barnett strata of the Bear Spring and Cherokee areas. On Plate 4 the patternless patches immediately northwest of TF–406 and just north of culvert 10 that are surrounded by the symbol for the Barnett formation are now known on faunal evidence to represent limestones of the Barnett formation. Local revision of the Barnett-Marble Falls boundary in other parts of the area may prove advisable when fossils are collected more extensively.

The thickness of the Barnett formation varies from a feather edge to possibly as much as 50 or 60 feet, but it is difficult to estimate and the upper figure is little better than a guess.

Pennsylvanian

Pennsylvanian strata mapped in the Bald Ridge area are limited to the Marble Falls limestone. That formation consists of granular to locally sublithographic, gray to brownish gray and black limestone interbedded with marly limestones and calcareous shales. The limestones locally contain coal black chert or black and light gray speckled chert. Only its lower beds were mapped and no estimate of its thickness was made. It is overlapped by strata of Canyon age north and northwest of the area mapped, and it rests on the Barnett formation, the Chappel limestone, or the Gorman formation.

Fusiform fusulines resembling *Fusiella* extend to the base of the formation, and it is unlikely that beds of Morrow age are included in the Marble Falls limestone of the Bald Ridge area. Other fossils seen were large bellerophonts recalling *Bellerophon crassus* Meek and Worthen, small silicified high-spired gastropods, "*Spirifer*" cf. *S. rockymontanus* Marcou, *Marginifera* sp., and large *Linoproductus.*

DESCRIPTION OF THE McCULLOCH COUNTY SECTIONS

The Highway 87 section, along the Brady-Mason road (U.S. 87) between San Saba River and a point 4.6 miles by speedometer northwest, includes the San Saba limestone member of the Wilberns formation and all units of the Ellenburger group present in the Bald Ridge area. Poor exposures, gentle dips, and gentle topography contrive to make measurement of this section difficult and unreliable; but it is of such importance to show the character of the Ellenburger group in the northwestern part of the Llano uplift that an approximation was attempted.

The Camp San Saba section, outside the Bald Ridge map area, completes a composite section of the Ellenburger group and the Wilberns formation for the northwestern part of the Llano region.

Because of the unusual development of the lower part of the Gorman formation and the relationships at the Tanyard-Gorman boundary, a third section was located on the south slope of Bald Ridge, below the windmill known as High Lonesome, where the best exposures of this part of the Ellenburger sequence were found.

Reconnaissance studies in other parts of McCulloch County indicate that the sequence of units involved in the Ellenburger problem is as well displayed in the Bald Ridge area as anywhere else in the northwestern part of the Llano region, and the area is accessible and structurally

simple. The sequence, in the Bald Ridge area, of stratigraphic units between the base of the Wilberns formation and the Carboniferous strata is essentially as follows:

Stratigraphic unit	*Thickness in feet*
Mississippian (variable thicknesses of the Barnett formation and Chappel limestone)	
Lower Ordovician—Ellenburger group (830 feet)	
Gorman formation (295 feet)	
Calcitic facies	295– 90
Dolomitic facies	0–205
Tanyard formation (535 feet)	
Staendebach member (280 feet)	
Calcitic facies	0– 23
Dolomitic facies	280–257
Threadgill member (225 feet)	
Calcitic facies	255
Upper Cambrian (539 feet measured)	
Wilberns formation (539 feet)	
San Saba limestone member	200
Point Peak shale member	190
Morgan Creek limestone member	125
Welge sandstone member	24
Approximate total thickness of Ellenburger group and Wilberns formation	1370

For measurements of the Camp San Saba section above the Welge sandstone the authors are indebted to Dr. Josiah Bridge. In the same section the Welge sandstone member was measured and the Morgan Creek limestone member was remeasured by Barnes and Cloud in January 1946. The Highway 87 section was marked and described, and the Bald Ridge section was measured, painted at 5-foot intervals, and described by Cloud in April 1945.

The lower part of the Bald Ridge section is on the T. Brook ranch, the middle part on the Fred Otte ranch, and the upper part on the May Brook Kothman ranch. The Highway 87 section traverses a number of properties as shown on the geologic map of the area. The Camp San Saba section is mostly on the T. Brook ranch.

The location of the Bald Ridge section and its offsets is shown on the geologic map of the Bald Ridge area (Pl. 4) by lines of inverted V's and rows of dots. The Highway 87 section follows the Brady-Mason road and does not require a special symbol. The location of the Camp San Saba section is described thereunder.

Highway 87 Section

The Highway 87 section, as described below, includes approximately 830 feet of the Gorman and Tanyard formations and 230 feet of the Wilberns formation. The Wilberns strata described constitute the total thickness (200 feet) of the San Saba limestone member in its type section, as well as 30 feet of stromatolitic limestone here included in the Point Peak shale member. It is roughly estimated that an additional 50 feet of the biohermal limestone intervenes between the base of the described section and the characteristic shales of the Point Peak shale member.

Thicknesses given for this section were not measured directly because it would be impossible to do so with any semblance of accuracy. After the area was mapped and the route of section traversed to obtain and balance all available data on the attitudes of the beds, the section was described by intervals whose limits were located on the aerial photographs and paced to recognizable points such as highway culverts. A profile was then plotted at vertical and horizontal scales of 1 inch to 200 feet from data derived from an instrumental traverse furnished by the Texas State Highway Department. On this profile were superimposed the contacts of the various intervals described, their boundaries being projected at the angle of dip determined from a balance of all apparent attitudes obtained. Thicknesses of the intervals were scaled directly from the constructed profile and applied to the described section.

Because the Highway 87 section is not marked at regular intervals it is difficult to sample. In order to minimize this difficulty the stratigraphic position is given for the floor of each of the 10 culverts between San Saba River and the top of the section, as well as for a few other recognizable points. Yellow numbers were painted on these culverts, beginning with the first one north of the river. and their positions on the geologic map of the Bald Ridge area are shown by the symbols C1, C2, etc. The contacts of the various strati-

graphic units, as well as the principal Gorman zone of *Archaeoscyphia*, were marked with yellow paint spots on fence posts or rocks.

The top of this section is at an altitude of 1778 feet on U.S. highway 87, approximately 4.6 miles by speedometer northwest of San Saba River and just north of culvert 10. Stratigraphically it is at the boundary between the Gorman formation and the overlying Mississippian strata.

The base of the section is at an altitude of 1570 feet at the north end of the highway bridge over San Saba River. It is about 30 feet stratigraphically below the base of the San Saba limestone member of the Wilberns formation.

Description of the Highway 87 section is based largely on observations made on the west side of the road and in the adjacent pastures. Neither the description nor the measurements approximate the degree of detail or accuracy to be expected in the descriptions of the other sections in this report.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Ellenburger group: 830 feet thick			
Gorman formation: 295 feet thick			
Calcitic facies: 90 feet thick			
1. Interbededd limestone and dolomite; the sequence from bottom to top being essentially 15 feet of dolomite, 5 feet of limestone, 3 feet of dolomite, and 17 feet of limestone but obscured by poor exposures, aberrant dips, and an incipient structural sink centered on culvert 8 (altitude 1778 feet at the top of section)—the dolomite is predominantly very fine grained to microgranular, in part grading to fine grained; mostly light gray or brownish gray, grading in part to brown or nutria. The limestone is sublithographic; pearl gray toward ash gray, in part with irregular greenish argillaceous films. Beds poorly exposed and being generally indeterminate, but apparently ranging from less than 1 inch to about 24 inches thick. Weathers brownish gray to gray where dolomite and medium light bluish gray where limestone. The interval is in large part covered, except for some very conspicuous ledges, and the character of the underlying beds is revealed principally by abundant rubble at the surface. Minor chert occurs intermittently throughout interval 1, and may be seen in place as conspicuous rings around stromatolite heads at the base of the calcitic upper portion of the interval. It is semichalcedonic to chalcedonic or subporcelaneous, in part highly oölitic to crypto-oölitic, bluish to brownish gray to white. Locally float blocks of fine grained quartz druse arranged in conspicuously undulating bands suggest archaeosolon-like stromatolites. Small, well-rounded, frosted sand grains, poorly sorted within their small size-limits, are scattered to abundant in some of the finer grained dolomite beds. "*Euconia*" was noted but not collected in limestone near the middle of interval 1 and *Rhombella* was noted but not collected in limestone on the trace of the top of the interval about 1300 feet northeast of the line of section on the old Brady-Mason road. Culvert 8 (altitude 1802 feet) is approximately 5 feet, culvert 9 (altitude 1783 feet) about 10 feet, and culvert 10 (altitude 1770 feet) about 30 feet above the base of interval 1.	40	40	1020–1060
Mississippian strata occupy a structural sink between intervals 1 and 2 on the highway. Culvert 7 is about on the contact between the Barnett formation and the Chappel limestone at the south side of this collapse feature.			
2. Mostly limestone, with occasional thin interbeds of dolomite above the principal *Archaeoscyphia* bed—the limestone is sublithographic, in part a fine pellet limestone; woodash gray to pearl gray, in minor part grading to light brownish gray and light grayish yellow, and in part with irregular greenish to yellowish argillaceous films. The dolomite, where it occurs, is fine	50	90	970–1020

Description	Thickness in feet: Interval	Cumulative	Feet above base
grained to very fine grained; yellowish brown to nutria. Beds from a fraction of an inch to 24 inches thick; discontinuous, but in part fairly well exposed. Weathers solution-pitted; medium to light bluish gray to woodash gray, with dolomite beds weathering yellowish to brownish gray. Minor chert occurs, being mostly subchalcedonic, but in part grading to porcelaneous or chalk textured in the weathered perimcters, and locally oölitic. The principal zone of *Archaeoscyphia* in the Gorman formation occurs about 5 feet above the base of interval 2, and a second *Archaeoscyphia* bed was seen about 20 feet above the base of the interval.			
Base of calcitic facies of Gorman formation at base of interval 2 (altitude approximately 1797 feet). Total thickness of facies 90 feet.			
Dolomitic facies: 205 feet thick			
3. Dolomite, in part grading laterally to limestone from about 20 to 45 feet above the base—the dolomite is predominantly fine grained, locally grading to medium grained, in part vuggy; but from about 15 to 20 feet below the top of the interval it is microgranular to very fine grained. It is light gray, in part grading to brownish gray and grayish brown. The limestone is sublithographic, in part a fine pellet limestone; grading to fine or medium grained where dolomitic. It is pearl gray to woodash gray, with irregular greenish and yellowish argillaceous films, and in part with pink blotches and specks where dolomitic. For the most part very poorly exposed, weathering to a covered interval displaying rough to smooth, in part pitted cobbles of dolomite in the float and occasional ledges. The minor occurrences of limestone weather medium to light bluish gray to woodash gray, in large part reticulate. Chert occurs occasionally in the interval, being abundant only near the base. It is porcelaneous to chalcedonic, locally with scattered small dolomolds, in minor part with fine drusy coatings, and china white to bluish gray to dull gray. Interstitial chert is abundant in some of the dolomite. *"Euconia"* was noted in the chert about 10 feet above the base of the interval and *Lecanospira* and *"Euconia"* were collected from the chert at about the middle of the interval (TF–277). Culvert 6 (altitude 1790 feet) is approximately 65 feet above the base and 25 feet below the top of interval 3.	90	180	880– 970
4. Dolomite—microgranular, woodash gray to white, bedding indeterminate. Weathers to a covered interval displaying smooth, woodash gray to white cobbles. Minor chert is present; being subchalcedonic, in part micro-oölitic, in part quartzose, bluish gray to white, and weathering shiny white.	5	185	875– 880
5. Dolomite—very fine grained at the base, grading to fine or medium grained above; light gray with local yellowish tinges; bedding indeterminate. Weathers to a mostly covered interval strewn with smooth to rough, light gray to light yellowish gray cobbles. Oölitic, bluish gray to white, white-weathering chert occurs locally. Interstitial chert is very abundant in some of the coarser grained blocks.	30	215	845– 875
6. Dolomite; in part grading to limestone at the top and base of the interval on the west side of the road, and from about 20 to 35 feet above the base on the east side of the road—the dolomite is fine to medium grained, in part vuggy; light gray. The limestone is sublithographic; in part a fine pellet limestone; pearl gray to woodash gray, in part with greenish to yellowish irregular argillaceous films and locally with yellow to pink splotches of dolomite. Bedding indeterminate, exposed ledges uncommon. Weathers to a largely covered surface strewn with rough, largely	80	295	765– 845

Description	Thickness in feet: Interval	Cumulative	Feet above base
pitted, medium to light gray to yellowish gray blocks of dolomite, and with occasional inconspicuous ledges. The limestone weathers medium bluish gray and is largely reticulated with dolomite. Chert is common and locally very abundant, both as loose pieces and in the dolomite blocks; and one large mass was seen in place in a ledge near the base of the interval. It is chalcedonic to subgranular, in large part crypto-oölitic to micro-oölitic and oölitic, locally with scattered dolomolds or included dolomite rhombs, bluish gray to white with local brownish bands and tinges, and weathers shiny white. Interstitial chert is also locally abundant. Sand grains were found by Barnes in dolomite about 11 feet below the top of the interval on the east side of the road. A few grains of sand were also seen in float of oölitic chert near the base of the interval. An east-west fence abuts both sides of the highway about 8 feet stratigraphically above the base of interval 6. It is about 773 feet above the base of the section, at an elevation of 1729 feet.			
Base of dolomitic facies of Gorman formation at base of interval 6 (altitude 1726 feet). Total thickness of facies 205 feet, and of formation 295 feet.			
Tanyard formation: 535 feet thick *Staendebach member: 280 feet thick* *Dolomitic facies: 280 feet thick*			
7. Dolomite—predominantly fine grained, locally grading to medium grained, and in part very fine grained in the lower beds; in large part vuggy in the upper half and less commonly below. Light gray to light brownish and yellowish gray, grading to grayish brown and woodash gray; bedding quite indeterminate. Weathers to rubble-strewn slopes with very few recognizable ledges, the character of the interval being determinable from abundant, blocky rubble that weathers rough, pitted, and medium gray to light yellowish gray. The base of interval 7 is marked by a prominent zone of conspicuously drusy chert that weathers to closely spaced large blocks. These blocks represent a layer several feet thick that falls about 6 feet vertically below the top of a 1748-foot hill on its south side, and are well exposed on the east side of the road. This chert is mostly conspicuously and finely dolomoldic and drusy, yellowish white to bluish gray and light yellowish brown. Locally, however, large blocks, patches, and irregular layers of it are subchalcedonic to chalcedonic, streaked and blotched in tones of bluish gray to white, and weather to shiny white or bluish white patches in the larger chert masses. Chert is generally abundant as float throughout this interval; being largely similar to that described except that it is generally more dolomoldic and less drusy, with the different types varying in predominance and also containing much oölitic to crypto-oölitic and locally oölitic laminar chert. Interstitial chert occurs in the dolomite but is seemingly not common. A few fossils were seen in chert along the trace of the lower part of interval 7 near the highway, *Helicotoma* cf. *H. uniangulata* (Hall) and *Ozarkina* being the only ones identified and recorded. *Ophileta* and chertified *Rhabdoporella* were found by Barnes about 10 feet below the top of the interval on the west side of the highway. Although no fossils were collected along the line of section, several collections of fossils and notations on their occurrence indicate that *Ozarkina, Sinuopea, Chepultapecia, Helicotoma* cf. *H. uniangulata* (Hall), *Paraplethopeltis,* and cephalopods occur at the top of interval 7 along its trace.	190	485	575– 765

Description	Thickness in feet: Interval	Cumulative	Feet above base
The floor of culvert 4 (altitude 1737 feet) is approximately 50 feet and that of culvert 5 (altitude 1684 feet) is approximately 90 feet above the base of interval 7.			
8. Dolomite, with very minor inclusions of limestone near the base—very fine grained to fine grained, in part vuggy; light to medium gray, in part grading to yellowish, brownish and pinkish gray. Beds 1 to 14 inches thick. Weathers to largely covered slopes strewn with blocks of dolomite that weather fairly smooth to pitted and medium gray to iron gray, grading to light yellowish gray near the base. Occasional to fairly abundant plates and thinly extensive lenses of chert occur at 40 feet above and again at 65 feet above the base of interval 8. It is semichalcedonic, in part micro-oölitic to crypto-oölitic, locally porcelaneous to chalk textured, light tan to shiny white. Similar chert, seemingly more chalcedonic and more commonly weathering white, was noted along the trace of the base of interval 8 and even into the limestone of the upper part of interval 9 about 0.5 mile northeast and again 0.5 mile southwest of the line of section. Minor quartz druse occurs on some beds. The floor of culvert 3 (altitude 1708 feet) is roughly 5 feet above the base of interval 8.	90	575	485– 575
Base of Staendebach member of Tanyard formation at the base of interval 8 (altitude 1708 feet). Total thickness of member, which is entirely in the dolomitic facies in the line of section, 280 feet thick.			
Threadgill member: 255 feet thick			
Calcitic facies: 255 feet thick			
9. Limestone; with rare thin interbeds of dolomite probably not totaling over 3 feet thick, and in very minor part with an irregular internal meshwork of dolomite — predominantly sublithographic, in conspicuous part a fine pellet limestone and locally with coarser pellet layers that have a granular appearance; light brownish gray to pearl gray and old ivory, grading to pink or grayish yellow, in part with irregular yellowish patches where dolomitic, and locally with pale dusty green to yellowish irregular argillaceous films. The minor dolomite beds are very fine grained, yellowish gray to grayish and pinkish yellow. Interval 9 begins at the base of a conspicuous 27-inch bed, with the overlying beds ranging from 1 to 27 inches thick and with beds over a foot thick forming a conspicuous part of the total thickness. Weathers to fairly conspicuous, smooth to solution pitted, medium to light bluish gray ledges that locally grade to woodash gray and are separated by intervals of poor exposure. Very fine grained quartz druse occurs as rosettes and occasional incrustations that are scattered to abundant on a number of beds. Thin plates and extensive lenslike inclusions of tan- to russet-weathering "pebble" chert composed of silicified fragments of fossils and pelletlike debris occur about 9 feet below the top of interval 9, with a second occurrence about 16 feet lower. *Ophileta*, a trilobite with affinities to *Leiostegium*, and other fossils were collected from this "pebble" chert 9 feet below the top of the interval (TF–411). Besides these, scattered to abundant calcitic and dolomitic sections and impressions of *Lytospira* cf. *L. gyrocera* (Roemer), *Ophileta* cf. *O. polygyrata* (Roemer), *Gasconadia*, and less commonly cephalopods were seen on occasional bedding surfaces. The center of an intersection of the present highway with the former highway (altitude 1689 feet) is about 10 feet above the base of interval 9.	100	675	385– 485
10. Limestone—predominantly sublithographic, in part a coarse pellet limestone, grading to a granule conglomerate with a granular appearance similar to some of the beds in interval 11. Pearl gray	155	830	230– 385

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*

and old ivory to light brownish gray; less commonly grading to light greenish gray, grayish brown, and brownish yellow, and in part with pale dusty green to yellowish irregular argillaceous films. Some of the beds are mottled with an irregular, yellowish, dolomitic meshwork, especially near the base; but the dolomitized trails and fossils so common in equivalent beds in the Threadgill Creek and Llano River sections are much less conspicuous in the Highway 87 section. Beds from a fraction of an inch to 12 inches thick, in general averaging less than 8 inches thick. Weathers to generally discontinuous, poorly exposed, medium to light bluish gray to woodash gray ledges that are locally mottled in tones of yellow to buff where dolomitic. The lower 25 feet especially shows mottled beds, with woodash gray to white patches of sublithographic limestone in darker gray to buff-weathering limestone or slightly dolomitic limestone which is in part granular. The occurrence in the limestone ledges of the sublithographic patches that weather woodash gray to white and similarly weathering plates of limestone in the float, characterizes the basal limestones of the Threadgill formation in this area, as in other areas where they rest upon the San Saba limestone member of the Wilberns formation.

No glauconite was seen in any of the beds in interval 10 in the line of section, but corroded globular glauconite was seen at a few places in the area in beds probably equivalent to the lower part of the interval.

Occasional rosettes of fine-grained quartz druse were seen on some of the beds, and chert was noted in one bed about 10 feet below the top of the interval. The chert occurs as small, irregular, nodulelike inclusions; being semiporcelaneous, grading to chalk textured in the weathered perimeter, light brownish gray to grayish brown or dirty white, and weathering tan. In general, elements that would be insoluble in dilute hydrochloric acid are relatively rare in interval 10. Dolomite rhombs would doubtless be common in acetic acid residues.

Silicified *Finkelnburgia* cf. *F. bellatula** Ulrich and Cooper was collected from the basal part of interval 10 about 490 feet southwest from the highway (TF–409). Inasmuch as this locality is in a structural sink its actual position in the section is difficult to judge. Silicified specimens of the same species of *Finkelnburgia* were obtained in the line of section about 95 feet above the base of interval 10, on the west side of the highway and about 300 feet north-northwest of culvert 2 (TF–410). Silicified *Finkelnburgia* cf. *F. buttsi** Ulrich and Cooper was obtained from limestone 30 to 50 feet above the Tanyard-Wilberns boundary about 0.5 mile west-southwest of U.S. Highway 87 and beyond the limits of the area mapped (TF–229). *Gasconadia* and *Ophileta* were noted in place as calcitic impressions in the limestone about 5 feet above the base of the interval but were not collected. Occasional bedding surfaces throughout the interval display calcitic or dolomitized sections of *Lytospira* cf. *L. gyrocera* (Roemer), *Gasconadia*, *Ophileta* cf. *O. polygyrata* (Roemer), *Sinuopea*, and occasionally cephalopods, but such occurrences seem to be less common than they were in the Llano River section.

The floor of culvert 2 (altitude 1638 feet) is about 60 feet above the base of interval 10.

Base of Threadgill member (entirely calcitic) of Tanyard formation, and Cambrian-Ordovician boundary, at base of interval 10 (altitude 1647 feet). Thickness of member and calcitic facies 255 feet, of formation 535 feet.

Upper Cambrian: 230 feet described

Wilberns formation: 230 feet described

San Saba limestone member (type section): 200 feet thick

*Cloud (in press) refers these specimens to his new species *Finkelnburgia helleri*.

Description	Thickness in feet: Interval	Cumulative	Feet above base
11. Limestone, in part with yellow- to buff-weathering dolomitic patches—except for the upper and lower few feet, which contain sublithographic, medium bluish and yellowish gray to brownish gray patches, the limestone in this interval is conspicuously granular. It varies from microgranular to coarse grained and in general is crowded with fine to coarse pelletlike bodies. Its color is mostly brownish to greenish gray or grayish brown, with local patches and specks of yellow buff or cinnamon where dolomitic, and locally with scattered to abundant green specks of globular glauconite. Beds from a fraction of an inch to 6 inches thick. Weathers to thin, in part solution-pitted, in general poorly exposed ledges that are brownish gray to greenish and bluish gray or grayish brown; in part with yellow to buff tinges, mottles, and blotches; and locally with very light bluish gray to woodash gray mottles and patches. The upper and lower few feet especially are marked by thin beds that weather mottled in yellow to buff and light bluish gray to woodash gray. Globular glauconite occurs occasionally throughout interval 11, being quite abundant in some beds. Acetic acid residues would probably yield abundant dolomite rhombs as well as glauconite. Several of the beds are crowded with fragments of trilobites and gastropods, with *Kingstonia*-like trilobites occurring in medium to coarsely granular limestone near the top of the interval. No fossils were collected, however. The attitudes and sequence of the beds in the upper part of the interval 11 are obscured by collapse structure, and in general the Cambrian-Ordovician contact in the vicinity of the highway is not well marked. The floor of culvert 1 (altitude 1605 feet) is about 15 feet above the base of interval 11.	140	970	90– 230
12. Limestone—conspicuously granular in appearance, varying from very fine to coarse grained; in general crowded with fine to fairly coarse pelletlike bodies, and with several beds crowded with fragments of trilobites and other fossils, especially in the lower few feet. Rare interbeds of limestone in interval 12 are similar to that in interval 13. Grayish brown to brownish gray, grading to yellowish brown and yellowish gray; in part with scattered to abundant green specks of glauconite, and with occasional beds that are quite green. Beds 1 to 16 inches thick, mostly less than 8 inches thick. Weathers gray to brownish gray, in part with yellowish tinges. Glauconite was the only "insoluble" noted, except that acetic acid residues of many beds would probably yield abundant dolomite grains. The glauconite is generally not abundant, but it is common enough to be found without difficulty, and some thin beds are quite crowded with glauconite globules. Saukiinid trilobites, determined by Dr. Josiah Bridge as *Saukiella* sp., were collected in an outlying pocket of the basal beds of interval 12 in December, 1940, during a field trip led by Bridge and Barnes. The lower few feet of the interval is highly fossiliferous, being crowded with trilobites.	60	1030	30– 90
Base of San Saba limestone member of Wilberns formation at base of interval 12. Thickness of member 200 feet.			
Point Peak shale member: 30 feet described			
13. Limestone, with occasional zones of dolomite; comprising the upper beds of a zone of stromatolitic bioherms—the limestone is sublithographic to microgranular, in part a fine pellet limestone; greenish to brownish gray to woodash gray or light yellow, in part with yellowish argillaceous films. It weathers medium bluish gray to woodash gray. The dolomite is very fine-grained to microgranular and brownish to yellowish gray. It weathers medium gray to brownish gray. Beds generally fairly thick; those measured	30	1060	0– 30

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*

being from less than 1 inch to 14 inches thick, but with some beds probably a good deal thicker than this.

Most beds in interval 13 weather to large, subcircular, hummocky, reticulated reef masses. *Stenopilus* was collected near the base of the interval in December, 1940, during a field trip led by Bridge and Barnes.

Interval 13 and the approximately 50 feet of section below it to the base of the lowest prominent stromatolitic limestones are included in the Point Peak shale member because the normal association of the bioherms at this position, judged from the Llano region as a whole, appears to be with the Point Peak shale member, and because shale appears to occur between the bioherms in the Bald Ridge area.

Beds below the base of interval 13 are not formally described because they are almost wholly covered by alluvium in the vicinity of the highway. The stromatolitic nature of some of these beds is well displayed in a small park on the south side of San Saba River. Projection of beds both eastward and westward along the north bank of the river leads to the supposition that additional biohermal limestones there intervene between those of the park and the base of interval 13 in the part of the section above noted as being covered, and the shale that locally intervenes between the bioherms may be seen at the mouth of Hudson Creek or in a road material pit 3 miles south-southwest from the highway bridge over San Saba River. The massive biohermal limestones at the base of the zone of bioherms outcrop prominently in the river bed for a distance of about 370 feet downstream from the highway bridge. Because the bottom of the river channel below the highway bridge (altitude 1531 feet) is 39 feet below the base of interval 13 (altitude 1570 feet), the strata in interval 13 are almost flat, and the basal biohermal bed is about 10 feet thick, 50 feet is considered a fair estimate for the thickness of the stromatolitic Point Peak strata below interval 13.

The contact of the San Saba limestone and the Point Peak shale members of the Wilberns formation is wrongly shown at the base of the zone of stromatolitic bioherms on the map of the Bald Ridge area (Pl. 4). Although it was stated by Dake and Bridge (1932, p. 727) that "the reef material is embedded in shaly layers," and the local presence of shale between the biohermal limestone was observed by the authors, it was not considered appropriate, at the time the map was made, to include these limestones in a member characterized by the dominance of shale. After the map was in the hands of the engraver additional work by the authors in other areas showed that the normal association of the bioherms at this position in the Llano region as a whole is with the Point Peak shale member, and that consistency is best served by a similar assignment of the biohermal limestones in the Bald Ridge area. The biohermal limestone extends higher in the section along U.S. highway 87 than it does a short distance to the west, where a prominent shale band at the top of the biohermal zone can be traced for several miles southwest from the western limit of the Bald Ridge map area.

Base of Highway 87 section at base of interval 13; altitude 1570 feet. At extreme north end of concrete span over San Saba River, on west side of road. Total approximate thickness of section 1060 feet, of which 230 feet belongs to the Wilberns formation of Upper Cambrian age and 830 feet to the Tanyard and Gorman formations of Lower Ordovician age.

Camp San Saba Section

The Camp San Saba section supplements the Highway 87 section by furnishing information on the Wilberns formation below the upper biohermal limestones of the Point Peak shale member. In this section the beds above the Welge sandstone member of the Wilberns formation were measured along the left (northeast) bank of San Saba River in the vicinity of Flatrock Crossing, at the village of Camp San Saba and a little over 1 mile down San Saba River from the bridge at U.S. highway 87. The Welge sandstone was measured in a bluff immediately east of the juncture of Katemcy Creek and San Saba River, not quite one-half mile down San Saba River from Flatrock Crossing. The Morgan Creek limestone member of the Wilberns is very well exposed in the vicinity of Flatrock Crossing and a bed-by-bed measurement of it with a steel tape by Barnes checked closely with an earlier measurement by Dr. Bridge.

The Camp San Saba section is structurally continuous with the Highway 87 section and the units studied are uncomplicated and well exposed. They are, from the base of the Wilberns formation upward, as follows: 24 feet of the Welge sandstone member, 125 feet of the Morgan Creek limestone member, and 110 feet of the Point Peak shale member to the zone of stromatolitic bioherms. *Eoorthis texana* Walcott and many other fossils are abundant about 70 feet above the base and *Plectotrophia bridgei* Ulrich and Cooper is locally abundant near the top of the section. The general characters of the units measured are shown graphically on Plate 14.

Bald Ridge Section

The Bald Ridge section, as described below, includes 187 feet of the Gorman formation and 23 feet of the Tanyard formation. It is described for the purpose of showing how different the development of this part of the Ellenburger sequence is from that displayed in the Highway 87 section, 1.3 to 1.5 miles southwest of here. In contrast to the principally dolomitic Gorman strata below *Archaeoscyphia* in the Highway 87 section, the Bald Ridge section is largely calcitic. Moreover, limestones occur on both sides of the Tanyard-Gorman boundary in the Bald Ridge section, whereas the same boundary is within a sequence of dolomites in the Highway 87 section. In both sections the criterion of grain size of the dolomites, widely applied in the placement of the Tanyard-Gorman boundary in other parts of the Llano region, was useless. However, as in other parts of the region, sand does not occur in the Tanyard formation. In the Bald Ridge area the lowest occurrence of sand in the Ellenburger approximately coincides with the Tanyard-Gorman faunal boundary and a zone of blocky white-weathering chert, the three together constituting the basis on which the boundary was here mapped.

The top of the Bald Ridge section is about 300 feet north of and a little below the base of High Lonesome, a windmill at an elevation of approximately 1840 feet at the northeast end and highest part of Bald Ridge (Pl. 4). Stratigraphically it is about 187 feet above the base of the Gorman formation and presumably not far below the principal zone of *Archaeoscyphia* in the Gorman which occurs at approximately 210 feet above the base of the Gorman formation in the Highway 87 section. The section terminates at the top of Bald Ridge, with the nearest exposures of Carboniferous rocks in a collapsed syncline 0.5 mile northwest, but at a considerably lower altitude and probably not over 50 feet above the highest beds described.

The base of the Bald Ridge section is at an altitude of about 1745 feet in a draw that is the principal wet-weather tributary to Hudson Creek, at the south foot of Bald Ridge, and about 0.55 mile airline south and slightly east from the top of the section. The section follows the draw for about 2000 to 2100 feet and then ascends an open hillslope to High Lonesome.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Ellenburger group: 210 feet described			
Gorman formation: 187 feet described			
1. Limestone; with occasional interbeds of dolomite, especially in the lower 5 feet and from 206 to 208 feet (altitude approximately 1840 feet at top of section)—the limestone is mostly sublithographic, in part a fine pellet limestone, and in part grading to fine grained where dolomitic; pearl gray to light brownish and yellowish gray. The dolomite is fine grained and light gray to light pinkish gray. Beds from a fraction of an inch to possibly as much as 12 inches thick. Weathers to irregular, solution-pitted ledges or largely covered intervals strewn with thin slabs; medium to light bluish gray to woodash gray. The dolomite weathers medium to light gray. Chert occurs at 196.5 feet as chalcedonic to subchalcedonic, dark gray to bluish gray to white, shiny, white-weathering blocks in the float. At 197 feet is a layer of semichalcedonic, oölitic chert tending to be laminar and ranging up to several inches thick. From 198.5 to 200 feet are lenses and irregular inclusions of semichalcedonic to chalcedonic chert that is oölitic to crypto-oölitic, bluish gray to white, and weathers shiny white. At 205 to 206.5 feet is fairly abundant float of chert that is semichalcedonic to chalcedonic, in part crypto-oölitic, in part with chalk-textured patches, dark gray to brownish or bluish gray to white, with the colors irregularly streaked. At 207 feet are many small nodules and irregular inclusions of chert that is subchalcedonic to chalcedonic, in part grading to chalk textured, and largely crypto-oölitic and pseudospicular.	15	15	195 – 210
B bed at 195 feet, a 6-inch bed of dolomite. Offset 100 feet east-northeast if going up in the section and west-southwest if going down.			
2. Limestone, capped by 6-inch bed of dolomite—sublithographic, in part a fine pellet limestone; pearl gray to woodash gray, in minor part grading to a light greenish gray, and in part with irregular dusty green and yellowish argillaceous films; beds from a fraction of an inch to 10 inches thick. Weathers to irregular, solution-pitted, light to medium bluish gray to woodash gray ledges. The 6-inch bed of dolomite at the top is fine grained; woodash gray to white, and weathers rough and medium gray. Chert is abundant as float at 178 feet, apparently being derived from this part of the section. It is chalcedonic to subchalcedonic, with occasional quartzose patches, bluish to brownish gray to white, and weathers shiny white. Prominent, large, extensive lenses of white-weathering chert are abundant in place from 182 to 185 feet; in part bowing up through the beds as large concentric stromatolitic masses up to 6 feet or more across. This chert is chalcedonic to semichalcedonic, in part highly oölitic, locally with quartzose patches and in minor part a granule conglomerate; it is dark gray to bluish, brownish, or white and weathers shiny white to dull white. This may be the source of much of the chert seen in interval 3. Sand occurs as scattered small grains in limestone at 187 feet.	17.5	32.5	177.5– 195
A bed at 177.5 feet, a prominent ledge of limestone. Offset 250 feet east-northeast if going up in the section and west-southwest if going down.			

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
3. Limestone; locally with irregular dolomitic inclusions, but otherwise apparently quite pure—sublithographic, in part a fine pellet limestone, locally grading to fine grained where dolomitic; pearl gray to woodash gray; beds from a fraction of an inch to 12 inches thick. Weathers to a series of terraces, with heavier ledges forming steps which are separated by benches strewn with thin slabs of limestone and pebbly to blocky float of white-weathering chert. The weathered color of the limestone is medium to light bluish gray to woodash gray or almost white. The pebbly to blocky chert float on the benches was especially noted at 146 to 147, 151 to 153, 156 to 157, 161 to 163, 166 to 168, 170 to 171, and 174 to 176 feet. It is generally similar at all these places; being subchalcedonic to chalcedonic, in part micro-oölitic, locally with quartzose patches, bluish gray to white, in part streaked in varying tones of the named colors and ivory yellow, and weathering white and shiny. It was not determined whether this chert was weathering out at any or all of the places mentioned or how much has floated down from above, but it seems likely that some of it was locally derived. Conspicuously oölitic, gray to brownish gray chert, in part tending to be laminar, occurs in place as thin layers that in part run together to form thicker layers at 141 to 142 feet. Minor inclusions of chalcedonic, white-weathering chert occurs at 148 feet. Just below 174.5 feet the limestone contains scattered angular grain to granule size inclusions of quartz and an occasional small sand grain. Sand was noted only as occasional grains in the limestone at 174.5 feet. *Lecanospira* was seen on the trace of the limestone at about 140 feet, about 60 feet northeast of the line of section in the axis of the draw.	40.5	73	137 – 177.5
4. Dolomite and limestone; interbedded, laterally intergrading, and in part probably mixed by collapse—the dolomite is fine to medium grained and light gray; the limestone is sublithographic, in part a pellet limestone, and pearl gray with yellowish to pale salmon tinges where dolomitic. Bedding indeterminate. Weathers medium gray to yellowish gray where dolomite, medium to light bluish gray where limestone. Chert occurs at about 132.5 feet as shattered nodules and blocks of float that are partly massive and partly cavernous. It is semichalcedonic to chalcedonic, in part conspicuously oölitic to crypto-oölitic and micro-oölitic, bluish gray to white, and weathers mostly shiny white. Locally it contains abundantly scattered, small, subround to round sand grains and included flat pebbles of limestone that weather out to give a cavernous appearance. Sand grains occur in the chert at 132.5 feet, as noted above.	14	87	123 – 137
5. Mostly covered except for the basal foot; dolomite was seen in place and limestone in the float—the dolomite is fine grained and light gray. The limestone float is sublithographic, in large part pelletted, pearl gray. A nodule of chert seen in the float at 115 feet was subchalcedonic to chalcedonic, bluish gray, brittle, and weathered yellowish white. At 115.5 to 116 feet is float of porcelaneous to chalk-textured, white, conspicuously and finely dolomoldic chert and coatings of fine grained quartz druse. Chert projects from the hillside at 121 feet indicating a	9	96	114 – 123

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
bed or an extensive lens about 5 inches thick near this point. It is subchalcedonic to chalcedonic, in minor part grading to porcelaneous, in part conspicuously oölitic to crypto-oölitic, bluish to brownish gray to white, weathers shiny white, and has scattered small, well rounded sand grains throughout. Interstitial chert is abundant in the dolomite. Sand occurs as small, well-rounded grains abundantly scattered in chert at 120 and 121 feet.			
6. Covered interval; with float of chert, limestone, and dolomite—the limestone and dolomite are similar to that described in interval 9. The chert is subchalcedonic, in minor part crypto-oölitic, bluish gray to white, and weathers shiny white to bluish white or dull tan. It may be from above.	4	100	110 – 114
7. Dolomite—fine grained to very fine grained, light gray to light brownish gray, bedding indeterminate. Weathers to a largely covered interval strewn with smooth, medium gray cobbles. Interstitial chert is abundant. Fine grained quartz druse occurs as films and rosettes on the dolomite.	5	105	105 – 110
8. Dolomite—very fine grained to microgranular; light gray, in minor part grading to beige; bedding indeterminate, exposures poor. Weathers to smooth plates and cobbles on the hillslope and in the draw.	5	110	100 – 105
9. Mostly limestone; in large part with an irregular internal meshwork of dolomite, in part grading laterally to dolomite, and with occasional interbeds of dolomite—the limestone is sublithographic, in large part a fine pellet limestone; pearl gray to woodash gray, in minor part grading to light yellowish gray. The dolomite is medium to fine grained, in part vuggy; light gray to light brownish and yellowish gray, in minor part with salmon pink tinges. Beds from a fraction of an inch to 14 inches thick, exposed only in the draw. Weathers medium to light bluish gray, reticulate where dolomitic limestone and medium gray where dolomite. Interstitial chert occurs in some of the dolomitic layers. Sand occurs as small, well rounded, frosted grains that are scattered to fairly abundant in a 1.5-inch limestone bed at 97.5 feet. Unrecognized gastropods were seen in the limestone at 92 feet. The limestone from 83 to 84 feet is stromatolitic, with dolomitization following a concentric pattern in circles 5 to 16 inches in diameter.	25	135	75 – 100
10. Dolomite—fine to medium grained, in large part vuggy; light gray, in part with pinkish tinges; beds from 1 to 16 inches thick. Weathers to medium to light gray ledges that are in large part pitted and rough. Interstitial chert occurs intermittently throughout and is abundant in some beds.	32	167	43 – 75
11. Limestone and dolomite, interbedded and laterally intergrading—the limestone is sublithographic to microgranular, in part a fine pellet limestone; pearl gray to woodash gray, in part with pinkish tinges. The dolomite is medium grained, in part vuggy; light gray, in part with brownish to yellowish tinges. Beds from a fraction of an inch to 8 inches thick, slabby and poorly exposed away from the draw. Weathers medium to light bluish gray, with woodash gray to white patches, in the calcitic parts and medium gray where dolomitic; rough and in part reticulate.	14.5	181.5	28.5– 43

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	Chert occurs from 29 to 30 feet as minor angular inclusions that are subchalcedonic, bluish gray to white, and white weathering. At 34 to 35 feet it occurs as an irregular meshwork in the limestone and dolomite; being subchalcedonic to chalcedonic, in part with chalk-textured patches, and bluish gray to bluish white. From 35.5 to 36.5 chert is abundant as rough, ropy excrescences that are semichalcedonic, crowded with indistinct pinpoint markings, bluish to brownish gray or bluish white, and tan weathering. At 41 feet chert occurs as irregular plates that are semichalcedonic to subchalcedonic, chalk textured, and locally porcelaneous; bluish white to chalk white, grading to bluish gray; and tan weathering. At 43 feet are prominent lenses of chert that are chalcedonic to subchalcedonic, in part quartzose, brittle, bluish gray to white and pale carnelian, and weather shiny white to tan. Sand grains are abundantly scattered in a 5-inch bed of conglomeratic pellet limestone at 30 feet. The individual grains are small, frosted, and well rounded to poorly rounded; and the conglomeratic fragments range from the size of granules to flat pebbles 2 inches across and 0.5 inch thick. "*Euconia*" was collected from 34 to 35 feet (TF–400). The limestone at 29.5 feet is stromatolitic, with dolomitization following a concentric pattern.			
12.	Limestone, dolomite, and chert; the limestone and dolomite apparently intergrading—the limestone is sublithographic, in part a fine pellet limestone, in part with scattered to abundant euhedral rhombs and irregular inclusions of dolomite, pearl gray to woodash gray. The dolomite is medium grained and light yellowish gray. Bedding thin but indeterminate. This basal zone of the Gorman formation characteristically weathers to a chert-strewn bench or terrace, the chert weathering to shiny, white or bluish white blocks apparently derived from fairly thick lenses varying in position within the interval. Chert in the line of section is abundant from 23 to 26 feet and from 28 to 28.5 feet. That at 23 to 26 feet is mostly highly oölitic or pelletted, in part quartzose, in minor part with scattered dolomolds, locally subchalcedonic to porcelaneous, and bluish to brownish gray to white. Close examination shows that this chert is in part truly oölitic and in part a chertified pellet limestone. The lower 18 inches is in part a granule conglomerate that contains subangular to subrounded inclusions of limestone and occasional sand grains. The chert from 28 to 28.5 feet is subchalcedonic to chalcedonic, in part with porcelaneous to chalk-textured patches, in part slightly quartzose, locally crypto-oölitic to oölitic, and bluish gray to white. Interstitial chert occurs in the dolomite. The chert described is similar to that which occurs widely at the base of the Gorman formation in the Bear Spring area, and which there locally contains *Rhombella*. However, no *Rhombella* was found at this locality or from this chert anywhere in the Bald Ridge area. Sand occurs in the chert of the lower 18 inches of interval 12 as scattered, small, well rounded grains that in part form nuclei for oöids. Such grains were especially common about 1 foot above the base of the interval.	5.5	187	23 – 28.5

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
"Euconia" and *Ophileta* were collected from the chert at 25 feet (TF–399). The limestone at 27 feet is stromatolitic, with dolomitization following a concentric pattern in circles from 6 to 13 inches in diameter.			
Base of Gorman formation at base of interval 12 (altitude about 1750 feet). Total thickness of formation described 187 feet.			
Tanyard formation: 23 feet described			
Staendebach member: 23 feet described			
Calcitic facies: 23 feet thick			
13. Limestone; for the most part with an irregular internal meshwork of dolomite and in part grading to dolomite—the limestone is sublithographic, in part a fine pellet limestone, in part grading to fine and medium grained where dolomitic; pearl gray to woodash gray, grading to light brownish gray. The dolomite is medium to fine grained and light yellowish to pinkish or brownish gray. Beds less than 1 inch to 18 inches thick. Weathers rough, reticulate, hummocky, medium bluish gray with darker brownish gray reticulations representing the internal dolomitic meshwork.	23	210	0 – 23
Interval 13 represents an approximate maximum thickness for the calcitic facies of the Staendebach member in the Bald Ridge area, and through a large part of the area this facies is entirely absent. At approximately 0.25 mile south of the line of section the limestone disappears, and 0.3 mile to the east-northeast it has disappeared or thinned drastically.			
Chert is abundant throughout the interval. A meshwork of subchalcedonic to semichalcedonic, medium to dark bluish gray chert is present from 0 to 1 and 4 to 7 feet, weathering to a ropy, tan fretwork on the surface of the beds. Oölitic chert that is in part laminar and weathers punky, cavernous and russet is abundant from 7 to 9 and 17 to 19 feet. Abundant chert between 13 and 17 feet is subporcelaneous to chalk textured, in part finely drusy, in part dolomoldic, chalk white, and weathers punky, cavernous, rough, blocky, and tan to russet. Thin plates and lenticles of semichalcedonic, slightly calcitic, gray to white, tan-weathering chert were seen at 7.5 feet.			
Fossils are common in chert in place at 6 feet. Those noted were *Schizopea*, *Helicotoma* cf. *H. uniangulata* (Hall), and *Ozarkina* cf. *O. complanata* Ulrich and Bridge. *Ozarkina complanata* Ulrich and Bridge, *Helicotoma* cf. *H. uniangulata* (Hall), and a brevicone cephalopod were collected from chert between 13 and 17 feet (TF–397). *Ozarkina*, *Helicotoma*, *Clarkoceras* (?) and a trilobite were obtained from granular to chalk-textured chert along the trace of the upper foot of this interval, 300 feet east of the line of section (TF–398). The limestone at 20 feet is stromatolitic, with dolomitization following a concentric pattern in circles up to 2 feet in diameter.			
Base of calcitic facies of Staendebach member of Tanyard formation and base of Bald Ridge section at base of interval 13; altitude roughly 1745 feet. At axis of a draw about 0.5 mile south and slightly east from the windmill known as High Lonesome, at the south foot of Bald Ridge. Total thickness of section 210 feet, of which 23 feet belongs to the Tanyard and 187 to the Gorman formation.			

BEAR SPRING AREA, MASON COUNTY

INTRODUCTORY STATEMENT

Lying in southwestern Mason County, 7 to 11 miles airline southwest to west-southwest of the town of Mason, the Bear Spring area displays a sequence of Ellenburger rocks that may be taken as representative of the southwestern part of the Llano region. About 15 square miles was mapped geologically between the latitudes of 30° 38′ to 30° 43′ north and longitudes of 99° 18′ to 99° 24′. Plate 5 shows the geology of the area at a scale of 1:10,000 and Plate 36 includes stereograms of parts of the area at the approximate scale of 1:20,000.

Control for the base map of the Bear Spring area was taken from an alidade and plane-table traverse by Barnes and L. E. Warren along the county road in the southeastern part of the area. The base was plotted and adjusted by L. E. Warren and Cloud from data recorded by the latter on aerial photographs of the U.S. Department of Agriculture.

The Bear Spring area includes ground on both sides of the Llano River, from White's Crossing to the mouth of Bluff Creek. It is most accessible from the southeast side, the distance by the county road from Mason to White's Crossing (Doell highway no. 1) being 10 miles. Ingress to the southwest side of the area may be had from the same county road by way of pasture roads on the Tom White ranch. From the north side, the area may be reached from the old Mason-Streeter road via the C. S. Vedder ranch and pasture roads to Bear Spring, Airheart Spring, and Gunstock Springs. The northwest portion of the area may be reached by going south from U.S. highway 187 at the west edge of Streeter on pasture roads through the Bob Hoffman ranch to the mouth of Bluff Creek.

Rocks mapped in the Bear Spring area include the undifferentiated Wilberns formation (Upper Cambrian), the Tanyard and Gorman formations of the Ellenburger group, two new Devonian formations (the Bear Spring and Zesch formations), and beds of Mississippian and Pennsylvanian age. The Honeycut formation is missing due to pre-Devonian truncation. The names of the Devonian formations do not appear on Plate 5 because the map had been sent to the engraver before evidence relating to the Zesch formation was finally worked out.

Structurally the Bear Spring area is bounded on the southeast by the Honey Creek fault and on the northwest by the Bluff Creek fault. The latter is of peculiar structural interest because of the fan-like "unraveling" or diffusion into minor zones of failure that it undergoes at either end of a short, clear-cut, profound rupture. Branch faulting is complex in the southeast corner and at the west side of the area, and several obscure faults near the middle of the area complicate the measurement of sections. Dips of strata are mostly very gentle and seldom exceed 7°, except in the vicinity of some faults, the flexed west side of the faulted Honey Creek syncline, and near collapse structures.

For the most part the larger vegetation is sparse in the parts of the Bear Spring area that are underlain by pre-Carboniferous rocks, and consists of scattered live oak, cedar, and mesquite, with local growth of deciduous oaks on the Cambrian sandstones. Low and spiny bushes such as the scrub-mimosa known as catclaw, black persimmon, agerita, blue-brush, bee-brush, and others are scattered over the area, along with many kinds of cactus and several of yucca. Parts of the area underlain by Carboniferous rocks are mostly more thickly wooded; the Mississippian strata commonly bear a thick and locally impenetrable chaparral of blue-brush and other low and spiny bushes, whereas the Pennsylvanian Marble Falls limestone supports cedars and the Smithwick shale is marked by scrub-elm, scrub-oak, black persimmon, agerita, blue-brush, and bee-brush.

The composite Llano River section displays the Ellenburger and related rocks of the Bear Spring area, and the sections which comprise it are described on pages 163–187 and diagrammatically represented on Plate 14.

UPPER CAMBRIAN

Wilberns Formation

All units of the Wilberns formation, except the Welge sandstone member, are present in the Bear Spring area and may be differentiated. They were not separately mapped because the areal representation of members below the San Saba limestone member is slight and their delineation would have prolonged mapping in the area without materially enhancing the usefulness of the map. A 7-foot sandstone near the top of the formation was mapped for most of its length because it furnished a structural datum parallel and close to the Cambrian-Ordovician boundary.

Welge sandstone member.—This member is not actually present in the area mapped, but poor exposures may be seen northeast of the Bear Spring area at the base of a section about 3 miles southwest of the Mason courthouse. Here it is about 25 feet thick and consists of brown, sparingly glauconitic sandstone.

Morgan Creek limestone member.—The *Eoorthis* zone of the Morgan Creek limestone member is the lowest bed exposed on the south bank of Llano River east of the Honey Creek fault. A minor fault 80 feet southeast of the Honey Creek fault at this place raises the *Eoorthis* zone about 5 feet to expose the beds immediately below it. A complete and well exposed section of the Morgan Creek limestone member above the *Eoorthis* zone at this place displays the granular, glauconitic, greenish gray to gray limestones characteristic of the upper Morgan Creek throughout the Llano region. The thickness of the Morgan Creek limestone in the Mason section is 120 feet.

Point Peak shale member.—The shaly portions of the Point Peak shale member are poorly exposed and not well represented in the area mapped. However, the stromatolitic bioherms at the top of the member are well displayed along Bluff Creek, and Point Peak strata occur in some of the draws east of the Honey Creek fault and above the Morgan Creek limestone, in the southeastern corner of the area. A prominent northeast-trending branch fault that may be seen in the east bank of Honey Creek 700 feet northeast of the Mrs. J. Rogers ranchhouse raises beds to the southeast and is responsible for the exposures of the Morgan Creek limestone and Point Peak shale members on the south bank of Llano River east of White's Crossing. The thickness of the Point Peak shale in the Mason section is about 155 feet.

Magnificent exposures of the stromatolitic bioherms at the top of the Point Peak shale member, and of the interbedded shales and limestones below them may be seen in a bluff extending about 0.4 mile along the south (right) bank of Llano River between the mouth of Mill Creek and a point 0.2 mile west of the mouth of Honey Creek (Pl. 18; Pl. 19, fig. A). The interbioherm beds contain more limestone than shale, but the latter is a conspicuous lithic element and there is no doubt that the bioherms are properly associated with the Point Peak shale at this place. The bioherms extend upward from a floor of Point Peak strata, commonly with compaction basins beneath them. Apparently they grew considerably above the sea-floor of their time, for peripheral beds abut them without noticeable intertonguing; and, whereas some of them are wholly within the Point Peak shale member, others extend upward into the stratigraphic level of the San Saba limestone member, with San Saba beds deposited against them and over them. The overlying beds, moreover, display marked dips that can only in part be explained by compaction and are perhaps largely initial. In the bluff described the bioherms are about 30 to 60 feet thick, and vary slightly in stratigraphic position. A prominent shale zone (marked x on Pl. 18 and Pl. 19, fig. A) that abuts the most prominent bioherm in the bluff a little above its middle is above the next several bioherms east of it, and the prominent limestone bed (marked y on Pl. 18 and Pl. 19, fig. A) through which its base extends forms a base for the same bioherms over which the shale zone extends.

The stromatolitic limestone of the bioherms is microgranular to sublithographic and medium to light brownish, greenish,

or olive gray. The interbioherm beds consist of granular, brownish to greenish gray, glauconitic limestone; platy green limestone with crinkled surfaces; and green calcareous shale. Below the biohermal zone, shale constitutes more of the total thickness and limestone less.

The Wilberns graptolites described by C. E. Decker in 1945 came from the Point Peak shale member just east of the Bear Spring map area and about a mile north of the mouth of Honey Creek. Stratigraphically they occur about 120 feet below the top of the Point Peak shale member and 380 feet below the top of the Wilberns formation. Decker gives their position as 85 feet below the top of the Wilberns, their collector evidently having taken the biohermal limestones of the upper Point Peak shale as the base of the Ellenburger.

Plectotrophia was not found in or near the Bear Spring area, but the related huenellid brachiopod *Mesonomia* is assumed to mark its approximate position, and it was noted 6 to 16 feet below the biohermal zone at the top of the Point Peak shale member.

San Saba limestone member.—Of the 260 feet of beds that represent the San Saba limestone member in the Bear Spring area, quartz sand is intermittently abundant through 80 to 100 feet. Four zones of calcareous sandstone or highly arenaceous limestone are recognizable locally, but at other places the two lower zones spread out and run together. The upper sandstone, known in the field as the fourth or 7-foot sandstone, is persistent throughout the small area mapped, averages between 7 and 8 feet thick, and maintains a position 28 to 35 feet below the Cambrian-Ordovician boundary as mapped. This variation might indicate inconsistency in the selection of the Cambrian-Ordovician boundary, variation in position of the 7-foot sand, or even minor disconformity at the systemic boundary.

The 7-foot sandstone is a very useful reference datum for the Cambrian-Ordovician boundary in the Bear Spring area and is easy to trace because black persimmon thrives on it, showing as a narrow dark band on the aerial photographs (Pl. 36, fig. B). In general black persimmon and scrub-oak grow well on the Cambrian sandstones, probably because they are local aquifers, and clusters of these trees suggest the presence of sand. The individual sand grains in the San Saba limestone member of the Wilberns formation are small, moderately frosted and pitted, subround to round, and not uncommonly stained pink or brownish orange. In general they are less well rounded, less smoothly frosted, and better sorted than the very small clean sand grains that characterize the Gorman formation of the Ellenburger group.

The limestones of the San Saba limestone member in the Bear Spring area are mostly granular, fresh surfaces varying in color through brownish, yellowish, or greenish gray to grayish brown and weathered surfaces being medium brownish to bluish gray. They are commonly silty and dolomitic, weathering yellow to buff or even brick-red in such instances. Glauconite occurs intermittently throughout the member. The limestones of the San Saba in the Bear Spring area are characteristically more impure and dirtier in appearance than those of areas to the east.

Recurrent sand beds are distinctive of the San Saba limestone member not only in the Bear Spring area but generally west of longitude 99° 20′. During reconnaissance studies along San Saba River on the Blockhouse ranch in northwestern Mason County and south and southeast of the village of Erna in west-central Mason and southeastern Menard counties sand zones of varying thickness were seen at several stratigraphic positions within the San Saba limestone member. The greatest continuous thickness of sand observed was 47 feet on the Blockhouse ranch, and the next greatest was about 40 feet in a faulted bluff on the west side of Leon Creek 0.9 mile southeast of Erna. Thinner sandstones at other stratigraphic positions were observed at both of these localities, but the sands observed in the three areas noted do not correspond when plotted with reference to the faunally established Cambrian-Ordovician boundary and are therefore apparent local de-

velopments within a generally arenaceous San Saba limestone member.

Mechanical and chemical analyses of some sand from the San Saba limestone member are given by F. B. Plummer (1943), who calls attention to its possible industrial applications. Due to numerous high-angle faults and the probable lateral discontinuity of these sand tongues attempted commercial exploitation should be preceded by detailed geological mapping in order to locate the thicker and more extensive of the several sand intervals. Possibly the thicker and more continuous calcareous sands in the lower part of the Cap Mountain limestone member of the Riley formation would be more suited to commercial exploitation.

LOWER ORDOVICIAN

Ellenburger Group

The most complete composite sequence of Ellenburger rocks in the Bear Spring area includes only 973 feet of beds, the Honeycut formation being absent.

Tanyard formation, Threadgill member.—As mapped in the Bear Spring area the Threadgill member of the Tanyard formation is wholly limestone, corresponding to the original "Threadgill limestone" of Bridge and Barnes (*in* Barnes, 1944). The member was so mapped as a matter of convenience, the lowest porcelaneous to chalcedonic white-weathering cherts occurring in the general vicinity of the transition from limestone to dolomite, but not in sufficient abundance to be readily mapped. The chemical transition in the western part of the Llano uplift normally involves so small an amount of section as to make a reasonable member-boundary, the limestones below being assigned to the Threadgill member and the dolomites above to the Staendebach member of the Tanyard formation. Measured thicknesses of the Threadgill member in the Bear Spring area range from 265 to 294 feet.

The limestones of the Threadgill member in the Bear Spring area are predominantly sublithographic, essentially nonglauconitic, and pearl gray to light brownish or bluish gray to woodash gray. For the most part they are thinly bedded, and bedding surfaces are commonly covered with sections or selectively dolomitized casts of *Lytospira gyrocera* (Roemer), *Ophileta polygyrata* (Roemer), and trails made by them. Both fossils and trails commonly are selectively dolomitized, weathering in relief and to a darker color than the adjacent rock. A few of the dolomitized markings penetrate the rock and are probably borings, but most are restricted to bedding surfaces and are undoubtedly the trails of creeping organisms. Most of these trails are discontinuous, relatively smooth, dolomitized welts and were probably made by some buoyant benthonic organism such as the gastropods named. A few corrugated vertebra-like markings may have been made by trilobites. *Tetralobula texana* Ulrich and Cooper marks a zone about 40 to 45 feet above the base of the Threadgill member, and a distinctive robust species of *Finkelnburgia** occurs about 260 to 285 feet above the base.

The limestones of the Threadgill member of the Tanyard formation differ from those of the San Saba limestone member of the Wilberns formation in being purer, predominantly sublithographic, and essentially nonglauconitic. The Cambrian-Ordovician boundary is not abrupt, however, and sedimentation may have been essentially continuous across it. In the Bear Spring area it is drawn at the base of a 5- to 10-foot zone of mottled rock that consists of irregular inclusions of buff dolomitic limestone in light gray pure limestone, or the opposite. The transition between the two is fairly sharp, yet at the same time sufficiently gradational in appearance that the effect is not that of a conglomerate but rather of chemically varying portions of the same bed. In mapping, this was referred to as the buff-bed and made a good bottom to the Tanyard formation at most places, in that it contained the lowest very light gray sublithographic limestone, was above most of the observed glauconite, and was essentially coincident with the Cambrian-Ordovician faunal boundary. Abundant glauconite was seen in a 1-inch zone about 5 feet above this buff-bed at many places and probably marks

**Finkelnburgia obesa* Cloud (in press).

a persistent zone, but *Gasconadia* was seen between it and the top of the buff-bed. Locally a second buff-bed occurs above the first, and somewhat similar beds below it, so care must be taken as to which bed is mapped. In this connection the 7-foot sand near the top of the Wilberns formation is of great help.

Occasional beds of fine grained dolomite occur in the upper part of the Threadgill member of the Tanyard and rare globules of glauconite were seen locally in the upper beds. Small quantities of silt grains were seen in siliceous residues from the lower 130 feet of the Threadgill member and occasionally above. As in other parts of the Llano region, no sand was found below the Gorman formation but the occurrence of silt grains in the Tanyard formation of the western areas prognosticates a possible influx of sand in the Tanyard formation of the subsurface west of the Llano region.

Tanyard formation, Staendebach member.—In the Bear Spring area the beds mapped as the Staendebach member are wholly dolomite. They overlie limestones assigned to the Threadgill member of the Tanyard formation and underlie microgranular to very fine grained, locally arenaceous dolomites belonging to the Gorman formation. The measured thickness of the Staendebach member in the Pete Hollow section is 229 feet, of which the lower 19 feet intergrades with limestone. Local variation in thickness results from downward extension of the dolomitic facies and lateral gradation to limestone, but these do not ordinarily involve notable stratigraphic intervals. The change from limestone of the Threadgill member to dolomite of the Staendebach member is generally marked by a decrease in the abundance of cedar, increase in abundance of live oak, a clumpier pattern of tree growth, and disappearance of strong bedding patterns.

The dolomite in the lower half of the Staendebach member is fine grained to very fine grained, grading locally and in minor part to microgranular. In color it is light to medium brownish to yellowish gray, grading to nutria. That of the upper half is mostly fine grained to medium grained, rarely grading to very fine grained. It is commonly vuggy and its color is pearl gray to light brownish or yellowish gray, grading to woodash gray.

Chert is scarce in the Staendebach member of the Bear Spring area except locally in the upper part. Oölitic to oömoldic chert occurs sporadically and coatings of quartz druse are locally conspicuous in the lower half of the member. In the upper half of the member dolomoldic and in part quartzose cherts, as well as oölitic to oömoldic chert and free siliceous oöids, are locally abundant, and commonly are associated with lesser quantities of chalcedonic, porcelaneous, or subgranular white-weathering chert. As in the Bald Ridge area chalcedonic to semichalcedonic, and porcelaneous to semiporcelaneous, white-weathering cherts are locally abundant near the top of the Staendebach member, occurring on both sides of the Tanyard-Gorman contact as local accumulations of float suggesting lenslike masses such as that illustrated by figure C of Plate 21. The chalcedonic to semichalcedonic varieties are commonly oölitic.

Ozarkina, Helicotoma, and other Tanyard fossils occur to within a few feet of the top of the Staendebach member, furnishing faunal control of the physical evidence used in mapping the Tanyard-Gorman boundary. However, the genera that characterize the upper 90 to 100 feet of the Staendebach member in the eastern areas *(e.g., Paraplethopeltis* and *Ribeiria; Rhabdoporella* perhaps occurs, p. 169) were not found in the Bear Spring area. Although the Tanyard-Gorman contact is locally irregular (Pl. 24, fig. B) and may be disconformable it is doubtful that truncation could have been sufficient to eliminate the upper faunal zone of the Tanyard formation, and facies changes may account for its apparent absence.

Gorman formation.—The lower half of the Gorman formation in the Bear Spring area is wholly dolomite, and the upper half is principally limestone. The dolomite (Pl. 24, fig. B) is microgranular to medium grained, with microgranular

being a very conspicuous but not a predominant grain size. In color it varies from light to medium brownish to yellowish gray to light gray, light brown, pinkish gray, beige, brownish beige, or rose beige. The limestone (Pl. 24, fig. C; Pl. 25, fig. B) is predominantly sublithographic and woodash gray to pearl gray. It is more thickly bedded and markedly purer than that of the Threadgill member of the Tanyard formation in this area and is further distinguished by lacking the dolomitized gastropods and gastropod-tracks and by containing relatively abundant chert. As in other areas the upper beds are notably pure and thickly bedded limestones.

Sand is characteristic of and recurrent throughout the Gorman formation as scattered to abundant grains in dolomite, limestone, and chert. These grains are typically small, well rounded, smoothly frosted, clean, and poorly sorted within their small size limits. They occur to the base of the formation, combining with microgranular dolomite to set it apart from the Tanyard formation below.

Chert is more abundant in the Gorman formation of the Bear Spring area than in any but the highest beds of the underlying Tanyard formation. It occurs as nodules, lenses, plates, irregular inclusions, and incrustations that are commonly chalcedonic to semichalcedonic and oölitic, less commonly porcelaneous, locally granular, and locally dolomoldic or drusy. Incrustations or rosettes of quartz druse are locally conspicuous, and chert-matrix sand was noted at several places. Chalcedonic to subchalcedonic and partly oölitic cherts are conspicuous on both sides of the Tanyard-Gorman boundary in parts of the area, and some of the oöids in the Gorman cherts have sand grains for centers. The concentration of such chert at the formational boundary is a great aid to its quick, approximate location, but exact determination of its position depends on fossils and on the distribution of sand and microgranular dolomite.

There is a general topographic and vegetative break at the Tanyard-Gorman boundary, the dolomitic facies of the Gorman formation being expressed as a gently rolling upland that supports scattered clumps of live oak, a thin growth of mesquite, and local cedar; whereas the ground underlain by dolomites of the Staendebach member of the Tanyard supports few mesquites.

Rhombella occurs in the basal chert of the Gorman formation and ranges through the entire unit. *Lecanospira* first appears a little higher but ranges to the top. *Syntrophina* is a common element in porcelaneous cherts about 70 to 110 feet above the base of the formation. *Archaeoscyphia* characterizes a zone 220 feet above the base of the formation but was found locally at positions about 25 feet below and 6 feet above its principal occurrence.

The 450 feet of Gorman strata in the Bear Spring area probably displays almost the full normal thickness of the formation, but it is directly overlain by beds of Devonian or Mississippian age (Pl. 28, fig. C; Pl. 36, fig. A). Strata of the Honeycut formation are missing due to pre-Devonian truncation, but the former presence of Honeycut strata at least as young as the zone of *Ceratopea* 5 is demonstrated by the occurrence of that "species" of *Ceratopea* as pebbles in the Devonian Zesch formation and the Mississippian Ives breccia in the valley of Honey Creek 300 yards west-southwest of the rock cabin on the Roy Zesch ranch. Pre-Mississippian weathering apparently imparted a yellow to buff discoloration to beds at the upper surface of the Gorman formation so that limestones along this zone of weathering can be mistaken for dolomite. This discolored zone served as a clue to the location of some of the smaller patches of Mississippian that are mapped, and suggests the recent removal of the Mississippian from the tops of some hills where none is mapped.

DEVONIAN

Rocks of lower Middle Devonian and probable Upper Devonian age occur in a structural sink 200 to 300 yards west-southwest of the rock cabin on the Roy Zesch ranch and southwest of Honey Creek in the northeast corner of the Bear Spring map area (Pl. 5; Pl. 36, fig. A).

The lower unit consists of granular, yellowish or greenish brown to white, in

part cherty limestones containing a fauna of lower Hamilton age and is called the Bear Spring formation. The upper unit is a thin, highly siliceous limestone or leached silica rock containing a fauna suggestive of that occurring in the Ithaca and Cornell shales but with faunal affinities possibly as low as the Tully formation and as high as the Enfield shale. It is called the Zesch formation. A peculiar olive green to brown, finely laminated, ferruginous and phosphatic silica rock occurs at the margins of the structural sink, as float only, suggesting that it represents remnants of rock that were dragged loose during collapse and probably came from below the Bear Spring formation. This rock contains no fossils, its stratigraphic relationships are not known, and it is not deemed worthy of a name. These rocks are described by Barnes, Cloud, and Warren (1947) and their probable correlation is shown in figure 1 of the present report.

The names of the Devonian formations do not appear on Plate 5 because the map had been sent to the engraver before evidence relating to the Zesch formation was finally worked out.

CARBONIFEROUS

Mississippian

Mississippian rocks of the Bear Spring area comprise two small patches of the Ives breccia and good representations of the Chappel limestone and the Barnett formation. The characters of these rocks are described in another part of this report (pp. 42–59) and only local details need concern us at this place.

Sections of the Mississippian were measured at six places in the Bear Spring area and probably all outcrops of Mississippian rocks in the area were seen.

The Chappel limestone consists of larger crinoid fragments in a finely granular matrix and is dark rose to gray and olive gray in color. Macrofossils are rare at most outcrops, but *Brachythyris chouteauensis* Weller, *Plicatifera*, and other fossils of Chouteau affinities were obtained at TF–417b and TF–417c, just off the northeast edge of the map. Conodonts were found in most of the samples taken and according to W. H. Hass (oral communication) are of the same types that occur at the type locality of the Chappel limestone. The Chappel limestone of the Bear Spring area ranges from a maximum of about 35 feet thick to a feather edge. It rests directly on the Gorman formation except at one locality where the Ives breccia and Devonian strata intervene, and for the most part it is collapsed into the Gorman formation to some extent, a notable structural sink being in a draw about 400 yards northeast of Rattlesnake Hill (Pl. 36, fig. A). Mixing of float from the Chappel limestone with weathered and discolored cobbles of Gorman rocks is commonly intimate and it is locally difficult to say exactly where the contact between Mississippian and Ordovician should be drawn.

The Barnett formation of the Bear Spring area consists of white to light gray crinoidal limesands and finer grained limestone, local tongues of dark petroliferous limestone, dun to buff pellet limestones, and caliche-covered zones probably representing shale. There seems to be a general increase in proportion of limesand and decrease in shale and petroliferous limestone from north to south along the Barnett outcrop belt in this area. Shale was noted locally in the dominantly covered zones and there is little doubt that they are underlain by shale at most places. The Barnett formation of this area varies from as much as 140 feet thick in the southeastern corner of the area (TF–418, TF–420) to a feather edge. Variations in thickness apparently result both from truncation of the upper beds and nondeposition at the base of the formation, as well as probable variation in the rate of accumulation of the original sediments.

Where the shale intervals and petroliferous limestones are well developed they support a dense chaparral of bluebrush and other stiff and thorny bushes that gives the approximate position of the Ellenburger-Mississippian boundary. However, the nonpetroliferous white limesands and Chappel limestones do not differ vegetatively from the limestones of the Ellenburger group and careful mapping is necessary to locate all lobes and

outliers of Mississippian limestones (see Pl. 36, fig. A).

At many places the lower 20 to 40 feet of the Barnett formation is comprised of white to very light gray limestones and crinoidal limesands with an apparently sharp break to interbedded shales, petroliferous limestones, and limesands above. A macrofauna with obvious Keokuk affinities (p. 56) was found in the lower limesand at White's Crossing (Pl. 28, figs. D, E, and F) and other places, and in the early phases of the mapping an attempt was made to separate these basal beds as a distinct unit intervening between Barnett and Chappel strata. However, continued mapping brought out the fact that lateral shifts of facies took place and that where, by nondeposition, a higher limesand came to rest upon Ellenburger rocks it could not ordinarily be distinguished from the lower limesands. It was also once supposed that significance might be attached to size of the detrital particles or to the occurrence of concretions of finely mottled, white to light gray, subporcelaneous chert, or cavernous crinoidal chert in the lower white limestones assigned to the Barnett formation at localities TF–417, 420, 421, and a few other places in the Bear Spring area. But, again, as the mapping continued it became increasingly difficult to make any consistently satisfactory physical distinction between the lower limesands and the upper strata of the Barnett formation in the Bear Spring area. These various attempted subdivisions were actually mapped on the aerial photographs in order to see their special relations, but were finally given up as meaningless. The essential unity of the sequence is further shown by the occurrence of a tongue of shale and petroliferous limestone with *Leiorhynchus carboniferum* Girty, *Productella* cf. *P. hirsutiformis* Walcott, *Moorefieldella* cf. *M. eurekensis* (Walcott) and other Moorefield fossils in the midst of a 140-foot limesand sequence at locality TF–420, about one-half mile west of White's Crossing, and by the occurrence of *Goniatites* at several places in another 140-foot sequence of white limesands containing Keokuk and Warsaw types of fossils (p. 56) at TF–418 in the southeastern corner of the Bear Spring area. According to W. H. Hass, the conodonts from samples collected by him and the writers at White's Crossing, TF–416, TF–418, TF–420, and TF–422, are like those from the Barnett formation at and in the vicinity of its type locality in San Saba County (oral communication). The equivalence of the petroliferous shales of the Barnett formation in its type area with the limesands of Keokuk and Warsaw age of the Bear Spring area is thus supported by the macrofossils, the conodonts, and by detailed mapping *(see* also p. 57).

The lithic break from the dark compact Chappel limestone to the light and commonly friable limesands and limestones of the Barnett formation is marked at most places, and at one locality, near the head of the draw at the southeast side of a panhandle pasture on the P. G. Rogers ranch, limestone conglomerate occurs between them. At some places, however, dark limestone suggesting that of the Chappel beds actually occurs as lenses in the Barnett limesands, and if exposures are poor or fossils scarce such situations may be quite confusing. Such a situation may be seen at White's Crossing, immediately north of the more conspicuous outcrops along a fence that trends north-northwest.

A few cobbles of limesand and limestone occur in the limesand matrix at White's Crossing, but they contain fossils similar to those of the matrix and apparently indicate no more than rapid deposition and consolidation in waters that were at times turbulent.

The Barnett formation rests on the Chappel limestone or the Gorman formation of the Ellenburger group. The gently synclinal structure of many of the outliers of the Barnett formation indicates solution below it, with resultant settling of the Barnett strata into the underlying beds, and at a few places it has actually collapsed into direct contact with Ellenburger rocks. It is not, however, so conspicuously collapsed as is the Chappel formation.

Pennsylvanian

Pennsylvanian rocks in the Bear Spring area consist of the Marble Falls lime-

stone and the Smithwick shale. Neither was measured or studied in detail.

The Marble Falls limestone is mostly quite fine grained, gray to black, and locally contains quantities of black and gray speckled chert. It is several hundred feet thick. Macrofossils are locally abundant, but few were collected. Foraminifera are abundant in some of the chert and limestone and fusiform fusulines probably referable to *Fusiella* were found in the basal beds at many places. Beds of Morrow age are thus apparently absent.

Late in the work on the Bear Spring area it was discovered that the basal foot or two of the Marble Falls limestone was conglomeratic, containing scattered subangular to angular small pebbles and granules of varicolored chert in a grayish to yellowish brown matrix. This zone of chert pebbles was observed at widely separated localities and apparently occurs in the subsurface west of the Llano region, but it has not been seen east of the Bear Spring area. It is possible that local occurrences of dark, microgranular to sublithographic limestones at the top of the Barnett formation may have been included with the Marble Falls limestone at a few places due to failure to recognize the basal conglomerate of the Marble Falls early in the mapping.

At most places the Marble Falls limestone contains scattered clumps of cedar and live oak and is sparsely vegetated in comparison to the shaly zones of the Barnett formation, the Smithwick shale, and the Marble Falls limestone of areas to the east. It is more thickly vegetated at other places, however, and generally supports a better growth of trees than the Ellenburger rocks of the Bear Spring area. Vegetational banding is common on the Marble Falls outcrops.

The Smithwick shale of the Bear Spring area is a dark gray fissile shale with siltstone and limestone beds near the base. Its top is not preserved and its thickness is unknown. It weathers to a soft yellow clay, being so nonresistant to weathering that few outcrops are known in the area. Undoubtedly most of the alluvium in the valley of Honey Creek between the Honey Creek fault and the outcrop belt of the Marble Falls limestone is underlain by Smithwick shale. Above the level of the present valley floor of Honey Creek, and best displayed on the southeast side of its valley, is an older terrace capped by alluvium and displaying a few small outcrops of Smithwick strata. This terrace is thus mapped as Smithwick shale on most of the southeast side of the valley, but its few remnants on the northwest side are mapped as alluvium.

Where it is near enough to the surface to influence the vegetation the Smithwick shale fosters dense thickets of scrub-elm, scrub-oak, black persimmon, blue-brush, agerita, and bee-brush.

Among fossils collected from the Smithwick shale at TF–156, Dr. J. B. Knight identified a new species of *Neilsonia* and a new species of a new genus of high-spired gastropods, which he states to be characteristic of the *Cumminsia aplata* zone (Plummer, 1945, p. 73) of the lower Smithwick shale southwest of Bend and at other localities.

DESCRIPTION OF THE LLANO RIVER SECTIONS

The Rattlesnake Hill, Pete Hollow, and Bluff Creek sections, measured along and near the Llano River in the Bear Spring area, comprise a composite section displaying the full thickness of the Ellenburger group and the San Saba limestone member of the Wilberns formation, in this part of southwestern Mason County. The Mason section, a supplementary section, 6.5 miles by speedometer northeast of White's Crossing furnishes information on the Wilberns formation below the San Saba limestone member and completes the composite Llano River section, while the supplementary Buck Spring section furnishes a check on the measured thickness of the Threadgill member of the Tanyard formation. In the Bear Spring area the Honeycut formation is entirely absent and the Carboniferous strata rest directly on the Gorman formation. An interesting feature of the Bluff Creek section is the presence of four prominent arenaceous zones in the San Saba limestone member of the Wilberns formation. The sequence of stratigraphic units in the

composite Llano River section is as follows:

Stratigraphic unit	*Thickness in feet*
Mississippian (variable thicknesses of the Barnett formation and Chappel limestone)	
Lower Ordovician—Ellenburger group (973 feet)	
Gorman formation (450 feet)	
Calcitic facies	237
Dolomitic facies	213
Tanyard formation (523 feet)	
Staendebach member (229 feet)	
Dolomitic facies	229
Threadgill member (294 feet)	
Calcitic facies	294
Upper Cambrian (560 feet measured)	
Wilberns formation (560 feet)	
San Saba limestone member	260
Point Peak shale member	155
Morgan Creek limestone member	120
Welge sandstone member	25
Approximate total thickness of Ellenburger group and Wilberns formation	1530

Each of the three principal sections described is a unit structurally separated from the others and selected to present the best exposures in the shortest horizontal distance. Although they are described as individual sections, they are presented graphically, along with the supplementary Mason section, as a single composite section on the local correlation chart.

The Rattlesnake Hill, Pete Hollow, and Bluff Creek sections were measured, painted, and described by Cloud in February, 1945. They are marked at approximately 5-foot intervals with yellow paint spots, and a number showing actual feet above the base of the particular section is painted every 50 feet or less. Control for computed measurements was taken from large scale (approximately 4 inches to 1 mile) aerial photographs and intersecting vertical traverses made with a Paulin precision altimeter to determine elevations based on numbers of readings averaged to the nearest 5 feet for each point of determined elevation. The computed measurements checked so closely with field measurements made with a Brunton compass that no adjustment was made, although reëxamination of the sections indicates that some intervals include less and others more than 5 feet of section. The Mason section was measured by Barnes and Cloud in January 1946, and the Buck Spring section by Cloud in February 1945.

The Rattlesnake Hill section is mostly on the Roy Zesch ranch, but in part also on the Mary Rogers and Melvin Capps ranches. The Pete Hollow section and the supplementary Buck Spring section are entirely on the Tom White ranch. The Bluff Creek section is on the Bob Hoffman ranch, crossing the property line to the Ben Jordan ranch in the upper few feet. Property ownership for the Mason section was not ascertained. The locations of the various sections on the geologic map of the Bear Spring area (Pl. 5) are shown by lines of inverted V's. Offsets are indicated by dotted lines except where self-evident, and the letter S indicates the supplementary Buck Spring section.

Rattlesnake Hill Section

The Rattlesnake Hill section (Pl. 24, figs. A and B), as described below, includes 450 feet of the Gorman and 5 feet of the Tanyard formation. This is a complete and probably a maximum thickness for the Gorman formation in the Bear Spring area, and comparison with other sections suggests that a very few more feet of section would have displayed the Gorman-Honeycut contact.

The top of this section is at an altitude of approximately 1705 feet at the northwest side and almost at the top of Rattlesnake Hill, about 0.9 mile airline north of White's Crossing of Llano River. Stratigraphically it is at the top of the Gorman formation and is overlain by a 12-foot rubble-covered interval probably representing the Barnett formation, and followed by about 23 feet of medium gray to brownish gray, cherty Marble Falls limestone (undifferentiated) containing macrofossils and small fusulines and extending to the top of Rattlesnake Hill.

The base of the section (Pl. 24, fig. B) is at an altitude of about 1375 feet, about 0.75 mile airline northwest up Llano River from the top of Rattlesnake Hill and 5 feet stratigraphically below the Tanyard-Gorman contact.

Description	*Thickness in feet Interval*	*Cumulative*	*Feet above base*
Ellenburger group: 455 feet described *Gorman formation: 450 feet thick* *Calcitic facies: 237 feet thick*			
1. Limestone (altitude approximately 1705 feet at top of section)—predominantly sublithographic, in minor part a breccia and in part with irregular argillaceous films. It is of apparently great purity to the naked eye. The color is woodash gray to pearl gray with minor yellowish gray to yellowish olive beds. The beds range from a fraction of an inch to 24 inches thick where measurable, but are massive and hummocky-weathering in the lower 6 feet and for the most part relatively massive in appearance, averaging perhaps 8 to 16 inches thick. Weathers to light to medium bluish gray, smooth to solution-pitted, conspicuous ledges. Chert occurs as scattered nodules, lenses, and irregular inclusions and was specifically noted at 402 and 444 feet. It is predominantly chalcedonic and subchalcedonic, in part oölitic, and locally with included sand grains; bluish to brownish gray varying to white and dull carnelian, in part color laminated; and weathers shiny white to rough and dull or white. Grape-sized rosettes of quartz druse were noted at 430 and 434 to 435 feet: and the upper 5 feet is characterized by rough, russet-weathering, granular, fossiliferous chert externally resembling cannonball chert but only questionably approximating the textural detail of that chert type. Scattered sand grains were noted in some of the chert and limestone float (abundant at 402, 410, and 453 feet) but were seen in place only at 446 feet where they occur in great abundance in a dull orange to brownish gray, mottled, calcareous chert. Cross sections of *Lecanospira* were noted in limestone float at 395 feet and in chert float at 407 feet. A few *Lecanospira* were collected (TF-293) from chert float 15 feet above the north end of bed D, or by projection at 403 feet in the line of section. These were very abundant at the locality where collected but search up the slope and laterally yielded no additional specimens, so it is likely that they were derived from a local occurrence very near the gathering place. *Hormotoma* and other high-spired gastropods were collected from the rough chert in the top 5 feet of the interval (TF-183), and *Ophileta* and poorly preserved cross sections of unidentified gastropods were observed in limestone at 450 feet. D bed at 388 feet; a prominent ledge at top of interval 2, in part covered laterally. Shift about 370 feet south-southwest if going up in the section and north-northeast if going down. The offset on this bed is based on a projection along the west slope of Rattlesnake Hill, along which the rocks are generally well exposed, and was checked by a shift on bed C, 37 feet stratigraphically below. Bed C is marked below the southeast end of bed D in an undescribed alternate segment of the section.	67	67	388 – 455
2. Limestone—sublithographic, woodash gray; beds from a fraction of an inch to 22 inches thick. Weathers light to medium bluish gray. Minor chert occurs in the basal part as thin plates; being semichalcedonic to subchalcedonic, bluish gray to white, and in part oölitic with scattered grains of sand.	4	71	384 – 388
3. Dolomite, in part slightly calcitic and with minor interbeds of and lateral gradation to limestone in upper part—fine grained to microgranular, yellowish beige; beds 1 to	24	95	360 – 384

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
24 inches thick. Weathers light to medium yellowish gray, poorly exposed.			
4. Limestone, with dolomite beds from 312 to 313.5 and 341 to 343 feet—predominantly sublithographic, in minor part a granule conglomerate with a medium to fine grained matrix and locally grading to medium grained where dolomitic; woodash gray to pearl gray; beds from a fraction of an inch to 24 inches thick with the more massive beds commonly weathering to thin plates. Weathers to uneven, solution-pitted, light to medium bluish gray surfaces. The dolomite is medium to fine grained, in part vuggy, and light gray to yellowish gray from 312 to 313.5 feet and microgranular to very fine grained and yellow beige from 341 to 343 feet. Chert is fairly abundant in the interval, both in place and as float. It was noted in place at 307.5, 309, 315, 317, 334, and 344 to 355 feet. The chert in the lower 10 feet is chalcedonic to subchalcedonic, oölitic to crypto-oölitic, with included rhombs of dolomite. It is mostly of a striking brownish orange to carnelian color but grades in part to brownish or bluish gray to white. That at 315 feet occurs as an anastomosing network in limestone, weathering to a dull ropy surface, and is white and slightly calcitic on the fresh surface. In the upper 45 feet the chert is mostly chalcedonic to semichalcedonic, in part oölitic to crypto-oölitic, and in part with scattered sand grains; weathering typically to shiny white surfaces. At 353 feet is a thin film of russet-weathering quartzose chert with scattered oöids and sand grains. Sand grains were noted in abundance in some of the chert and limestone float especially at 322 and 353 feet and in place in limestone from 309.5 to 310 feet and in chert at 317, 334, and 345 feet. These grains are small and well rounded, but irregular in size within their small limits. "*Hormotoma*" was noted in ropy chert at 315 feet and *Lecanospira* was collected from limestone ledges in place between 350 and 355 feet (TF–292). C bed, at 351 feet, was traced laterally about 400 feet southeast along the southwest slope of Rattlesnake Hill to check the offset on bed D, 37 feet stratigraphically above.	60	155	300 – 360
5. Dolomite—microgranular, in minor part grading to very fine grained; beige to rose beige, with purplish to purplish rose bands, streaks, and mottles. Beds 4 to 18 inches thick, poorly exposed. Weathers to mostly smooth, uneven, light to medium yellowish gray to brownish gray ledges.	8	163	292 – 300
6. Limestone, grading laterally to dolomite in upper 3 feet—predominately sublithographic, but in minor part a granule breccia with sublithographic fragments of limestone in a fine to medium grained dolomite matrix and in part with irregular greenish yellow argillaceous films; woodash gray to pearl gray, in part with yellowish pink dolomite rhombs or patches; beds from a fraction of an inch to 30 inches thick with more massive beds commonly weathering to thin plates. Weathers to uneven, medium to light bluish gray surfaces which are commonly pitted or radially grooved by solution. Chert occurs as layers or extensive flat lenses, 2 to 4 inches thick, in the lower 20 feet; and as nodules, lenses, and irregular inclusions in the upper portion of interval 6. Cherty zones were noted at 229.6 to 230, 235, 236.5, 242.5,	68	231	224 – 292

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
265 to 266, and 288 to 290 feet. The chert is chalcedonic to semichalcedonic, conspicuously oölitic at 236.5 feet, and commonly banded with brownish to bluish gray and white and in part clear brown streaks. Sand grains occur in limestone about 30 feet above the base and 10 feet below the top of interval 6. Snail impressions were noted on some of the limestone ledges but none were collected or identified. Chertified *Archaeoscyphia* occurs in the basal 3 feet (TF–163), marking the principal Gorman zone of *Archaeoscyphia* in the Bear Spring area. An occurrence of *Archaeoscyphia* 25 feet below the principal zone was noted about 0.5 mile north of the line of section, and another occurrence about 6 feet above at a locality 0.9 mile north of the line of section.			
B bed at 224 feet. Shift about 380 feet south if going up in the section and north if going down. The basis for this offset is the sponge *Archaeoscyphia* which occurs immediately above. At the south end of the offset (altitude 1490 feet) the dolomite limestone contact is somewhat farther below bed B than at the north end (altitude 1530 feet) due to lateral transition.			
7. Limestone, in minor part with irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic; woodash gray to pearl gray, with yellowish specks and mottles where dolomitic; bedding indistinct. Weathers uneven, light to medium bluish gray to almost white. Chert occurs as float in blocks which are subchalcedonic to subgranular or chalk textured, in part slightly quartzose and with scattered tiny dolomolds, white to light brownish gray, and weather whitish.	6	237	218 – 224
Base of calcitic facies of Gorman formation at base of interval 7 (altitude approximately 1530 feet) Total thickness of facies 237 feet.			
Dolomitic facies: 213 feet thick			
8. Dolomite—medium to fine grained, in part vuggy; light gray; bedding indistinct. Weathers rough, in part pitted, medium to light brownish to yellowish gray. Chert occurs as nodules and irregular inclusions which are in part chalcedonic to porcelaneous, in part oölitic to micro-oölitic, and locally contain scattered sand grains. Sand grains were noticed in dolomite float near the base of the interval and in some of the chert.	8	245	210 – 218
The 210-foot horizon in the Rattlesnake Hill section is at the west end of a west-northwest trending spur, near its truncated terminus in a 160-foot bluff on the northeast bank of Llano River, and the 210- to 218-foot interval is measured over a distance of about 450 feet along the south edge of the spur-crest in the direction of dip. Little reliance can be placed, therefore, upon the accuracy of the measured thickness of interval 8.			
9. Dolomite—medium grained to microgranular: being medium to fine grained, and in part vuggy from 95 to 112, 122.5 to 128, 129 to 137, 146 to 148, 155 to 159, 162 to 192, 197 to 202.5, and 208 to 210 feet; and microgranular, in	115	360	95 – 210

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
minor part varying to fine grained and vuggy, from 112 to 122.5, 128 to 129, 137 to 146, 148 to 155, 159 to 162, 192 to 197, and 202.5 to 208 feet. The medium to fine grained dolomites are light gray to light yellowish or brownish gray. The microgranular dolomites range from light yellowish or brownish gray to light beige, and are in part mottled and streaked with darker beige to nutria. The beds range from 1 to 24 inches thick, with more massive-looking beds in an adjacent cliff. Weathers medium gray or brownish gray to light yellowish gray, being commonly rough and pitted in the medium to fine grained portions and tending to be sphenoidally jointed with smooth surfaces in the microgranular portions.			
Chert occurs intermittently as nodules, lenses, irregular inclusions, and as abundantly interstitial chert that shows, on weathering, as dolomoldic surfaces. It was specifically noted at 117 to 118, 124 to 126, 128, 134 to 136, 158 to 160, 163, and 191 to 193 feet. It is chalcedonic to porcelaneous or chalk textured, in part oölitic or with tiny indistinct cloudy pelletlike markings, and in part interstitial or dolomoldic. The color varies from light bluish gray to brownish gray, grading to china white where interstitial or porcelaneous. Many bedding and joint surfaces are conspicuously coated with fine to coarse grained quartz druse.			
Sand occurs as scattered to fairly abundant grains in some of the chert and dolomite. It was noted in dolomite at 112, 119, 125, and 168 feet and in chert at 119, 139, and 192 feet; and it is sufficiently abundant at 195 feet to constitute in part a chert matrix sand. The individual grains are well rounded, frosted, and poorly sorted within their small size-limits.			
Poorly preserved specimens of "*Euconia*" and a small, moderately high-spired, sharply keeled gastropod were noted in chert at 128 feet. Chert similar to that from which *Syntrophina campbelli* (Walcott), and *Hormotoma* were obtained about 0.4 mile northwest of here (TF–291) was noted at 117 to 118 feet, but although suggestions of a small syntrophid brachiopod were seen in this chert no definitely recognizable fossils were obtained.			
10. Dolomite—predominantly microgranular, in minor part grading to very fine grained especially at 67.5 feet and 77 feet, in minor part vuggy; color light gray to light yellowish gray to beige or brownish beige; beds apparently ranging from 2 to 24 inches thick, but more massive-looking in an adjacent cliff. Weathers to sphenoidally jointed ledges with smooth, or rarely pitted, surfaces; medium to dark gray or brownish gray to light yellowish gray.	32	392	63 – 95
Nodules and irregular inclusions of chert are scattered through interval 10, and were specifically noted at 68, 75, and 92 feet and along the trace of the interval at its base. This chert is mostly chalcedonic to subporcelaneous and in part chalky. It is in part quartzose, locally oölitic, and locally contains scattered oöids and sand grains. The			

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
color of a fresh surface is light bluish to brownish gray to white, and it commonly weathers shiny white. Some bedding and joint surfaces coated with quartz druse. Small, well-rounded, frosted sand grains; varying considerably in size within their small dimensions; are abundant in the dolomite at 69 and at 77.5 feet, and scattered grains were noted between 84 and 87 feet and in some other beds. Small nodules of chert matrix sand are conspicuous at 69 feet, and at 92 feet sand is abundant in chert nodules.			
A bed at 63 feet. Shift about 2500 feet southeast if going up in the section and northwest if going down, following the approximate trace of bed A along the northeast (left) bank of Llano River. A minor syncline causes bed A to be concealed by alluvium for about 350 feet near the midlength of this offset; but as nearly as could be determined from tracing, geometric projection, and comparison of chert and lithology, the shift is made within a relatively small limit of error. The contact between the predominantly microgranular dolomites above and the fine to medium grained dolomite below is fairly persistent, and the intermittent occurrence of prominently developed white-weathering chert in the stratigraphic vicinity of bed A, and commonly just above it, is noticeable. The white weathering chert, however, varies somewhat in character, position, and quantity.			
11. Dolomite—fine to medium grained, in part vuggy; light gray to light yellowish gray, in part with darker streaks; bedding indistinct. Weathers to poorly exposed, rough, in part pitted, medium to light yellowish gray ledges and scattered cobbles. Chert is abundant in this interval both as float and in place, being particularly noted at 47 to 48 feet but seeming to appear and disappear when traced laterally. It occurs as lenses, nodules, and irregular inclusions and is subporcelaneous to chalcedonic, in part oölitic, locally quartzose, and in part slightly dolomoldic. It weathers conspicuously white and shiny except where dulled by films of quartz druse. Quartz druse also occurs as rosettes and incrustations on the dolomite. Sand occurs as scattered grains in some of the chert and in dolomite at the top of the interval. *Syntrophina* was collected from float of subporcelaneous to subgranular white chert at 60 feet (TF-289), but probably this *Syntrophina* bearing chert floated down from a 2-foot ledge of chert that occurs 50 feet above the top of interval 11, and toward the top of a northwest-trending spur, at a stratigraphic position of about 108 to 110 feet above the base of the Gorman formation. Additional collections of *Syntrophina campbelli* (Walcott) were made from chert float 10 to 35 feet stratigraphically above the top of interval 11 (TF-290) and from the ledge 50 to 52 feet above it (TF-291).	20	412	43 – 63
12. Dolomite, all but lower 12 inches covered in the line of section—a little to the southeast of the line of section it is microgranular, in part grading to very fine grained especially in upper 5.5 feet; light gray to light yellowish gray or beige; beds 6 to 42 inches thick. Weathers medium to light brownish gray. Chert occurs as nodules and irregular inclusions, especially at about 34 feet. It is chalcedonic to subchalcedonic, light bluish gray to white, and weathers shiny white. Quartz	12	424	31 – 43

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
druse occurs as conspicuous incrustations and rosettes in the lower part of interval 12.			
13. Dolomite—medium grained, in part grading to almost coarse grained; light brownish to yellowish gray; beds 2 to 19 inches thick. Weathers to rough, uneven, medium to light brownish gray to yellowish gray ledges. Interstitial, chalk-textured, white chert is abundant in some beds. Chert also occurs as irregular inclusions that are porcelaneous and white. Nodules and inclusions of a conspicuously oölitic, light brownish to bluish gray, shiny white-weathering chert occur at 28.5 feet. Sand grains appear to be present as centers for some of the oöids in the chert at 28.5 feet and scattered grains were seen in dolomite near the middle of the interval. An essentially east-west offset of about 200 feet between intervals 14 and 13 was accomplished by shifting on the top of interval 14 about 100 feet east along the north bank of Llano River and then sighting with a Brunton compass set for a 2° east dip to the east side of a draw at a point 15 feet northeast of a northwest-trending fence.	12.5	436.5	18.5– 31
14. Dolomite—microgranular in minor part grading to very fine grained from 5 to 13 feet, medium grained to fine grained from 13 to 14 feet, fine to very fine grained from 14 to 15.5 feet, and medium to fine grained from 15.5 to 18.5 feet; light gray to light brown, beige, or faintly pinkish gray, grading to light olive gray in the upper foot; beds 4 to 25 inches thick. Weathers to hackly or sphenoidally jointed ledges which are dark to medium gray with a brownish tinge. Chert occurs as small concretions, nodules, and irregular inclusions at 10 to 11 feet. It is subchalcedonic to porcelaneous to chalk textured, in part oölitic and in part with scattered oöids, and white to bluish or brownish gray. The medium grained dolomite from 13 to 14 feet is conspicuously interlaced and coated with fine to coarse grained quartz druse, accompanied by minor oölitic to oömoldic incrustations and interstitial chert. Sand grains occur sporadically throughout the interval but are most abundant in the lower 25 inches and quite conspicuous in the lower 8 inches. They are small, well rounded, and frosted. Tiny interstitial inclusions of a greenish substance that is probably glauconite occur near the base of the interval and again at 11.5 feet. Samples isolated by dissolution of the matrix in hydrochloric acid were a brighter green than the interstitial glauconite of the Cambrian Pedernales dolomite but resemble it in other respects.	13.5	450	5 – 18.5
Base of dolomitic facies of Gorman formation at base of interval 14 (altitude 1380 feet). Total thickness of facies 213 feet, and of formation 450 feet.			
Tanyard formation: 5 feet described *Staendebach member: 5 feet described* *Dolomitic facies: 5 feet described*			
15. Dolomite, in part slightly calcitic—medium to fine grained, in part vuggy; light gray to light brownish gray; bedding indeterminable. Weathers rough, irregularly jointed, in minor part pitted, medium to dark brownish gray. Excrescences and surficial coatings of fine to coarse grained quartz druse and oölitic to oömoldic chert occur throughout the interval. Minor chert containing "*Rhabdoporella*"-like objects occurs in the basal ledge and imme-	5	455	0 – 5

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
diately below. Irregular inclusions of white-weathering oölitic chert occur at the top. Scattered sand grains occur in the upper part of the interval and some of the oöids in the upper oölitic chert appear to have sand grains for centers. This sand is by no means conspicuous in a hand specimen and must be searched for with a hand lens. Perhaps the sand-bearing beds should be included in the Gorman formation; but the prominent grain size break occurs a little above the lowest sand, which is assumed in this instance to represent a premature contamination or a secondary introduction, due to disturbance by wave action or by burrowing organisms of the upper layers of the Tanyard formation before diagenesis. Interval 15 marks the top of the Tanyard formation as mapped at this place and is overlain by microgranular dolomite of the basal Gorman formation which is conspicuously sandy in the lower 8 inches. The designated formational contact is clearly visible and is irregularly undulating, due to slight disconformity if not to solution by ground water. Visible apparent truncation at the contact is about 4 to 6 inches and geometric projection westward along the low bluff at this place suggests that it may be greater. There is, however, no evidence to preclude the possibility that this irregular contact was developed by solution. *Ozarkina, Ophileta,* a high-spired gastropod suggesting *Hormotoma,* and *Ectenoceras?* were collected between the base of interval 15 and a point 10 feet stratigraphically below it and within a distance of 250 feet northwest along the northeast side of Llano River (TF–200). An undoubted *Ozarkina* was obtained 3 feet below the base of the interval, or 8 feet below the Tanyard-Gorman boundary here mapped.			
Base of Rattlesnake Hill section, a segment of the composite Llano River section, at base of interval 15; altitude approximately 1375 feet. Northeast bank of Llano River, about 1.65 miles up the river from White's Crossing. Total thickness of Ellenburger rocks included in this section 455 feet. 5 of which belong to the Tanyard and 450 to the Gorman formation.			

Pete Hollow Section

The Pete Hollow section includes 523 feet of the Tanyard formation and 24 feet of the Gorman formation. A typical and essentially complete sequence of the Tanyard formation for the Bear Spring area is here displayed.

The top of this section is at an altitude of about 1575 feet, at the crest of an east-west ridge on the south side of Llano River, between the river and Turkeyroost Draw, and about 1500 feet airline southwest of and across the river from Bear Spring (Pl. 5). Stratigraphically it is 24 feet above the Tanyard-Gorman contact.

The base of the section is at an altitude of approximately 1425 feet, about 0.85 mile airline north-northwest up Llano River from the top of the section and 500 feet south of the water's edge on Llano River at the mouth of Pete Hollow. Measurements indicate that it is not over 7 feet above the base of the Tanyard formation, if not actually coincident with it.

In the Pete Hollow section, as throughout the Bear Spring area, the boundary between the Staendebach and Threadgill members of the Tanyard formation, placed on the basis of chert in the eastern part of the Llano region, is nearly coincident with the transition from limestone in the lower Tanyard to dolomite in the upper Tanyard. So few beds are involved in this transition in the greater part of the area that it is appropriate to consider as the Threadgill-Staendebach boundary the contact betwen limestone and dolomite. The Staendebach member as described below, therefore, is wholly dolomite; whereas the Threadgill member contains only a few thin beds of dolomite within a sequence of thinly bedded limestones.

Examination of the siliceous residues from the Pete Hollow section, prepared under the direction of Dr. Leo Hendricks from samples taken by him and Lincoln Warren in September 1945, revealed sand grains in a number of residues from the Tanyard formation. Discounting those in which less than 5 grains were seen, 13 of the samples of residues from 5-foot intervals showed sand. In 9 of these instances the grains are very few in number. However, residues from 110 to 115, 350 to 355, and 375 to 380 feet each contained several dozen and the residue from 115 to 120 feet several hundred sand grains. Because sand had not been seen in ordinary field methods of examination of the Tanyard formation at any place, except locally in the top few inches (*see* Rattlesnake Hill section), these occurrences were of importance. However, contamination was suspected, because of the occurrence of grains with ferruginous films in all samples. Microscopic investigation of cuts of the chips from which the residues had been prepared revealed no sand grains in the rock, but did show small contaminant chips of slightly ferruginous sandstone in 4 of the samples studied and loose stained grains in others. One small chip of caliche containing embedded sand grains was also found in the sample from 115 to 120 feet. As a further check, a fresh cut of residues was prepared from washed chips of fresh rock from the 115- to 120-foot interval; but no sand was found in these residues. No reasonable doubt remains that a large part, if not all, of the sand in the residues from the Tanyard formation of the Pete Hollow section is due to contamination.

Detrital angular clear silica grains, judged from microscopic examination with a graduated scale to average less than 0.05 mm. and therefore to be considered silt in any generally used classification, comprise the bulk of the quantitatively insignificant siliceous residues from the rocks below 130 feet in the Pete Hollow section and are occasional in the residues from the rocks between 130 and 365 feet. Above 365 feet silt grains as such were not recognized, the silica having probably been reconstituted or redistributed as crystalline druse. Scattered clear flakes of detrital clear mica, probably muscovite, are relatively common in the silty, siliceous residues below 130 feet. Needless to mention, airborne detrital particles of the dimensions noted are apt to occur in any sedimentary rocks, are not a macroscopically observable physical character unless their bulk is great, and are not considered in the columnar section on Plate 14.

Since the above observations were made sand grains have been found by S. S. Goldich and E. B. Parmelee on examination with a petrographic microscope of hydrochloric acid residues from samples of fresh rock from the Tanyard formation of the Riley Mountain section. Goldich and Parmelee (manuscript) found sand positively at 180 feet above the base of the Tanyard formation and possibly a few grains at 7, 113, 513, and 548 feet above its base in this section. Thus sand grains do occur rarely in the Tanyard formation, at least toward the south side, and possibly at the southwest side of the Llano uplift.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Ellenburger group: 523 feet (incomplete)			
Gorman formation: 24 feet (incomplete)			
Dolomitic facies: 24 feet (incomplete)			
1. Dolomite (altitude approximately 1575 feet)—medium grained to fine grained, in part vuggy; pearl gray to light yellowish gray; bedding indistinct. Weathers to rough, cement gray to limestone gray cobbles, strewn over a gentle slope. Chert fairly abundant throughout; being chalcedonic to subgranular, in part conspicuously drusy and dolomoldic, in part oölitic, locally interstitial, and white to bluish gray in color. This appears to be one of the zones in which the chert comes in and out abruptly along its trace and from which fossils were locally obtained. A few fossils were seen in the highest cherts. These consisted of *"Euconia," Rhombella,* and *Ophileta* (TF–199).	9	9	538 – 547
2. Dolomite—microgranular to fine grained; mostly light yellowish gray to biege, grading to olive gray or light rose gray; bedding indistinct. Weathers to smooth to moderately rough, cement gray to limestone gray. Chert occurs throughout the interval, varying in abundance along its trace but not conspicuously abundant in the line of section. It is chalcedonic and banded, with scattered to abundant oöids, or porcelaneous to chalk textured; in part with scattered dolomolds and white to light bluish gray in color. A conspicuous zone of oölitic chert occurs in arenaceous dolomite at 525 feet, the chert showing prominent concentrically banded oöids and occasional granule-sized inclusions. A thin band of chalcedonic chert, conspicuously laminated in white and gray, occurs at 528 feet. Sand occurs throughout the interval as occasional small, round, frosted grains, in the dolomite as well as the chert, and is conspicuous at 525 feet. *"Euconia," Rhombella, Ophileta* sp., *Chepultapecia?,* cf. *Hystricurus,* and small brevicone cephalopods were collected from chert float at 535 feet in this interval about 230 feet east along its trace (TF–182).	13.5	22.5	524.5– 538
3. Dolomite—microgranular; beige with brownish mottles; bedding indistinct. Weathers smooth, yellowish gray. Chert occurs as scattered irregular inclusions, being subchalcedonic to chalcedonic and white to bluish gray. Sand grains are scattered to abundant in basal 4 inches.	1.5	24	423 – 524.5
Base of dolomitic facies of Gorman formation at base of interval 3 (altitude approximately 1555 feet). Total incomplete thickness of facies and formation in this section is 24 feet.			
Tanyard formation: 518 feet thick			
Staendebach member: 229 feet thick			
Dolomitic facies: 229 feet thick			
4. Dolomite—medium grained to fine grained, with about half the beds vuggy; pearl gray to woodash gray, light olive, or yellowish gray, with olive and purplish mottlings; beds as much as 24 inches thick, bedding indistinct. Weathers pitted to smooth, dark to medium gray to yellowish gray. The basal 5 feet of interval 4 is the most conspicuously cherty portion of the upper Tanyard in the vicinity of the Pete Hollow section, and similar chert occurs sparingly above here to the top of the Tanyard formation. The most conspicuous type of chert is chalcedonic to subgranular;	21	45	502 – 523

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
white to bluish or brownish gray; with tiny, rounded, indistinct inclusions and scattered oöids; in part dolomoldic to dolomitic; and in minor part quartzose. This chert occurs in beds which at places almost exclude the dolomite. Scattered lenticles of oölitic subchalcedonic chert containing concentrically banded oöids occur at 520.5 feet. Most of the chert weathers to a smooth shiny surface, except where strongly dolomoldic or quartzose. Fine to coarse grained quartz druse is present in varying abundance as surficial coatings. *Ozarkina complanata* Ulrich and Bridge, *Helicotoma* cf. *H. uniangulata* (Hall), and a trilobite were collected at 507 feet in this interval (TF–198) and the conspicuously cherty lower 5 feet is probably the zone from which *Ozarkina complanata* Ulrich and Bridge, *Ophileta* sp., brevicone cephalopods, and the trilobite *Paraplethopeltis* were collected about 1400 feet west and 250 feet east from the line of section at localities TF–180 and TF–181.			
5. Dolomite—medium grained to fine grained, with about half the beds vuggy; pearl gray to light brownish or yellowish gray; beds 1 to 32 inches thick. Weathers rough and pitted to smooth, dark gray to medium brownish or yellowish gray. Chert is present, though not abundant, throughout the interval and some beds are conspicuously coated with medium to coarse grained quartz druse. The chert occurs as rough excrescences, nodules, or irregular intergrowths. It is semiporcelaneous to subgranular; in part quartzose; in part dolomitic to dolomoldic; locally with tiny, indistinct, cloudy, rounded inclusions and occasional scattered micro-oöids; and weathers to rough, ropy excrescences or smooth, dirty white surfaces. Fossils were noted in a number of pieces of chert float which could equally well be derived from this interval or from the more conspicuously cherty interval above. *Ozarkina* is most abundant and fossils noted in the float at 490 feet were *Helicotoma, Ophileta,* brevicone cephalopods, and *Ozarkina* cf. *O. complanata* Ulrich and Bridge.	32	77	470 – 502
6. Dolomite, in part slightly calcitic—mostly fine grained, in minor part medium grained, locally porous to vuggy; pearl gray to light yellowish gray, with one ¼-inch band at the top that is dark brownish gray to nutria. Beds 4 to 14 inches thick, poorly exposed. Weathers mostly smooth but in part pitted; medium yellowish gray to dark gray. Free siliceous oöids may be seen on some rock surfaces in the lower three-fourths of interval 6, and lateral tracing indicates that at places surfaces underlain by equivalent rocks are conspicuously littered with oölitic to oömoldic laminated chert. In addition, much chert float, seemingly from above, occurs at the surface of interval 6. This is subporcelaneous to subchalcedonic, irregularly intergrown with dolomite irregularly dolomoldic, white to bluish or brownish gray. It weathers to rough, thickly matted, ropy excrescences on the surfaces of pitted dolomite blocks. *Helicotoma* cf. *H. uniangulata* (Hall), a high-spired *Ophileta,* and a brevicone cephalopod were collected at 430 feet (TF–197) and *Ozarkina* sp., *Helicotoma* cf. *H. uniangulata* (Hall), cf. *Ectenoceras* sp., and a brevicone cephaloped were noted but not collected at 455 feet in a float block of cherty dolomite.	43	120	427 – 470

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
7. Dolomite, slightly calcitic—fine grained, in part visibly porous; pearl gray. Weathers to smooth, indistinctly bedded surfaces that are dark gray with light yellowish gray splotches and in part coated with white patches of caliche. Occasional free siliceous oöids may be seen on close inspection of some surfaces in interval 7.	12	132	415 – 427
8. Covered by caliche and float from above, and no applicable data obtainable by lateral tracing.	22	154	393 – 415
9. Dolomite—mostly fine to very fine grained; in part almost microgranular from 362 to 363.3, 378.5 to 382, 383.5 to 385, and 388 to 389 feet; in minor part vuggy. Light to medium brownish to yellowish gray, in part varying to medium dark brownish gray or nutria. Beds 2 to 19 inches thick, indistinct in the top 14 feet. Weathers rough to smooth, in minor part pitted, dark to medium brownish gray. Chert has floated down over this interval from above, but none was noted in place. However, on weathered slopes underlain by rocks belonging to this interval chert similar to that mentioned for interval 6 is not uncommon. Rosettes of finely crystalline quartz druse occur in minor quantity. Greenish interstitial material suggesting glauconite was seen as scattered specks at 359.5 to 360 feet and was relatively abundant in a 1-inch zone at 365.5 feet. No fossils noted.	38	192	355 – 393
Above 355 feet the section ascends the south bank of the Llano River gorge; below 355 feet it follows excellent exposures on the south bank of the river.			
10. Dolomite—principally fine grained to very fine grained, in part grading to microgranular from 339.5 to 342 and 345 to 347.6 feet, in part vuggy; light yellowish to brownish gray to medium brownish gray or nutria; beds 2 to 21 inches thick. Weathers to irregularly jointed, rough to smooth, in part conspicuously pitted, dark to light brownish or yellowish gray ledges. No chert and no oöids were noted in the line of section, but at some places weathered slopes underlain by rocks thought to belong near the upper part of this interval are littered with oölitic or oömoldic laminated chert. Fine grained quartz druse occurs as excrescences and rosettes on the dolomite.	42	234	313 – 355
11. Dolomite and limestone, interbedded and laterally intergrading—the limestone is sublithographic, grading to fine grained where dolomitic; light yellowish to brownish gray; in beds a fraction of an inch to 7 inches thick, predominating in the lower 6 feet. It weathers to rough, light to medium yellowish to brownish gray surfaces which are in part marked by yellowish reticulations and anastomosing trail-like markings where dolomitic. The dolomite is fine grained, light to medium yellowish to brownish gray, in beds 2 to 21 inches thick. It weathers to partly pitted, irregularly jointed, medium to light yellowish to brownish gray ledges. Fine grained quartz druse occurs as rosettes and irregular excrescences in both limestone and dolomite. Minor interstitial glauconite was noted in a few thin beds in this transition zone on both sides of Llano River. *Lytospira* and *Ophileta* were seen in some of the limestone beds.	19	253	294 – 313

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
The contact between the Threadgill and Staendebach members of the Tanyard formation as mapped in the Bear Spring area appears most commonly to fall near the base of interval 11, for the distinctive robust *Finkelnburgia** which occurs at 285.5 feet in interval 12 (TF–196) has been found at several localities in the area about 10 to 15 feet below the limestone-dolomite contact mapped as the member boundary. In the line of section the Threadgill-Staendebach contact would be drawn at the base of interval 11 in the exposures nearest Llano River and at the top of this interval in the exposures nearest the south wall of the river gorge, but the base of the interval (altitude 1385 feet) is here chosen because the occurrence of the robust *Finkelnburgia** indicates that the thickness figures so obtained more nearly approximate the expectable means for the area.			
Base of Staendebach member of Tanyard formation at base of interval 11 (altitude approximately 1385 feet). Total thickness of member, which is entirely in the dolomitic facies, 229 feet thick.			
Threadgill member: 294 feet thick			
Calcitic facies: 294 feet thick			
12. Limestone, in part slightly dolomitic; with dolomite from 263 to 267.6 and 279.2 to 281.2 feet, and with calcitic dolomite and dolomitic limestone going laterally to limestone at 267.7 to 278.4 and 281.2 to 282 feet—the limestone is sublithographic, grading to fine grained where dolomitic; pearl gray to light brownish or yellowish gray; in beds a fraction of an inch to 7 inches thick. Its surfaces are generally rough and hackly and seemingly with thin films of argillaceous material; and it weathers light to medium bluish to yellowish gray. with yellowish reticulations and trail-like markings where dolomitic. The dolomite is fine grained. in part pitted; light to medium yellowish to brownish gray; in beds 7 to 26 inches thick. It is irregularly jointed and weathers medium yellowish to brownish gray. The dolomite beds noted seem to be fairly persistent laterally. Quartz druse, in rosettes the size of an English pea to that of a grape, was the only resistant element noted, aside from argillaceous material. *Ophileta* and *Lytospira* occur intermittently through the interval. Silicified brachiopods were collected at 285.5 feet (TF–196). The brachiopod is a distinctive robust *Finkelnburgia** which at other localities in the Bear Spring area occurs immediately below the limestone-dolomite contact mapped as the boundary between the Threadgill and Staendebach members of the Tanyard formation.	31	284	263 – 294
13. Limestone, in part with minor dolomitic inclusions—sublithographic, grading to fine grained where dolomitic; pearl gray to woodash gray, with light yellowish gray mottles where dolomitic and in part with pale argillaceous films; beds 1 to 14 inches thick. Weathers to regular, rough surfaced, light to medium bluish gray to woodash gray or light yellowish gray ledges. Yellow to buff-weathering dolomitic reticulations and anastomosing markings are not as common in interval 13 as in the beds below. but they do occur, especially in the lower part. The lowest chert noted in the Pete Hollow section occurs at the base of interval 13. It is fairly common as excrescences and surficial coatings from 233 to 237.5 feet. but uncommon in the higher beds of the interval. The lowest	30	314	233 – 263

*Equals *Finkelnburgia obesa* Cloud (in press).

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
"chert" occurs as calcareous incrustations composed of tiny rodlike hollow tubules which seem to be closed at the ends, elongate pelletlike objects, and scattered oöids. Along with this are tiny lenticles or inclusions of white to woodash gray, subporcelaneous to chalk textured, calcareous chert. A few grains of a green substance, apparently glauconite, are scattered in the lower siliceous beds. The interval is intermittently fossiliferous, beginning with poorly preserved trilobites and snails in the basal siliceous excrescences and occurring more or less abundantly throughout. *Finkelnburgia* cf. *F. macleodi* (Whitfield) was obtained from a ledge at 238 feet (TF–224). *Ophileta* was noted at 240 feet. *Lytospira*, *Ophileta*, and *Finkelnburgia* (?) were collected at 253.5 feet (TF–195).			
14. Predominantly limestone; with minor inclusions of dolomite, and with dolomite from 154.5 to 155 and 231.6 to 233 feet—the limestone is predominantly sublithographic, grading to fine grained where dolomitic; pearl gray to woodash gray, with yellowish to yellowish gray blotches where dolomitic and in part with pale argillaceous films; in beds a fraction of an inch to 12 inches thick. It weathers rough to smooth, light to medium bluish gray to very light gray; with many beds conspicuously marked with yellow- to buff-weathering, intricately and irregularly ramifying dolomitic welts. Many of the dolomitic welts on the limestone are limited to the bedding surfaces, not appreciably penetrating beyond and not transecting the rock in a vertical direction. They evidently represent trails of some benthonic organism, and the range in width of the commonest type closely coincides with the range in apertural diameter displayed by the abundant specimens of *Ophileta* and *Lytospira* in the same beds. The trails are, moreover, of varying but short lengths indicating that they were made by some naturally buoyant organism, such as a snail, which from time to time lost contact with the substratum. Their raised weltlike nature may be explained by their maker having secreted an agglutinating substance such as recent snails do. Less common types of trails are less easily correlated with the organic remains of their makers, and part of the dolomitization is probably localized by burrows and irregular zones of permeability rather than surface trails. An excellent display of dolomitized trails and the gastropods that probably made some of them may be seen at 174 feet, and is illustrated by figure D of Plate 20. Fossils occur intermittently throughout the interval and are extremely abundant on some bedding surfaces. *Gasconadia* is especially abundant at 152 to 154 feet, where it is associated with *Lytospira*, *Ophileta*, and brevicone cephalopods. *Ophileta* is abundant at 159 to 160 feet, *Ophileta* and *Lytospira* at 165 to 168 feet, *Lytospira* at 199 to 202 feet, and *Ophileta* and *Gasconadia* at 230 to 231.6 feet. A smooth-headed trilobite with 7 or 8 thoracic segments was collected at 174 feet by Leo Hendricks (TF–430). Commonly the fossils, like the trails they make, are preserved in relief on the bedding surfaces by dolomitic replacement. A little interstitial green material that is probably glauconite was noted in the dolomite near the top of interval 14. Except for this, rosettes of limonite after pyrite and the pale argillaceous films were the only macroscopically visible "insoluble" elements noted.	85.8	399.8	147.2– 233

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
15. Dolomite, slightly calcareous, grading laterally to limestone and dolomitic limestone—fine grained, light yellowish gray; beds 1 to 13 inches thick. Weathers gray to buff.	1.7	401.5	145.5- 147.2
16. Limestone, in part very slightly dolomitic—mostly sublithographic, grading to fine grained where dolomitic; mostly pearl gray, with light yellowish gray inclusions where dolomitic. Beds a small fraction of an inch to 5 inches thick; in part very thinly platy, with argillaceous material along the partings. Weathers medium to very light bluish or yellowish gray, with yellowish to buff reticulations of dolomite prominent in some beds.	21.5	423	124 - 145.5
Rosettes of limonite after pyrite were the only macroscopically visible "insoluble" elements noted, except for the argillaceous films between the platy beds. Silt grains are relatively common in the siliceous residues from the rocks below 130 feet, but less common above.			
Ophileta and *Lytospira* are not uncommon throughout interval 16, and broken surfaces of the rock show cross sections of trilobites and cephalopods.			
From 124 to 355 feet the section follows excellent exposures on the south bank of Llano River; below 124 feet it is on a sparsely cedared hillside south of the river and east of the mouth of Pete Hollow.			
X bed at 124 feet; a conspicuous 9-inch bed; shift about 450 feet east-northeast if going up in the section and west-southwest if going down (altitude approximately 1420 feet at west and 1395 feet at east end).			
17. Limestone—as in interval 18; beds 1 to 10 inches thick. W bed at 115 feet, an 8-inch ledge; shift about 130 feet east-northeast if going up in the section and west-southwest if going down (altitude approximately 1440 feet at west and 1325 feet at east end).	9	432	115 - 124
18. Limestone—in all respects similar to the pure ledges in the upper part of the interval below, except that it is slightly darker; beds 1 to 8 inches thick.	6	438	109 - 115
V bed at 109 feet, a prominent 16-inch ledge; shift about 640 feet east-northeast if going up in the section and west-southwest if going down (altitude approximately 1470 feet at west and 1435 at east end).			
19. Limestone—mostly pure and sublithographic, but in part with minor inclusions of fine grained dolomitic limestone, and in minor part with thin beds of limestone-granule conglomerate. Mostly pearl gray, grading in minor part to light brownish gray, with buff to yellow streaks and blotches where dolomitic. Beds a fraction of an inch to 12 inches thick. Weathers to smooth, light to medium bluish gray ledges alternating with poorly exposed intervals covered with thin, smooth slabs that weather very light gray. Interval 19 differs from interval 20 principally in having more prominent ledges and in the greater purity of the limestone, reticulate weathering beds being present but not conspicuous.	54	492	55 - 109
The quantitatively insignificant siliceous residues from interval 19 apparently consist wholly of silt particles less than 0.05 mm. in diameter and scattered to moderately abundant clear flakes of detrital muscovite.			
Globular glauconite was fairly abundant in a thin slab of limestone found at 67 feet in interval 19. It may have weathered out from this part of the section, but could also be a stray piece. Artifacts were found in the vicinity and it is near a pasture road.			

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	Fossils occur intermittently through the interval but are not generally conspicuous in the line of section. Those noted were *Lytospira, Gasconadia, Ophileta,* and a small brevicone cephalopod. A thin bed crowded with *Gasconadia* was seen at 80 feet.			
20.	Limestone, in minor part slightly dolomitic—sublithographic to fine grained, with minor medium grained portions; in part a limestone-granule conglomerate with sublithographic granules of pure limestone in a granular matrix of slightly dolomitic pellet limestone. Pearl gray to light bluish or brownish gray, with buff blotches and streaks where dolomitic. Beds a fraction of an inch to 6 inches thick. Weathers to fairly smooth, slabby, medium to light bluish gray ledges alternating with poorly exposed intervals strewn with smooth weathering slabs that are of such a light gray color that they give the appearance of being almost white in the sunlight. Some ledges are reticulated with raised buff colored markings where slightly dolomitic. Occasional small rosettes of limonite were the only macroscopically visible "insolubles" seen, but moderate quantities of fine silt and scattered clear detrital mica flakes appear in the quantitatively insignificant siliceous residues from this interval. Measurements with a graduated scale in a microscope indicate that the silt grains average less than 0.05 mm. in diameter. Fossils occur intermittently through most of the interval but are ordinarily not noticeably abundant. Those seen were species of *Tetralobula, Finkelnburgia, Lytospira, Ophileta, Gasconadia,* a short blunt brevicone cephalopod, and a few trilobites. The lowest *Lytospira* was at 28 feet. Silicified *Tetralobula* was collected at 41.5 feet (TF–192) and seen but not collected at 45 feet. Silicified *Finkelnburgia* cf. *F. bellatula* Ulrich and Cooper* was collected from 44.3 to 45 feet (TF–193) and again at 52 feet (TF–194).	39	531	16 – 55
21.	Covered, but with slabs of limestone from less than an inch to a few inches thick scattered over the gently sloping surface of the interval—on a fresh surface these limestone slabs are sublithographic to medium grained; pearl gray to brownish gray, in part with slightly dolomitic buff mottles. They weather very light gray to white. The surface at interval 21 is also fairly well salted with slabs of the upper Wilberns limestone, supplied either by the stream that intermittently flows in Pete Hollow, or by Llano River at a higher stage than its present course. Glauconite grains are common in some of the more granular beds represented by float between 10 and 15 feet in this interval. Fossils noted were *Gasconadia,* cf. *Sinuopea,* and a small blunt brevicone cephalopod. Fossiliferous slabs are not uncommon on the surface of the interval, especially in the upper 5 feet, and one of the slabs containing clearly recognizable *Gasconadia* and cephalopods contains granular glauconite. Silicified *Finkelnburgia* was seen in glauconitic limestone float at 12 feet, the specimens being discarded following preparation and identification.	11.5	542.5	4.5– 16
22.	Limestone, in part slightly dolomitic—sublithographic to medium grained; in part a granule-conglomerate with subrounded inclusions of sublithographic limestone in a matrix of slightly dolomitic pellet limestone. Light bluish gray	4.5	547	0 – 4.5

*Equals *Finkelnburgia helleri* Cloud (in press).

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
where pure limestone, varying to buff or yellow where dolomitic. Some of the rock consists simply of irregular inclusions of buff dolomitic limestone in light gray pure limestone, or the opposite; the transition between the two types being fairly sharp, yet at the same time sufficiently gradational in appearance that the effect is not that of a conglomerate but rather of chemically varying portions of the same bed. Beds 1 to 6 inches thick. Weathers to rough surfaces, mottled in light bluish gray and buff, with some beds weathering light woodash gray to almost white. No fossils were seen in this interval. The base of interval 22 is thought to be slightly above the actual base of the Ordovician. The buff-mottled lower 2 feet of this interval is very similar to the buff beds typical of the lower 5 to 10 feet of the Ordovician throughout the Bear Spring area. The projection of the Wilberns-Tanyard boundary from the west side of Pete Hollow brings it immediately below the point where the section begins. The 7-foot sand which occurs 28 to 35 feet below the base of the Tanyard formation throughout the Bear Spring area crosses the mouth of Pete Hollow, and measurements indicate that there is room for about 35 feet of strata in the covered interval between it and the base of the Pete Hollow section. The base of the Pete Hollow section is, therefore, thought to be 0 to 7 feet above the base of the Tanyard formation; and, as a matter of convenience, is assumed to be coincident with it.			
Base of Threadgill member of Tanyarad formation at base of interval 22. Total thickness of member, which is entirely in the calcitic facies, 294 feet thick. Total measured thickness of formation 523 feet. It may be noted here that an artesian well at the Melvin Capps ranch headquarters is said to obtain its water from sand at a depth of 586 feet. Assuming that this aquifer is the upper 7-foot sand of the San Saba limestone member of the Wilberns formation, the measured thicknesses show that it is about 551 feet below the Tanyard-Gorman contact. The residue of 35 feet is approximately correct for the stratigraphic distance above the Tanyard-Gorman contact at the Capps ranch headquarters and the well essentially checks the measured thickness of the Tanyard formation.			
Base of Pete Hollow section, a segment of the composite Llano River section, at base of interval 22; altitude approximately 1425 feet. About 500 feet south of the water's edge on Llano River at the mouth of Pete Hollow. Total thickness of Ellenburger rocks included in this section 547 feet, 523 of which belong to the Tanyard and 24 to the Gorman formation.			

Bluff Creek Section

The Bluff Creek section includes 18 feet of the Tanyard formation and 262 feet of the Wilberns formation. Of the latter 260 feet are assignable to the San Saba limestone member of the Wilberns formation, but the basal 2 feet are in a stromatolite bioherm that should be included in the Point Peak shale member of the Wilberns.

Sand is an interesting feature of the San Saba limestone member of the Wilberns formation in this section, occurring as four fairly well-defined zones of calcareous sandstone and as intermittently scattered grains or patches of calcareous sandstone between these four zones. The upper 7-foot sand zone is known to be persistent throughout the Bear Spring area; and the others are probably locally persistent, for sands were seen in the

approximate positions of the lower zones wherever this part of the section was traversed in the Bear Spring area. To the east, however, the sand disappears and, except for occasional grains, sand was not seen in the San Saba limestone member of the Threadgill Creek section 20 miles to the southeast or of the Brady-Mason highway section 22 miles north-northeast. Sand zones are present, however, in the San Saba limestone member of the Wilberns in northwestern and west-central Mason County and one or more of these was named the "Erna sand" by F. B. Plummer (1943).

The top of the Bluff Creek section is at an altitude of approximately 1630 feet at the peak of a west-southwest trending spur and about 0.6 mile airline north-northeast of the mouth of Bluff Creek (Pl. 5). Stratigraphically it is 18 feet above the diastem chosen as the Cambrian-Ordvician contact and the base of the Ellenburger group.

The base of the section is at an altitude of 1425 feet about 1200 feet airline west-southwest from the top, at the mouth of a draw on the east side of Bluff Creek.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Ellenburger group: 18 feet described			
Tanyard formation: 18 feet described			
Threadgill member: 18 feet described			
Calcitic facies: 18 feet described			
1. Limestone, in part slightly dolomitic (altitude approximately 1630 feet at top of section)—sublithographic to medium grained, in part a granule breccia with matrix and phenoclasts of similar lithology or with matrix slightly dolomitic; pearl gray to woodash gray with buff to yellow mottles and streaks where dolomitic. The dolomitic inclusions are especially prominent in the lower 8 feet, and the basal foot is a conspicuous buff bed that looks like an earthy dolomite but fizzes strongly upon application of HCl indicating that it is only slightly dolomitic. Beds poorly exposed, probably few of them exceeding a few inches in thickness. In contrast to the darker weathering limestones of the Wilberns formation below, the limestones in this interval weather conspicuously light gray or even white, with buff to yellow blotches representing the dolomitic portions. Scattered glauconite pellets are present about 5 feet above the base of this interval and lateral tracing has shown that a 1- to 3-inch conspicuously glauconitic zone is fairly persistent at about this position. Inasmuch as globular glauconite is very rare in beds considered to be of Ordovician age throughout most of the Llano region, it is possible that the Cambrian-Ordovician boundary should be drawn above this occurrence. However, the sublithographic smooth-fracturing, white to very light-gray-weathering lithology so characteristic of the Threadgill limestones of the western part of the Llano uplift begins as minor inclusions in a persistent thin buff bed below this glauconitic zone and becomes increasingly prominent above it. Hence the base of the buff bed is regarded as the base of the Ordovician and the glauconite is considered to represent either a belated manifestation of Cambrian conditions or reworked material. Fossils are fairly common in this interval, consisting of cross sections in the limestone, but none were collected. *Ophileta* cf. *O. polygyrata* (Roemer) is most abundant but *Gasconadia* cf. *G. putilla* (Sardeson), *Lytospira* cf. *L. gyrocera* (Roemer), and a small blunt brevicone cephalopod	18	18	262 – 280

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
also were noted. These fossils apparently occur to the very base of the Tanyard formation, for blocks containing them have floated down over the Wilberns formation below to as low as a point 12 feet stratigraphically below the Wilberns-Tanyard in the measured section. The lowest *Lytospira* noted in place in the Bear Spring area was found about 6 feet above the base of the basal buff-mottled bed of the Ordovician.			
Base of Threadgill member (entirely calcitic) of Tanyard formation, and Cambrian-Ordovician boundary, at base of interval 1 (altitude about 1615 feet). Thickness (incomplete) of member and formation in Bluff Creek section 18 feet.			
Upper Cambrian: 262 feet described *Wilberns formation: 262 feet described* *San Saba limestone member: 260 feet thick*			
2. Limestone—microgranular to coarse grained, includes fairly abundant small limestone pellets or micro-oöids and scattered irregularly shaped inclusions as well as individual small buff-weathered dolomite rhombs. Grayish brown to brownish, yellowish, and greenish gray; beds poorly exposed and apparently none over a few inches thick. Weathers medium brownish to bluish gray on the gentle slope where exposed ledges are few. The float in the upper 12 feet of interval 2 appears to be derived largely from the overlying Ordovician beds, thereby obscuring the Cambrian-Ordovician boundary. However, thin, granular, brownish gray limestone ledges of the Wilberns type of lithology project from several places in the obscured interval. Rare grains of sand occur in the lower part of interval 2. Scattered globular glauconite occurs throughout the interval and is abundant in some layers. *Plethometopus* and other trilobites were collected from 237 to 240 feet (TF–191). Similar trilobites were noted in a ledge at 252 feet and another ledge near the top of the interval, but these were not collected.	28	46	234 – 262
3. Calcareous sandstone and arenaceous limestone, in part slightly dolomitic—fine to medium grained, light yellowish gray with buff and brown streaks, beds 1 to 7 inches thick. Weathers to rough, irregular, poorly exposed, buff to medium brownish gray ledges. The individual grains of sand, like those stratigraphically below, are small, moderately frosted, and subround. However, few pink-stained grains are present. This sand has been traced through most of the Bear Spring area and has been found to maintain a uniform thickness of 7 to 8 feet, to average close to 30 feet of stratigraphic separation from the base of the Ordovician above, and to be marked by a concentration of black persimmon bushes so that it shows on the aerial photographs as a narrow dark band. Glauconite occurs as scattered pellets, which are locally fairly abundant. Trilobite fragments are fairly common in the more coarsely granular limestone lenticles.	7	53	227 – 234
4. Limestone; mostly a zone of flat-pebble (shingle) conglomerate—matrix, phenoclasts, and nonconglomeratic beds varying from microgranular to medium grained, with most conspicuously conglomeratic beds being at 202, 207 to 212, and 214 to 216 feet; medium brownish, yellowish, or olive gray with buff dolomitic streaks, the phenoclasts generally being	28.5	81.5	198.5– 227

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	darker in color than the matrix; beds poorly exposed, apparently not exceeding 8 inches thick. Weathers medium bluish to brownish gray. Scattered grains of glauconite occur in various parts of interval 4 and are conspicuous in a few thin beds but not generally abundant.			
5.	Limestone in large part coarsely silty to very finely sandy and slightly dolomitic except for thin zones of flat-pebble conglomerate at 184.5 to 185 and at 198 feet—microgranular to very fine grained, except where conglomeratic; light yellowish gray to buff; beds from a small fraction of an inch to a few inches thick. Weathers to flaggy ledges or scattered slabs of float, dull brownish buff varying to yellowish gray. The abundant, clear, angular grains of detrital silica in the siliceous residues from the rocks average 0.06 to 0.12 mm. in diameter and thus are very fine grained sand. Small flakes of clear mica are scattered among it. Glauconite is uncommon, but occurs as scattered grains in some beds.	16	97.5	182.5– 198.5
6.	Calcareous sandstone and arenaceous limestone—very fine to medium grained; yellowish gray to almost white, with russet and buff spots where included dolomite grains have weathered; bedding indistinct, seemingly from 1 to 10 inches thick. Weathers to rough, slabby, medium yellowish or brownish gray ledges which uncommonly vary to buff and brick red. The weathered surface consists of a series of exposed ledges of sandstone and minor covered intervals with arenaceous limestone float. The sand grains in both the limestone and the sand, like that stratigraphically below, are small, moderately frosted, and subrounded to rounded. In general they seem less well rounded and less frosted than the sand in the Gorman formation of the Ellenburger group; and many are stained pinkish orange, whereas the sand grains in the Gorman formation are clear and untinted. Occasional glauconite grains occur but are uncommon except in the lower few inches which are quite glauconitic.	21.5	119	161 – 182.5
7.	Limestone—fine to medium grained, with occasional flat-pebble inclusions; mottled in yellowish and greenish grays; beds 1 to 10 inches thick. Weathering rough, medium bluish to brownish gray, poorly exposed in upper portion. Locally contains scattered globular glauconite. Fossils occur throughout interval 7, with *Owenella*, other small gastropods of unknown affinities, and trilobite fragments being common. *Owenella* was collected in the basal foot of the interval (TF–189) and small, unidentified gastropods resembling in their general form *Dirhachopea* and *Sinuopea* were collected at 159 to 160 feet (TF–190).	8	127	153 – 161
8.	Limestone, in part with irregular inclusions and abundantly scattered individual rhombs of dolomite; a conspicuous flat-pebble conglomerate in the top 5 inches—coarse to fine grained, with scattered individual oöids and irregularly shaped inclusions of various types throughout; medium to light brownish to yellowish gray; beds 1 to 12 inches thick. Weathers slabby, rough to smooth, medium to dark brownish to bluish gray. Lower 2 feet poorly exposed. Rare sand grains occur in the lower half and scattered to locally abundant sand grains in the upper half of interval 8.	21.5	148.5	131.5– 153

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
	Glauconite occurs as a few scattered globules in various parts of the interval and is fairly abundant in a thin bed a little below the middle. *Calvinella* and other trilobites were collected at 138 feet (TF–187). The gastropod *Owenella* was noted at 148 feet. At 150 feet the upper surface of the rock is crowded with narrowly conical fossils averaging 0.8 to 1.0 inch long and 0.2 inch in diameter at the wide end, composed of several similar cones packed one inside the other, and suggesting a primitive *Salterella*-like cephalopod (TF–188). *Owenella* and fragmentary trilobites were collected at 152 feet (TF–188a).			
9.	Limestone; in considerable part arenaceous, similar to that of interval 11—weathers as interval 11, except that the upper 7 feet weather to a lighter buff or even to a medium bluish gray color. The rock is very sandy, grading to calcareous sandstone, from 114.5 to 115.5, 123 to 125, and 126 to 126.5 feet. In the intervening portions it tends to be silty. Glauconite is generally uncommon, but scattered grains occur in a few thin beds. Trilobite fragments occur in the more calcareous and coarsely grained rocks in this interval.	20.5	169	111 – 131.5
10.	Limestone—medium to fine grained, yellowish to brownish gray, beds 1 to 9 inches thick. Weathers to inconspicuous, medium to light bluish gray ledges. Sand and glauconite are uncommon except that locally the top 4 inches of the interval are conspicuously arenaceous. Coarse silt grains are fairly common in the upper part of the interval.	6	175	105 – 111
11.	Silty and slightly dolomitic limestone with occasional pockets and beds of sand—the limestone is mostly very fine grained, grading to medium grained. It generally appears buff to brick red on a broken surface, but this is probably due to deep oxidation of the permeable rock, and the color of a truly fresh surface is probably closer to the light gray exhibited by some specimens. Beds 1 to 15 inches thick. Very small individual buff-weathered rhombs of dolomite may be seen in the freshest samples of the limestone. It weathers to conspicuous, slabby to irregular, buff to brick or cinnamon red ledges. Calcareous sandstone occurs from 79.5 to 80.5 feet and 90 to 102.3 feet. The sand grains are small, subround to round, and frosted. Except in the intervals noted, sand is rare in interval 11 directly in the line of section, but pockets of similar sand may be seen to occur sporadically throughout most of the interval when it is traced laterally. Glauconite is very rare or absent in this interval.	30	205	75 – 105
12.	Limestone, in part slightly dolomitic—coarse to fine grained; light yellowish gray to buff, grading to almost white; beds 1 to 7 inches thick. Weathers to medium bluish to brownish gray, platy ledges. Sand and glauconite grains occur sporadically but are uncommon. Coarse silt grains are fairly common toward the top of the interval.	8	213	67 – 75
13.	Arenaceous limestone with pockets of calcareous sandstone—the limestone is mostly medium grained, light brownish to yellowish gray, and in beds 2 to 25 inches thick. Weathers rough, buff, with the principal 25-inch bed forming a conspicuous break in slope.	7	220	60 – 67

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
The sand grains are small, moderately frosted, and fairly well rounded. Glauconite is fairly common in the lower half of the interval, but inconspicuous in the upper part.			
14. Limestone; with minor irregular inclusions of dolomite and grading laterally to dolomitic limestone and calcitic dolomite in the upper 3 feet, and with conspicuous dolomitic inclusions at 45 to 48 feet—medium grained to microgranular, with occasional lenticles of coarsely granular fossiliferous rock; principally medium brownish gray, grading to greenish gray, light yellowish gray, brown, and buff; beds 1 to 11 inches thick. The rock is filled with all sorts of inclusions—micro-oöids, irregularly shaped pelletlike bodies of various kinds, and individual buff-weathered dolomite rhombs—but no conspicuously oölitic beds were noted. Weathers to conspicuous, uneven, medium brownish to bluish gray ledges that grade to buff where dolomitic. A little coarse silt and an occasional small sand grain occur in the lower half of this interval. Glauconite grains are scattered throughout the interval and a few conspicuously glauconitic beds were present. Fragments of trilobites occur throughout the interval, especially from 39 to 42 feet. Small trilobites and a small, high-spired gastropod were collected from 41.5 to 44 feet (TF–186).	22.5	242.5	37.5– 60
15. Limestone; conspicuously dolomitic at 35–36 feet—differs from the limestone in interval 16 mainly in being more noticeably granular, ranging from microgranular to medium grained. Beds average a few inches thick but range from 1 to 14 inches. Globular glauconite is conspicuous in several thin zones in this interval. Trilobite fragments are scattered throughout interval 15, especially at 23, 24, and 34 feet. Agnostids, *Prosaukia*, and small unidentified tribolites were collected from a 6-inch zone at the top of the interval (TF–185).	23.5	266	14 – 37.5
16. Limestone, in part with irregular inclusions of dolomite—microgranular to fine grained, with scattered to abundant micro-oöids and tiny hollow rod- to spindle-shaped bodies and in part truly oölitic; medium brownish to greenish tones of gray, irregularly streaked and speckled throughout with darker brown spots of glauconite; beds 1 to 5 inches thick. Weathers irregularly, medium to dark brownish to bluish gray, in part with yellowish reticulations where dolomitic. Green globules of glauconite are scattered throughout interval 16, and the top 6 inches is extremely glauconitic. Occasional fragments of trilobites were seen but not collected. Silicified *Billingsella* was collected elsewhere in the Bear Spring area from rocks thought to be stratigraphically close to interval 16 (TF–154, TF–177), but none was seen in the Bluff Creek section.	12	278	2 – 14
Base of San Saba limestone member of Wilberns formation at base of interval 16. Thickness of member within limits postulated is 260 feet.			
Point Peak shale member: 2 feet described			
17. Limestone with minor inclusions of dolomite—microgranular to sublithographic, with scattered oöids and occasional small patches of calcite; medium to light brownish to olive gray, with browner mottles and green spots of glauconite. Weathers to an irregular hummock with a medium bluish gray surface.	2	280	0 – 2

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
A few scattered grains of glauconite were seen. Interval 17 comprises the top of a stromatolitic bioherm similar to those occurring all along Bluff Creek from the mouth of Gunstock Draw to Llano River. Lateral tracing shows that at places within the Bear Spring area these bioherms are laterally separated by silty green shale and platy crinkled limestones of the Point Peak type. Observations made along Cottonwood Draw, Gunstock Branch, and east of the Honey Creek fault indicate that this biohermal zone goes laterally into the more normal facies of the Point Peak shale member by increasing distance between the bioherms and their eventual elimination. Similar stromatolitic bioherms at essentially the same stratigraphic position are magnificently displayed in bluffs on the south side of Llano River opposite the mouth of Honey Creek and just east of the Bear Spring map area (Pls. 17 and 18). The interbioherm beds at that place are predominantly granular limestone but include conspicuous quantities of shale and are properly assignable to the Point Peak shale member. The tops of some of the thicker bioherms grew considerably above the sea floor, resulting in quaquaversal initial dips, probably emphasized by compaction, in the blanketing lower San Saba beds. The huenellid brachiopod *Mesonomia* which apparently holds the position of *Plectotrophia* was found 6 to 22 feet below the stromatolite bioherms just east of the Bear Spring map area.			
Base of Bluff Creek section, a segment of the composite Llano River section, at base of interval 17; altitude approximately 1425 feet. Mouth of a draw on the east side of Bluff Creek about 0.45 mile by trail upstream from its juncture with Llano River. Total thickness of section 280 feet, of which 262 feet belongs to the Wilberns formation of Upper Cambrian age and 18 feet to the Tanyard formation of Lower Ordovician age.			

Mason Section

After the planned field work on the Ellenburger project had been done and the maps completed it was found desirable to round out the data on the correlation chart for central Texas by carrying all sections to the base of the Wilberns formation. To do this for the composite Llano River section without considerable additional field studies required going to a locality which on the basis of reconnaissance observations and its expression on the aerial photographs looked promising. Only three such localities were known in the general area involved, and the Mason section was selected because the others, although on and near Llano River and more appropriately to be included with the Llano River section, did not extend downward to the Welge sandstone member of the Wilberns.

The Mason section begins about 3 miles by speedometer southwest from the Mason courthouse on the county road to White's Crossing of Llano River and about 6.5 miles northeast from White's Crossing. It starts at the inferred base of the Welge sandstone about 250 feet west of the road to White's Crossing from a point about 0.5 mile south of the fourth right-angle bend beyond Mason and 800 feet north of a 55° bend to a long west-southwesterly stretch of road. From here it extends about 1500 feet to the south up a gentle north-facing scarp to the base of the zone of stromatolitic bioherms in the upper part of the Point Peak shale member. The zone of bioherms was not measured, due to erratic attitudes in this part of the section, but its average thickness along Llano River opposite the mouth of Honey Creek and on Gunstock and Cottonwood Spring Draws is in the vicinity of 40 feet. It is probably not less than 40 feet thick and not much, if any, over 40 feet thick

above the Mason section, and this figure is assumed as an average for tying the Mason section to the composite Llano River section.

Measurements of a partial section of the Wilberns formation along the right (south) bank of Llano River east of White's Crossing indicate that the characters and thicknesses displayed by the stratigraphic units included in the Mason section are essentially similar to those of the same units on Llano River and that no serious inconsistency is involved in plotting them with the composite Llano River section. The Morgan Creek limestone member above the zone of *Eoorthis* is well displayed in the section along the south bank of Llano River east of the Honey Creek fault, and the measurement there made checks closely with that made for the Mason section. The Point Peak shale member, including the biohermal zone at the top, measured 20 feet thicker in the section east of White's Crossing than it did in the Mason section, the discrepancy possibly being due to poor exposures but not out of line with the progressive southward thickening of the Wilberns formation between the Mason and the Threadgill Creek sections.

The Mason section exhibits, from the base of the Wilberns up, the following units: about 25 feet of the Welge sandstone member, 120 feet of the Morgan Creek limestone member, and 115 feet of the Point Peak shale member to the base of the upper zone of stromatolitic bioherms. *Eoorthis texana* Walcott was found 71 feet above the base of the Wilberns (TF–463). *Plectotrophia* was not seen by the authors in the Bear Spring area or the Mason section, but the related huenellid brachiopod *Mesonomia* occurs about at the position where *Plectotrophia* should appear, both in the Mason section and in localities on the east bank of Honey Creek and the south bank of Llano River east of White's Crossing. *Mesonomia* is therefore provisionally considered to mark the horizon of *Plectotrophia* in this part of the Llano region and is the basis for its placement on Plate 14. The general characters of the units measured in the Mason section are shown graphically on Plate 14.

Buck Spring Section (Supplementary)

The base of the supplementary Buck Spring section is at the top of the upper or 7-foot sand of the San Saba limestone member of the Wilberns formation, 0.4 mile airline south of Buck Spring on the south side of Llano River and immediately east of the Bluff Creek fault zone (Pl. 5). Its top is 0.3 mile airline southeast of and uphill from its base, at the contact of the Threadgill and Staendebach members of the Tanyard formation.

This section was measured (not described) in order to obtain information on the thickness of the Threadgill member of the Tanyard formation at a locality where exposures are relatively continuous from the highest sand of the Wilberns formation to the Threadgill-Staendebach boundary. The measured thickness of the Threadgill member of the Tanyard in this section is 265 feet, and the stratigraphic distance from the upper or 7-foot sand of the San Saba limestone member of the Wilberns formation to the Cambrian-Ordovician boundary is about 35 feet. These figures compare with 294 feet of Threadgill rocks measured in the Pete Hollow section and 28 feet between the top of the sand and the Cambrian-Ordovician boundary in the Bluff Creek section. The same species of robust *Finkelnburgia** that occurs 8.5 feet below the Threadgill-Staendebach boundary in the Pete Hollow section (TF–196) was seen about 12 feet below the same boundary in the supplementary Buck Spring section; so the apparent variation in thickness of the Threadgill member, assuming that the robust *Finkelnburgia* marks a stratigraphic horizon, cannot be attributed to lateral transition of the limestone-dolomite contact, even though such transition is known to occur. It is doubtful if there is sufficient lateral variation in thickness of chronologically equivalent parts of the Threadgill member and of the strata intervening between the top of the uppermost sand of the Wilberns and the Cambrian-Ordovician boundary to account for the discrepant measurements; and as a matter of fact the correspondence of these measurements is within the

**Finkelnburgia obesa* Cloud (in press).

limits of error to be expected from measurements based on the obtainable geometric data.

LANGE'S MILL AREA, GILLESPIE COUNTY

INTRODUCTORY STATEMENT

The Lange's Mill area is located in northwestern Gillespie County and Lange's Mill, from which the area is named, is 2.2 miles airline north of the village of Doss. The map (Pl. 6) accompanying this report is a small portion of a larger published map entitled "Building stone area of northwestern Gillespie County" (*see* fig. 13, Univ. Texas Pub. 4246). The type section of the Threadgill member of the Tanyard formation is along Threadgill and Mormon creeks south of Lange's Mill, and the Wilberns section is downstream from Lange's Mill along Threadgill Creek.

Detailed mapping in the Lange's Mill area was started January 18, 1940, by Barnes and Mr. Louis Dixon, assistant. The Wilberns formation and the overlying rocks of the Lower Ordovician were found to be excellently exposed along Threadgill and Mormon creeks, and in January 1941, Dr. Josiah Bridge and Barnes, accompanied by Dr. W. Charles Bell and Mr. Louis Dixon, measured a preliminary section of the Wilberns formation and the overlying limestones. The Wilberns portion of the section was later remeasured by Barnes and Dixon using a plane table. Dixon painted interval numbers every 5 feet in the section, chip-sampled each interval for insoluble residues and microscopic examination, and made fossil collections wherever possible.

The Lower Ordovician limestone sequence so well exposed on Threadgill Creek was originally defined as the "Threadgill limestone" (Bridge and Barnes, *in* Barnes, 1944). It since has been changed to Threadgill member by Cloud, Barnes, and Bridge (1945), so that the equivalent dolomites of the eastern part of the Llano region could be included in this unit.

UPPER CAMBRIAN

WILBERNS FORMATION

Plate 6 covers only the upper portion of the Wilberns formation in the Lange's Mill area; for a map covering more of the Wilberns of the Lange's Mill area the reader is referred to figure 13 of The University of Texas Publication 4246. The Wilberns has not been divided on this map into all of the members now recognized. The bottom member of the Wilberns formation, the Welge sandstone, is mapped separately and the other three members are included under one symbol. However, the boundaries of these members on most of the map can be placed approximately in reference to features which are mapped. The boundary between the Morgan Creek limestone and the Point Peak shale members is about halfway between the *Eoorthis* bed and the "lower reef" (biostrome). The boundary between the Point Peak shale and the San Saba limestone members is about 28 feet stratigraphically above the *Billingsella* bed and on the map consequently will be only a short distance south of the trace of the *Billingsella* bed. The Pedernales dolomite member is absent except for minor small areas which were not mapped, mostly beneath the upper reef in the vicinity of Squaw Creek. However, dolomite rhombs are common in portions of the San Saba limestone member along Threadgill Creek.

The Threadgill Creek section probably displays the best sequence of the Wilberns formation in the Llano region, its rocks being highly fossiliferous and well exposed. It is here designated as the standard section for the Wilberns formation of the western part of the Llano uplift, where the upper part of the Wilberns is entirely in the calcitic facies. In the type section, at Wilberns Glen, in the eastern part of the region, the upper portion of the Wilberns formation is a dolomite.

Welge sandstone member.—The Welge sandstone member, as well as the underlying Lion Mountain sandstone member of the Riley formation, is well displayed along Squaw Creek just north of the map area. The Welge sandstone is brown, very sparsely glauconitic, and in part with reconstituted grains. It is sharply distinct from the highly glauconitic Lion Mountain sandstone beneath.

The Welge is named for the H. Welge surveys through which it passes, but the type section is designated as being along Squaw Creek in Mason County.

Morgan Creek limestone member.—The Morgan Creek limestone is reddish and sandy in the basal portion, being transitional from the Welge sandstone beneath. Upward the limestone is gray with a greenish cast from the enclosed glauconite. A thin bedded shaly zone approximately 30 feet thick is present about 18 feet beneath the top of the Morgan Creek limestone, and if it were not that it feathers out northward this shale would logically be included with the Point Peak shale.

Point Peak shale member.—The Point Peak shale member in this area contains very little shale and is chiefly very thinly bedded argillaceous limestone, which in the lower part is interspersed with thin silty limestone beds, intraformational conglomerates, and thin zones of stromatolitic limestone. Near the center of the Point Peak shale member is a stromatolitic biostrome 35 feet thick which extends throughout the map area.

San Saba limestone member.—The limestones of this member along Threadgill Creek (Pl. 19, fig. B) are thinly to thickly bedded, mostly granular and highly glauconitic in the upper part. A feature not present in the San Saba limestone on Threadgill Creek, but which is well displayed on Squaw Creek, is a thick zone of stromatolitic bioherms which is higher in the Wilberns formation than others so far noted elsewhere around the Llano region. A species of trilobite has been found in this biohermal zone that has not been found in the bedded sediments along Threadgill Creek at the same stratigraphic level. The same trilobite, however, has been found in cherts of the Pedernales dolomite member in the eastern part of the Llano region. If these trilobites lived among and are preserved with algal structures, then the dolomites with which they are found may likewise be of algal origin. The size of the bioherm along Squaw Creek leads one to wonder if the coarse grained, poorly bedded dolomites in the Pedernales dolomite in the eastern part of the uplift might be dolomitized algal bioherms of large size. If a sufficient number of reef-living forms could be found in chert from these dolomites they would furnish substantiating evidence for this supposition.

LOWER ORDOVICIAN

Ellenburger Group

Ordovician rocks outcropping in the Lange's Mill area (Univ. Texas Pub. 4246, fig. 13) are predominantly limestones of the Threadgill member of the Tanyard formation. A small graben of cherty dolomite belonging to the Staendebach member of the Tanyard formation is located in the northwestern corner of the Thos. R. Miller survey (locality 86T–13–20C). Similar dolomite along Squaw Creek near the southern edge of the map probably belongs to the Staendebach member. In this same area a small isolated outcrop of microgranular dolomite may belong to the dolomitic facies of the Gorman formation. The next two outcrops southward along Squaw Creek before the Paleozoic rocks disappear under rocks of Cretaceous age are massive limestones containing a small amount of sand. These rocks are entirely similar to the massive limestone in the calcitic facies of the Gorman formation. The only other similar limestone seen in the Ellenburger is in the upper part of the Honeycut formation of Blanco County, and so far as known these rocks are absent by truncation in this area.

Superficially the San Saba limestone member of the Wilberns formation and the limestones of the Threadgill member of the Tanyard formation have marked similarity at their contact, and sedimentation seems to have been continuous across the systemic boundary (Pl. 19, fig. D). Differences, however, are sufficiently well marked for the contact to be placed within a few feet. The limestone of the Threadgill member contains sublithographic beds which weather very light gray to white and smooth, whereas the limestones of the underlying San Saba are granular, many being microgranular, and they weather to various shades of medium gray with a slightly rougher surface. The limestone of the San Saba is glauconitic, in many cases only slightly so near the contact, and that of the Threadgill is nonglauconitic. The bed-

ding surfaces in the Threadgill contain calcitic fossils, mostly *Ophileta* and *Lytospira,* which with careful search ordinarily can be found down to the contact.

Much of the limestone in the type section of the Threadgill member of the Tanyard formation has an appearance best described as mottled, produced by ramifying or anastomosing structures resembling burrows (Pl. 20, fig. D). Within the burrow-like structures, the limestone is mostly microgranular and somewhat dolomitic, contrasting with the sublithographic limestone surrounding them. The beds are mostly 1 to 6 inches thick with occasional thicker ones present. A very small amount of smoky gray, waxy lustered, quartzose chert was seen near the middle of the section. The color of the limestone of the Threadgill is predominantly old ivory with variations toward yellow beige, yellowish gray, and a color similar to putty; and with minor splotches of reddish buff, hazel, and buttercup yellow. On aerial photographs the limestones of the Threadgill appear similar to those of the San Saba beneath. The vegetation consists of black persimmon, the scrub-mimosa known as catclaw, and other semi-arid types of plants, as well as some cedar.

The limestone of the Threadgill member in the type section (Pl. 19, figs. C and D) contrasts with the limestone at the same horizon in the eastern part of the Llano uplift (Pl. 20, fig. C), where the predominant color is pearl gray to woodash gray and old ivory and the beds are commonly thick.

The obvious fossils in the limestone of the Threadgill in the type section are on bedding surfaces and consist mostly of *Lytospira, Ophileta,* and *Gasconadia.* Silicified *Tetralobula* and *Finkelnburgia* are common about 50 feet above the base, and calcitic trilobites in the lower 100 feet in part resemble ones in the top of the San Saba.

CRETACEOUS

The Hensell sand member of the Travis Peak formation of Hill (1898) and associated conglomerates overlap the Threadgill member of the Tanyard formation throughout the Lange's Mill area. The Hensell was deposited in an area of high relief with conglomerates accumulating in valleys and little if any conglomerate being deposited on hills. One of these valley-fill conglomerates crops out for about a mile in the vicinity of Lange's Mill and possibly the same conglomerate reappears in the bottom of Onion Creek to the northwest (Univ. Texas Pub. 4246, fig. 13). The conglomerate is composed chiefly of Upper Cambrian and Lower Ordovician carbonate rocks, is as much as 40 feet in thickness, and is a desirable decorative building stone. The basal portion of the Hensell is red in color with the reds playing out upward into grays. The Hensell sand member of the Travis Peak formation in this area is really a shoreward facies of the Glen Rose limestone and only a few calcareous beds above the Hensell in this area can be classed as Glen Rose limestone. It is here called a member of the Travis Peak formation only because that is its present official classification and the nomenclatural details of Cretaceous stratigraphy are beyond the scope of this report. The Walnut clay is represented only by a very thin zone containing *Exogyra texana.* It is followed by the Comanche Peak limestone and the Edwards limestone, the latter being a resistant unit of the Cretaceous, capping the mesas and forming the high lands of Gillespie and adjoining counties.

CENOZOIC

Quaternary terrace gravel, deposited when Threadgill Creek was at a much higher level, masks some of the Threadgill rocks near their type section. The gravel is distinguished from the basal Cretaceous conglomerate chiefly by its content of chert from the Edwards limestone. Alluvium is present along both Threadgill and Mormon creeks at the upstream edge of the Threadgill outcrops, and on Mormon Creek it probably masks the contact of the Threadgill member with the Staendebach member of the Tanyard formation.

DESCRIPTION OF THE THREADGILL CREEK SECTION

The Threadgill Creek section is composed of three parts; the lower one in-

cludes the Welge sandstone member of the Wilberns, the middle part includes the rest of the Wilberns formation, and the upper part includes most of the Threadgill member of the Tanyard formation. The section is not shown by symbol on any map, but its location can readily be seen in figure 13 of The University of Texas Publication 4246 if the following distances and directions are observed. The bottom portion of the section is 5000 feet north-northeast of Lange's Mill and is along a small drain; the middle portion extends from 3100 feet north of Lange's Mill to 2700 feet due east of Lange's Mill and is on the east bank of Threadgill Creek except in the upper part; and the top portion of the section extends from 2700 feet south to 5900 feet slightly east of south of Lange's Mill and is situated along Threadgill and Mormon creeks. The location of the upper portion of the section may be seen in Plate 6 of this publication. The section is not faulted and of the two offsets one was made along a member boundary and the other along a systemic boundary.

Only the Threadgill member of the Tanyard formation and a few feet of the San Saba limestone member of the Wilberns formation are described in the following somewhat generalized description. A bed-by-bed description was not made in the field at the time the section was being measured, and the textures and colors taken are described from the collected samples. The fossils noted in the section at the time it was measured are only the more prominent ones. The intervening beds are mostly fossiliferous to a lesser degree. The mottling noted in the following description has mostly the appearance of burrows and trails which are somewhat dolomitic causing them to be distinctly different in texture and color from the enclosing sublithographic limestone (Pl. 20, fig. D).

A bed-by-bed description has not been made of the Wilberns portion of the section, and even though samples for each 5-foot interval are available a description is not made here since this section will be described in a forthcoming publication on the geology of Gillespie County.

The double column portrayal of the Wilberns formation in the correlation chart (Pl. 14) indicates accessory lithic elements described in detail, but the dominant rock is generalized in this section. Insoluble residues were available, making it desirable to use the second column to note them.

The following section was measured in January, 1941, by Josiah Bridge and V. E. Barnes, accompanied by W. C. Bell and Louis Dixon. It was sampled by Leo Hendricks, Louis Dixon, and V. E. Barnes in July, 1941.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Lower Ordovician			
Tanyard formation			
Threadgill member (bottom 280 feet present)			
Station 22 at top of section.			
1. Limestone—sublithographic, old ivory, thickly bedded.	2	2	293 – 295
2. Covered.	8	10	285 – 293
Station 21 at bottom of covered interval.			
3. Limestone—sublithographic, mottled old ivory to cinnamon, thinly to thickly bedded.	6	16	279 – 285
4. Dolomite—fine grained, reddish buff to brownish, one bed.	3	19	276 – 279
Station 19 at base of interval.			
5. Limestone—sublithographic, mottled old ivory to yellow beige, thinly to thickly bedded. Calcitic fossils are *Ophileta*, cephalopods, and other fossils on the surface of a bed at 272.5 feet and large cephalopods on the surface of a bed at 269.5 feet. "Fucoidal" markings, silicified, are on the surface of a bed at 266 feet.	10.5	29.5	265.5– 276
Station 18 is at 272.5 feet and station 17 is at 269.5 feet in section.			

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
6. Dolomite—fine grained, yellow beige, one bed. Station 16 at base of interval.	1.5	31	264 – 265.5
7. Limestone—sublithographic, mottled, old ivory to reddish buff, hazel, and buttercup yellow; beds 4 inches to a foot or more thick. Calcitic fossils are abundant on the bedding surfaces of the top 4 feet. Station 15 at base of interval.	15	46	249 – 264
8. Covered—at the foot of the valley wall to the east, float suggests that this interval is rather thinly bedded limestone. Station 14 at base of covered interval.	19	65	230 – 249
9. Limestone—sublithographic, mottled old ivory with a few areas hazel or darker, medium to thinly bedded. Station 11 at base of interval.	11	76	219 – 230
10. Limestone—sublithographic, mottled old ivory to reddish buff, medium to thinly bedded. Calcitic fossils are *Lytospira* on top surface. *Gasconadia*, cephalopods, and other fossils at 216 feet. Station 10 at bottom of interval.	16	92	203 – 219
11. Limestone—sublithographic, mottled, old ivory, medium to thinly bedded. Calcitic fossils on top surface are *Ophileta*, *Lytospira*, and cephalopods. Station 9 at bottom of interval.	30	122	173 – 203
12. Limestone—sublithographic, mottled, old ivory in top half; mostly brownish gray to beige in lower part; medium to thinly bedded. Chert smoky gray, quartzose, rare. Calcitic fossils are *Lytospira* and *Ophileta* on top surface. Station 8 is at bottom of interval and at top of a small falls.	41	163	132 – 173
13. Limestone—sublithographic, mottled, old ivory and reddish buff, medium to thinly bedded. Calcitic fossils include *Gasconadia* and other fossils. Station 7 at bottom of interval.	31	194	101 – 132
14. Limestone—sublithographic. mottled, brownish gray, medium to thinly bedded. Calcitic fossils are *Lytospira* in top surface. Station 6 at bottom of interval.	15	209	86 – 101
15. Limestone—sublithographic, mottled, between old ivory and brownish gray and some reddish buff, medium to thinly bedded. Calcitic fossils are *Lytospira* in the top surface. Station 5 at bottom of interval is a chiseled triangle cut in a prominent ledge at the mouth of Mormon Creek (east side).	7	216	79 – 86
16. Limestone—sublithographic, mottled old ivory with some reddish buff, medium to thinly bedded. Calcitic fossils include *Ophileta* in top surface. Station 4 at bottom of interval.	11	227	68 – 79
17. Limestone—sublithographic, mottled old ivory, medium to thinly bedded. Calcitic fossils include *Sinuopea* in upper surface and trilobites at base. Station 3 at bottom of interval.	7	234	61 – 68
18. Limestone—sublithographic, mottled old ivory to medium gray and brown, medium to thinly bedded. Station 2 at bottom of interval.	24	258	37 – 61
19. Limestone—sublithographic, mottled brownish gray to old ivory with top 5 feet reddish buff to fawn, medium to thinly bedded. Station 1 at bottom of interval is on Cambrian-Ordovician contact.	22	280	15 – 37
Upper Cambrian			
Wilberns formation			
San Saba limestone member (top 15 feet sampled)			
20. Limestone—granular, light to medium gray, alternately medium to thinly bedded, glauconitic.	15	295	0 – 15

CHEROKEE AREA, SAN SABA COUNTY

INTRODUCTORY STATEMENT

The Cherokee area, as here considered, is in southeastern San Saba County, between the towns of San Saba and Cherokee. The area that was mapped geologically lies between latitudes of 30° 59′ to 31° 12′ north, and longitude of 98° 36′ to 98° 46′. It is approximately bounded by the Cherokee and Little Llano River fault zones on the east, the Simpson Creek fault zone on the north, the Cherokee-San Saba road (State highway 16) on the west, and the Cherokee-Chappel road on the south. The 85 square miles mapped geologically comprise Plate 2, at the approximate scale of 1:31,680 and on a planimetric base. The Cherokee area is divisible into two unequal major fault blocks, here called the principal block and the southeast block. The southeast block lies between the ends of the Cherokee and Little Llano River fault zones, and the geologic features of part of that block are shown at the approximate scales of 1:10,000 and 1:20,000 in Plates 7 and 37. General geologic relationships of the area mapped are shown on a planimetric base at a scale of 1 inch equals 1 mile by F. B. Plummer (1940).

Control for the base map of the Cherokee area was taken from Texas State Highway Department traverses of State highway 16 and U.S. highway 190, in combination with the U.S. Coast and Geodetic Survey's base line between Dee and Cherokee triangulation stations. The base was plotted and adjusted by Cloud and R. L. Heller from data recorded by them on aerial photographs of the U.S. Department of Agriculture.

Rocks mapped within the Cherokee area include several members of the Wilberns formation (Upper Cambrian), all units of the Ellenburger group, and strata of Mississippian and Pennsylvanian age. No Devonian strata were noticed, but small patches or pockets of Devonian rocks could have been overlooked along the Ordovician-Mississippian boundary. Dips are mostly very gentle except in the vicinity of some faults and collapse contacts.

Fossils were collected from 160 localities in the Cherokee area. Of these collections 16 were from the Wilberns formation, 50 from the Tanyard formation, 50 from the Gorman formation, 38 from the Honeycut formation, and 9 from Carboniferous rocks. In addition, fossils were seen but not collected at many localities, including about 50 which were recorded and mapped.

The Cherokee Creek section, described on pages 199–219 and diagrammatically represented on Plate 14, displays a characteristic development of the Ellenburger rocks in the Cherokee area. Its location is shown on Plates 2, 7, and 37, whereas Table 2 presents a statistical evaluation of the grain sizes of the dolomites to be found in the various formations of the Ellenburger group in that section.

UPPER CAMBRIAN

Wilberns Formation

Pre-San Saba strata.—In the Cherokee area the strata mapped as undifferentiated Wilberns include the Point Peak shale member, the Morgan Creek limestone member, and locally the Welge sandstone member.

At the base is the Welge sandstone member, about 9 feet thick, relatively fine grained, rusty, sparingly glauconitic, and sparkling from reflections of reconstituted quartz.

The Morgan Creek limestone member is granular, reddish in the lower part and gray above, and fairly glauconitic. The basal layers are arenaceous, grading to the Welge sandstone; and locally a 30-foot shaly zone occurs at the middle of the member. The Morgan Creek limestone is locally highly fossiliferous, and the important zone fossil *Eoorthis* occurs about 58 feet above the base of the member (67 feet above base of Wilberns formation) and just below the 30-foot shaly zone where that is present. Topographically the Morgan Creek limestone member expresses itself as a subordinate strike ridge lying below a scarp occupied by the Point Peak shale member and separated from that scarp by a gentle strike valley. Where the middle shaly zone is present the member expresses itself as a

pair of subordinate strike ridges, with the shaly zone between, the dip slope of the upper strike ridge extending below the valley at the base of the Point Peak scarp, and the scarp slope of the lower strike ridge facing the flat at the top of the Riley formation.

The Point Peak shale member of the Wilberns formation consists of interbedded greenish shale and brownish, greenish, or grayish fragmental limestone with local beds of microgranular to sublithographic limestone. It crops out on a prominent scarp capped by or giving way to the relatively thickly bedded limestones of the San Saba limestone member of the Wilberns. The top of the Point Peak shale member in the Cherokee area is drawn at the highest appearance of a significant quantity of shale, commonly judged from topographic expression. A feature of the Point Peak shale is the occurrence, in close association with the more shaly portions, of impure green micaceous limestones that weather to thin plates with crinkled surfaces that are transected by calcite veinlets.

In its typical expression of minor limestone scarps and shale benches interrupting a regional strike scarp, one of the minor limestone scarps in the Point Peak shale member is the *Plectotrophia* bed. In the Cherokee area *Plectotrophia* normally occurs in a single bed 2 to 2.5 feet thick and 30 to 50 feet below the base of the San Saba limestone member as mapped. At one place *Plectotrophia* was found in two limestone beds having a total vertical range of about 5 feet, but in the Cherokee area it most commonly occurs only in the top few inches of one bed, and locally it is so abundant in these few inches that the matrix is scarcely more than a cementing medium about the exquisitely preserved silicified shells. *P. bridgei* Ulrich and Cooper is the common species, but *P. alata* (Walcott) seems to occur locally in the same stratum. Associated with *Plectotrophia* and ranging up to about 15 feet above it is an alate species of *Billingsella* (also silicified), serving to give the approximate position of *Plectotrophia* where found. A small species of *Billingsella* also occurs just below the San Saba strata, but no *Billingsella* has been found at a higher stratigraphic position than this in the Cherokee area.

Lithically the *Plectotrophia* bed is a medium to coarse grained, fragmental, glauconitic, fossiliferous limestone that is mottled or speckled in tones of brown, gray, and green (glauconite globules). It weathers medium gray to rose gray. Immediately below the *Plectotrophia* bed in the Cherokee area is a shaly zone containing beds of flat-pebble limestone conglomerate resembling lithified beach shingle. Although it was nowhere measured, this conspicuously conglomeratic zone is roughly 50 to 60 feet thick at most places and may extend to the base of the Point Peak shale member at some places.

San Saba limestone member.—This member of the upper Wilberns formation lies between the Point Peak shale and the Pedernales dolomite members in the Cherokee area. It grades upward and laterally to the Pedernales dolomite member, the two being essentially equivalent facies. Its thickness is variable and at most places uncertain; but it is probably nowhere less than 70 feet thick, and was estimated to be about 140 feet thick southeast of the Harris ranch headquarters in the southeastern corner of the Cherokee area.

The limestones of the San Saba member are sublithographic to unevenly granular and commonly contain numerous small round stromatolites about as big as an ordinary concord grape and known by the name of "girvanella." The matrix limestone is ordinarily some light tone of gray or yellowish gray and is commonly mottled with light bronze to gold and pale green streaks or blotches; whereas the more compact girvanellas maintain even gray tones. The San Saba strata weather to smooth ledges in even tones of medium gray, commonly with a brownish tinge; sections of contained girvanellas ordinarily weather to lighter colored circles.

In the Cherokee area the basal limestone beds of the San Saba typically cap a scarp, the face of which consists of the Point Peak shale member of the Wilberns formation. The succeeding limestones dip gently north in undulating

wrinkles below an area of gentle topography and thick cedar, to merge almost imperceptibly with the Pedernales dolomite member somewhere in this featureless jungle. Not only the character of the terrain, the transitional nature of the San Saba-Pedernales contact, structure, and gentle and undulating dips, but even dolomitization along joints conspire to confuse the geologist; and he is frequently uncertain as to the actual superposition of the beds. Under these circumstances it is likely that the San Saba-Pedernales contact may not be accurately located throughout its trace and that some of the outlying and inlying patches shown on the map represent recurrences of lithic types.

Pedernales dolomite member.—This uppermost member of the Wilberns formation lies between the San Saba limestone member below and the Tanyard formation of the Ellenburger group above, grading downward and laterally to the San Saba member, an essentially equivalent facies. The thickness of the Pedernales dolomite member is variable and at most places uncertain; but within the area mapped it is nowhere less than 70 feet thick nor more than 150 feet thick, and it was estimated to be about 90 feet thick southeast of the Harris ranch headquarters in the southeastern corner of the Cherokee area.

The Pedernales dolomite member of the Wilberns formation in the Cherokee area is fine to medium grained, tending to be coarser grained in the lower part and fine to very fine grained toward the top. Its fresh color ranges through medium tones of gray or brownish gray, and green spots of interstitial glauconite, as well as pinkish and yellowish tinges, are not uncommon. The weathered surface is smooth, commonly hummocky, and colored in dull medium tones of gray or brownish gray.

In the Cherokee area the Pedernales dolomite member is slightly cherty, with the chert limited to a belt in its middle or upper part. At places this cherty zone is immediately overlain by the truncating dolomites of the Tanyard formation, and, at some places, notably southeast from the line of the Cherokee Creek section, pebbles of what appears to be Pedernales dolomite are included in the basal bed of the Tanyard formation. The chert of the Pedernales member in the Cherokee area is typically minutely spongy or vesicular; abundantly and finely dolomoldic or, less commonly, oömoldic; and platy in structure. Freshly broken surfaces are colored in tones of yellowish to olive brown and beige, or, where internally weathered, russet to brick red. This chert weathers to dull tones of brown.

Stenopilus, Plethometopus, Euptychaspis (Dake and Bridge, 1932, p. 740, Pl. 12, fig. 3), and fragments of other fossils have been found in chert of the Pedernales in the Cherokee area, indicating general equivalence with the Eminence dolomite of Missouri.

LOWER ORDOVICIAN

ELLENBURGER GROUP

Tanyard formation, Threadgill member.—In the Cherokee area the basal, coarse to medium grained, nonglauconitic, light gray to white dolomite of the Threadgill member of the Tanyard formation rests disconformably (*see* above) upon the upper fine grained, interstitially glauconitic, medium gray or brownish gray dolomite of the Upper Cambrian Pedernales dolomite member of the Wilberns formation (Pl. 20, figs. A and B). The approximate position of this contact is marked topographically as well as lithologically, because a little down dip from it the flat and typically cedar-covered lowland of the Pedernales outcrop belt breaks to the rough bald or sparsely wooded hills of the Tanyard formation (Pl. 31, fig. B; Pl. 32, fig. B). The thickness of the Threadgill member in the Cherokee area probably averages about 260 feet, its measured thickness in the Cherokee Creek section.

Although dolomite predominates, limestone (Pl. 20, fig. C) occurs erratically in the lower part of the Threadgill member, shifting abruptly to dolomite along the strike and back to limestone again for no evident reason. The maximum thickness of the limestone in the Cherokee area is about 65 to 75 feet, on the Porch ranch. None was seen in the Cher-

okee Creek section, but slightly over 40 feet was measured in the Kirk ranch section a mile south-southeast of the Cherokee Creek section. These limestones are predominantly sublithographic and pearl gray to woodash gray or white. They commonly contain an irregular internal meshwork of dolomite that causes the rock to weather in a reticulate pattern.

The limestone beds locally contain patches of silica showing prominent subconcentric "beekite" rings easily mistaken for fossils by the uninitiated. Also occurring in the limestone are small excrescences of subchalcedonic, waxy lustered chert that is colored dark gray to pearl gray or woodash gray to white and weathers dull brown. The chert of the dolomites is mostly dolomoldic, quartzose, and subgranular to granular, but chert of types more characteristic of the Staendebach member of the Tanyard occurs locally.

Tanyard formation, Staendebach member.—The contact between the Threadgill and Staendebach members of the Tanyard formation in the Cherokee area is typically marked by a minor but persistent topographic bench (Pl. 31, fig. A; Pl. 32, fig. A) displaying slabs and cobbles of fine grained to very fine grained, nutria to beige or light gray dolomite, as well as thin slabs of the lowest laterally persistent porcelaneous and chalcedonic chert in the Ellenburger group in any significant quantity. Both the chert and the dolomite commonly contain angular to subrounded granule-sized fragments of different types of chert and at a few places are quite conglomeratic. Although the chert is locally absent for considerable stretches laterally, it is notably persistent when considered in an areal sense; and, in its association with the fine grained dolomite, the topographic bench, and the granule conglomerate, it ordinarily makes a good marker, above which the dolomite is generally finer grained and darker colored than it is below. Locally, however, several similar dolomites occur on several similar benches, and chalcedonic and porcelaneous chert occurs lower in the section; so the Threadgill-Staendebach contact may not everywhere be mapped at exactly the same stratigraphic position within the Cherokee area.

Lateral variation from limestone to dolomite is common in the Staendebach member in the Cherokee area; but in no instance does the limestone disappear completely, as do the thinner limestones of the Threadgill member. The lower Staendebach is persistently dolomitic and the upper beds are persistently calcitic. It is roughly estimated that the dolomitic facies ranges from 100 to 170 feet thick and the calcitic facies from 130 to 200 feet thick. The limestones are mostly sublithographic, pearl gray to woodash gray, and commonly with an internal meshwork of dolomite, that results in a reticulate pattern of weathering. The dolomites are fine to medium grained, locally very fine grained, and colored light gray to light brownish, pinkish, or yellowish gray to grayish brown, beige, or nutria.

Chert is common in both dolomite and limestone, occurring as nodules, concretions, plates, and irregular inclusions that are mostly porcelaneous to chalcedonic and commonly oölitic. Such chert is associated with dolomoldic and quartzose chert like that of the Threadgill member, and oölitic laminar cherts are a feature of the upper beds.

Gorman formation.—The Tanyard-Gorman contact in the Cherokee area is not well marked topographically (Pl. 33, fig. A); but it does display a vegetation break and is abrupt lithologically at most places, while supporting faunal evidence may ordinarily be found on search. Although the break from the limestones and fine to coarse grained dolomites of the Tanyard to the commonly microgranular or very fine grained dolomites of the Gorman formation is ordinarily sharp, it is not invariably so; and at least one locality, a little south-southeast of the J. W. McConnell ranch headquarters, the contact is within a local limestone interval. Bright tones of rose and beige are especially notable in the dolomites of the Gorman formation in the Cherokee area, and the sublithographic, pearl gray to woodash gray limestones of this formation less commonly contain an internal meshwork of dolomite than do those of the Tanyard strata.

Table 2. Grain sizes of dolomites in the Cherokee Creek section. (A proportionate representation, expressed in terms of feet of section, of grain sizes determined in the field in March, 1945.)

Rock unit	Micro-gran-ular	Micro-gran-ular to very fine grained	Very fine grained to micro-granular	Micro-granular to fine grained	Fine grained to micro-granular	Very fine grained	Fine grained	Fine to medium grained	Medium to fine grained	Medium grained	Medium to coarse grained	Coarse to medium grained
Honeycut fm.			12.5	10	4	6	3.5					
Gorman fm. (calcitic facies)	15			16.5			21.5	17.5				
Gorman fm. (dolomitic facies)	62	15.5		23.5	5		4.5	22	13.5	5		
Total dolomite of Gorman fm.	77	15.5		40	5		26	39.5	13.5	5		
Tanyard fm., Staendebach mem. (calcitic facies)									11	19	2	
Tanyard fm., Staendebach mem. (dolomitic facies)						5		84	35			
Total dolomite of Staendebach mem.						5		84	46	19	2	
Tanyard fm., Threadgill mem. (dolomitic facies and total dolomite)								71	22	9	25	133
Total dolomite in Tanyard fm.						5		155	68	28	27	133

As elsewhere in the Llano region the local occurrence of sand grains in both dolomite and limestone distinguishes the Gorman formation from the Tanyard.

The thickness of the dolomitic facies in the Cherokee area probably varies between 130 and 170 feet, and that of the calcitic facies between 260 and 300 feet. Measurements in the Cherokee Creek section give 151 and 275 feet respectively for the dolomitic and calcitic facies. Although dolomite is common in the calcitic facies of the Gorman formation, significant quantities of limestone do not generally occur in the dolomitic facies. A notable exception to this rule for the dolomitic facies is in the eastern part of the area, north of Rough Creek, east of the San Saba-Chappel road, and west of the Cherokee fault zone.

Archaeoscyphia occurs in a thin zone about 225 feet above the base of the Gorman formation through most of the Cherokee area, making an important horizon marker. Typical Gorman faunas were obtained at many localities, but fossils are generally less common than in the Tanyard and Honeycut formations.

Honeycut formation.—The thinly interbedded dolomites and limestones of the basal Honeycut strata break abruptly from the thickly bedded pure limestone sequence at the top of the Gorman formation, and the two formations are easily separated where they are in normal stratigraphic superposition. Throughout much of the area silicified specimens of the brachiopod *Xenelasma* may be found on the upper surface of the top bed of the Gorman formation, marking the lowest recorded occurrence of that genus as well as the Gorman-Honeycut contact. In the southeast fault block of the Cherokee area, the topographic break from the Gorman to the Honeycut formation is not well developed, but in the principal block it is very evident. Here, for several miles, the break from the rough, thickly cedared, vegetationally banded, poor pastureland of the upper limestone of the Gorman formation to the more open pastureland, with fewer cedars and scattered mesquite underlain by rocks of the Honeycut formation, occurs abruptly at the lower margin of an almost bare bench which is so marked that it is followed for much of its length by old pasture roads (Pl. 34, fig. B). This bench is mostly covered, but it is evident from the float that it is underlain by thinly bedded dolomites and limestones. Two to three beds of chert-matrix sandstone, grading laterally to arenaceous dolomite and limestone, occur in the lower 10 to 15 feet of the Honeycut strata along this bench, one being at or very near the base of that formation. The zone of silicified *Xenelasma* in limestone and the top of the Gorman formation come at the lower margin of this bench.

Lithically the dolomites and limestones of the Honeycut formation resemble those of the underlying Gorman strata, except that the dolomites are generally lighter tones of gray or beige and probably not so commonly microgranular. The alternation of limestone and dolomite beds is distinctive of the Honeycut.

West of the Little Llano River and Cherokee fault zones the top of the Honeycut formation almost coincides with the principal *Archaeoscyphia* bed and the zone of *Ceratopea capuliformis* (130 to 140 feet above the base). Rarely the *Archaeoscyphia* bed is absent because of pre-Mississippian truncation, and for short distances, up to about 25 feet of Honeycut strata appear above the principal *Archaeoscyphia* bed and below the Mississippian. Thus the Ellenburger-Mississippian contact is seen to be inconspicuously unconformable. Immediately east of the Little Llano River fault zone, however, in the southeastern part of the area, about 60 feet of Honeycut is exposed between the zone of *Ceratopea capuliformis* and the Mississippian; and in this unmapped fault block additional Honeycut strata peel out from under the Mississippian to display 250 to 300 feet of Honeycut strata just west of Chappel.

Sand grains have been seen to the top of the Honeycut formation in the Cherokee area, but, except in the lower 15 feet, are much less common than in the Gorman formation.

Although separable without difficulty where in normal stratigraphic succession,

painstaking study is ordinarily required to separate Honeycut strata from Gorman in faulted zones. The separation can best be made where diagnostic fossils are found, although the occurrence of sand might suggest the Gorman formation.

CARBONIFEROUS

The post-Ellenburger beds have been described on pages 42–60, and most geologists will experience little difficulty in distinguishing the characteristically dark, granular, and commonly crinoidal limestone, shales, and sandstones of the Carboniferous from the Ellenburger strata.

In the Cherokee area all Mississippian beds are mapped under one symbol and all Pennsylvanian strata under another, the reader being referred to Plummer's map of San Saba County (1940) for additional information on the distribution of the formations so mapped.

The Mississippian beds in the Cherokee area are, in ascending order: the thin, discontinuous, brownish, Ives breccia; the thin, discontinuous, gray to olive gray, crinoidal Chappel limestone; and widespread, dark, petroliferous shales and minor limestones of the Barnett formation. The two lower formations are too thin and sporadic in occurrence to express themselves topographically or dendrologically, but the outcrop of the shaly Barnett formation is marked by a conspicuous narrow mesquite-covered bench between the cedar-covered Marble Falls limestone (Pennsylvanian) above and the cedar-supporting limestones and dolomites of the Honeycut formation below.

DESCRIPTION OF THE CHEROKEE SECTIONS

The Cherokee Creek and Kirk ranch sections, described in detail, and the supplementary Harris ranch and Salt Branch sections serve to illustrate the development of the Ellenburger group and related lower Paleozoic rocks in the Cherokee area. The first three sections are located in the southeastern corner of the area in a large wedge between the north end of the Little Llano River fault zone and the south end of the Cherokee fault zone, and the Salt Branch section is a supplementary section just south of the Cherokee map area.

The Cherokee Creek section displays an unbroken sequence of Ellenburger rocks, but the Threadgill member of the Tanyard formation is entirely dolomitic in this section. Therefore the Kirk ranch section is described, in order to present the calcitic facies of the Threadgill member. The supplementary Harris ranch section furnishes estimates on the thicknesses of Upper Cambrian strata above the *Plectotrophia* zone. Although it is in an area of steep dips and minor faults, it is the most favorable locality in the Cherokee area for obtaining estimates of the thicknesses of the Pedernales dolomite and San Saba limestone members of the Wilberns formation. The Salt Branch section, south of the Cherokee map area, was measured in order to obtain reliable data on the rocks between the zone of *Plectotrophia* and the base of the Wilberns formation with which to round out the correlation chart for central Texas.

The sequence and approximate thicknesses of stratigraphic units displayed by these sections is as follows:

Stratigraphic unit	*Thickness in feet*
Mississippian (about 12 feet of the Barnett formation, 7 inches of the Chappel limestone, and 1 foot of the Ives breccia)	
Lower Ordovician-Ellenburger group (1128 to 1141 feet)	
Honeycut formation	142
Gorman formation (426 feet)	
Calcitic facies	275
Dolomitic facies	151
Tanyard formation (560 to 573 feet)	
Staendebach member (300 feet)	
Calcitic facies	176
Dolomitic facies	124
Threadgill member (260 to 273 feet)	
Upper dolomitic facies	165
Calcitic facies	41.5
Lower dolomitic facies	66.5
Upper Cambrian (545 feet measured)	
Wilberns formation (545 feet)	
Pedernales dolomite member	90
San Saba limestone member	140
Point Peak shale member	141
Morgan Creek limestone member	165
Welge sandstone member	9
Approximate total thickness of Ellenburger group and Wilberns formation	1680

Responsibility for measuring, marking, and describing the Cherokee sections is noted under the individual sections.

The Cherokee Creek section is on the S. L. Kirk and T. H. Young ranches, the Kirk ranch section is entirely on the S. L. Kirk ranch, and the Harris ranch section is on the ranch of Mrs. Julia Callahan Harris.

The locations of the sections are shown on the geologic maps (Pls. 2 and 7) by lines of inverted V's, except that the line of the Harris ranch section is omitted from Plate 7 because of crowding in this part of the map, and the Salt Branch section falls south of the map area. An unnamed supplementary section (marked S on Pl. 2) at the south margin of the mapped area covers the same stratigraphic interval as the Salt Branch section, but exposures are poor and attitudes of beds unreliable.

Cherokee Creek Section

The Cherokee Creek section is the only one known on the basis of detailed mapping to expose an unbroken sequence of rocks of the Ellenburger group that is complete from the disconformably underlying Cambrian to the unconformably overlapping Mississippian rocks. Due to thick vegetation and poor exposures frequent lateral shifts are required in traversing a route that gives satisfactory exposures of the entire sequence, but enough recognizable beds were traced laterally to justify reasonable assurance that the section measured is essentially continuous and unfaulted. Other sections in the Llano uplift offer better exposures, but no section believed to be reliable is more compact. Moreover, the Cherokee Creek section is especially important to the surface stratigraphy of the Ellenburger group, for it was in the vicinity of this section that the detailed sequence of the rocks and faunas was first worked out; and the formational and member subdivisions delineated here were later carried, with modifications, to other parts of the Llano region. Aside from the poor exposures in some intervals, its principal deficiency as a display section is that it exposes only 142 feet of the Honeycut formation, as compared to a maximum known thickness (at the surface) of 678 feet in the type section of this formation at Honeycut Bend on Pedernales River in Blanco County.

The Cherokee Creek section was first measured and described by Cloud and R. L. Heller in March 1944. At the same time V. E. Barnes and L. E. Warren ran a plane-table traverse for control, furnishing the basis for adjusted measurements. Subsequent experience with other sections and improvement in technique made redescription of the section desirable; and it was accordingly restudied, remeasured, and redescribed by Cloud in March 1945 using base control taken from the earlier plane-table traverse by Barnes and Warren.

The location of the section described is shown on the geologic maps that include this part of the Cherokee area (Pls. 2 and 7) and on a photographic stereogram (Pl. 37) by lines of inverted V's whose apexes point up in the section. Lateral offsets are indicated by dotted lines except where self-evident or where necessarily short and numerous, and in the latter event the line of section is generalized on the map. On the ground the line of traverse was originally marked by closely spaced yellow paint spots and arrows (not related to footage), beginning at the sixth cattle guard northeast (4.5 miles by speedometer) from State highway 16 at Cherokee on the road from Cherokee to the San Saba-Chappel road and ending 1.7 airline miles to the northeast on the southeast bank of Cherokee Creek. On redescription orange spots were painted at 5-foot intervals to facilitate sampling by those interested in detailed studies. The footage is marked at least every 50 feet, more closely in the upper part of the section where the route is difficult, and on all beds that were traced laterally. Alternate lines of traverse above the X bed and below the H bed are marked by yellow paint spots only. Painted lines of lateral shift, and the dotted lines on the maps, do not follow the actual datum traced where it follows a circuitous or difficult route.

The top of this section is at an altitude of 1372 feet, a little southeast of the right bank of Cherokee Creek. It is at a point not quite 0.4 mile airline north-northwest from the eighth cattle guard northeast (6.2 miles by speedometer) from Cherokee on the county road from Cherokee to the San Saba-Chappel road.

Its base is at an altitude of 1428 feet on a flat between a north-draining draw and the foot of a west-facing scarp. It is about 0.2 mile airline southeast of the sixth cattle guard northeast (4.5 miles by speedometer) from Cherokee on the county road from Cherokee to the San Saba-Chappel road.

The Cherokee Creek section as given below includes only strata of the Ellenburger group restricted. Its top is immediately below the Mississippian and its base is immediately above the highest fine to very fine grained, interstitially glauconitic, relatively dark colored Pedernales dolomite member of the Wilberns formation (uppermost Cambrian). Measurement of the Mississippian strata 700 feet south of the top of the Cherokee Creek section, at locality TF–426, showed from base to top, the following succession: Ives breccia, 1 foot; Chappel limestone, 7 inches; Barnett formation, about 12 feet. Estimates and measurements of the thicknesses of the Wilberns formation (Upper Cambrian) are given under the Harris ranch and Salt Branch sections.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Ellenburger group: 1128 feet thick			
Honeycut formation: 142 feet thick			
1. Limestone, with minor dolomitic inclusions and with 1 to 2 inches of dolomite at the top (altitude 1372 feet at top of section)—the limestone is sublithographic, in part a fine pellet limestone; pearl gray to light pinkish gray. The thin dolomite bed at the top is fine grained and nutria to olive brown. Bedding indeterminate. Weathers rough, in part reticulate; medium bluish gray. Silicified fossils present are *Archaeoscyphia* sp., *Ceratopea* cf. *C. capuliformis* Oder, and the siphuncle of a brevicone cephalopod cf. *Mcqueenoceras* (TF–95).	3.5	3.5	1124.5–1128
2. Dolomite—very fine grained to microgranular; olive brown to yellowish brown and nutria. Seems to be a single ledge. Weathers smooth, brownish gray.	1.5	5	1123 –1124.5
3. Limestone, dolomitic in the lower 3 to 4 feet—the limestone is sublithographic, varying to a fine pellet limestone; pearl gray to woodash gray, in part with irregular yellowish argillaceous films. In the lower 3 to 4 feet fine grained, yellowish gray to brownish olive dolomite forms a matrix for about an equal proportion of limestone inclusions, whereas in the upper beds dolomite is a minor component. Beds 1 to 13 inches thick and poorly exposed. Weathers uneven, reticulate in the lower part; medium gray to bluish gray. Chert occurs as irregular inclusions and nodules at 1107 feet and as scattered partially calcitic cannonballs above 1120 feet. The chert at 1107 feet is semichalcedonic, oölitic to crypto-oölitic; in part pseudospicular and in part actually showing the spicular structure of the sponge *Archaeoscyphia;* brownish to bluish gray to white. Fossils collected along the trace of the top few feet of this interval are *Ceratopea capuliformis* Oder, *Orospira* sp., *Hormotoma* sp., *Ophileta* sp. (TF–95a).	21	26	1102 –1123
4. Dolomite, grading to calcitic dolomite and minor limestone in the upper 2 feet—very fine grained to microgranular; biege to light grayish yellow, with pinkish mottles; beds	11	37	1091 –1102

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	from less than 1 inch to 18 inches thick. Weathers uneven, medium gray to pinkish gray; mostly covered in upper 2 feet.			
5.	Limestone—sublithographic, in part a fine pellet limestone; pearl gray; bedding indistinct. Weathers irregularly, medium bluish gray. Partially to largely chertified cannonballs are abundant in this interval. Fragments of fossils occur in the cannonballs and a small brevicone cephalopod was seen in the limestone.	1	38	1090 –1091
6.	Dolomite, in part calcitic—very fine grained, beige with occasional pink streaks, bedding indeterminate. Weathers irregular, medium gray.	3	41	1087 –1090
7.	Limestone—sublithographic; pearl gray to woodash gray, with irregular greenish to yellowish argillaceous films; beds from a fraction of an inch to a few inches thick. Weathers smooth, platy, medium to light bluish gray. Chert concretions and lenses ranging from the size of a walnut to that of a small watermelon are abundant in the lower 3 feet. It is chalcedonic to subporcelaneous; irregularly variegated and in part laminated in tones of bluish gray, brown, and white; and weathers in part to a chalky texture.	4	45	1083 –1087
8.	Limestone, with occasional dolomitic inclusions and in part slightly dolomitic—sublithographic, varying to fine grained where dolomitic, in part a fine pellet limestone and locally an intraformational breccia; pearl gray, grading to yellow and rose where dolomitic, and with irregular greenish and yellowish argillaceous films; beds from less than 1 inch to 12 inches thick. Weathers platy, medium gray and bluish gray; mostly covered from 1065 to 1070 feet. Minor chert occurs as nodules, lenses, and angular inclusions from 1057 to 1060 and 1065 to 1067 feet. It is subchalcedonic, bluish to brownish gray to white, and weathers shiny white to dull pinkish white. *Xenelasma syntrophioides* Ulrich and Cooper, *Ophileta* sp., and *Jeffersonia* sp. were collected (TF–102) from conglomeratic chert thought to weather out along the trace of this interval or the beds immediately below it.	28	73	1055 –1083
9.	Limestone—sublithographic; pearl gray to woodash gray, with greenish to yellowish argillaceous films; a markedly thinly bedded interval, with beds varying from a fraction of an inch to only a few inches thick. Weathers smooth, platy, medium gray; poorly exposed in upper part. Chert nodules occur at 1053 feet; being porcelaneous to semichalcedonic, white to light yellowish or brownish gray, in part concentrically banded.	6.5	79.5	1048.5–1055
10.	Dolomitic limestone, grading upward to limestone—the lower foot is comprised of fine grained, grayish yellow dolomite, with occasional subround to angular inclusions of sublithographic, pearl gray limestone; and the limestone increases in proportion upward, being almost pure, except for irregular yellowish argillaceous films, in the top 10 inches. Weathers reticulate, medium bluish gray. Chert is abundant for 1 to 2 inches at the top and bottom of the interval. That at the top occurs as fractured lenticles and thin, extensive lenses. It is chalcedonic, in part crypto-oölitic and pseudospicular; bluish gray to brownish gray and dirty white. That at the base is a thinly irregular layer of calcitic and oölitic chert or a chertified fine pellet layer. Fossils seen in the chert were poorly preserved *Ophileta* (?) and a low-spired "*Euconia*."	1.9	81.4	1046.6–1048.5

	Description	Thickness in feet: Interval	Cumulative	Feet above base
11.	Dolomite—fine grained; grayish brown and brownish gray, grading toward nutria, with minor lavender streaks; composed of one or two thin ledges. Weathers uneven, medium gray. Chert occurs as scattered small nodules. It is subchalcedonic to chalcedonic, bluish gray and weathers dirty white.	0.6	82	1046 –1046.6
12.	Limestone, in part dolomitic—sublithographic, varying to fine grained where dolomitic; pearl gray to woodash gray, with rose, nutria, and lavender mottles and streaks where dolomitic. Beds from less than 1 inch to 10 inches thick. Weathers solution pitted to reticulate, medium bluish gray with darker gray reticulations.	4	86	1042 –1046
13.	Dolomite—very fine grained; grayish brown to rose gray, with rose and nutria mottles; a single ledge. Weathers hackly to smooth, medium brownish gray to yellowish gray. Subspheroidal, partially chertified, calcitic masses 1 to 8 inches in diameter represent the lowest well-developed "cannon-ball chert" seen in place in this section. In addition rosettes and excrescences of fine grained quartz druse are common in this interval. A brevicone cephalopod and fragments of gastropods were seen in the chert.	3	89	1039 –1042
14.	Dolomite, in part calcitic and grading to dolomitic limestone at the base—fine grained; pinkish to yellowish gray to light gray; beds 1 to several inches thick, poorly exposed. Weathers platy, medium dark brownish gray.	3	92	1036 –1039
15.	Limestone, in part dolomitic toward top of interval—sublithographic, grading to fine grained where dolomitic, in part a fine pellet limestone or an oölite; pearl gray, with streaks and mottles of rose and dull orange where dolomitic; beds 1 to 17 inches thick. Weathers to regular, solution pitted, medium bluish gray ledges. A few partially silicified cannonballs, the lowest recorded from the section, were seen at 1030 to 1031 feet, and chert float occurs in the upper part of the interval. This chert float is partly semichalcedonic and oölitic and partly a granule conglomerate. It is white to light gray in color. Small, rounded, frosted sand grains were seen in some of the chert and limestone float in the upper part of the interval. Fossils were collected from cannon-ball chert weathering out along the trace of this interval or near it. They are *Xenelasma syntrophioides* Ulrich and Cooper, and a species of *Jeffersonia* (TF–103). Also a few poor unidentified calcitic snails were seen in place.	13	105	1023 –1036
16.	Dolomitic limestone and calcitic dolomite—fine grained; light gray to light pink, varying to light greenish gray and light yellow; beds 1 to 6 inches thick. Weathers platy, medium dark brownish gray.	4.5	109.5	1018.5–1023
17.	Limestone, with irregular dolomitic inclusions and in minor part dolomitic—sublithographic, grading to fine grained where dolomitic, in part a fine pellet limestone; woodash gray to pearl gray, with pinkish mottles and streaks where dolomitic; beds from less than 1 inch to 30 inches thick. Weathers solution pitted, medium bluish gray. Chert occurs as scattered nodules in a thin calcitic dolomite bed at 1014 feet; being chalk textured to porcelaneous, locally oölitic, white, and white weathering.	6	115.5	1012.5–1018.5
18.	Dolomitic limestone and calcitic dolomite—fine grained, grading to sublithographic where the limestone is pure; brownish gray to light rose pink and pearl gray; beds from	3.5	119	1009 –1012.5

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
less than 1 inch to 32 inches thick. Weathers rough, medium gray.			
19. Limestone, in part dolomitic—sublithographic, grading to fine grained where dolomitic; pearl gray to woodash gray, with irregular greenish argillaceous films and with occasional pink streaks where dolomitic; beds from less than 1 inch to 11 inches thick. Weathers solution pitted, in part reticulate, medium bluish gray.	7	126	1002 –1009
20. Dolomite—microgranular to fine grained; beige to light yellowish gray and light pink; beds heavy, weathering 1 to 42 inches thick. Weathers smoothly irregular to hackly, medium to dark gray. Chert weathers from the covered basal 2 feet of the interval as loose nodules and excrescences on slabs of dolomite. It is chalcedonic to subchalcedonic, in part oölitic, bluish to brownish gray to brown and white.	10	136	992 –1002
21. Limestone, with irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic; pearl gray with pink streaks. A 10-inch bed is exposed at the base, with the remainder of the interval covered. Weathers reticulate, medium bluish gray.	1.5	137.5	990.5– 992
22. Dolomite, grading to dolomitic limestone in the upper foot and going laterally to dolomitic limestone away from the line of section—fine grained to microgranular, light yellowish gray to beige. Consists of a single ledge that weathers to thinner beds along the trace of the interval. Weathers rough, in part pitted, medium gray to iron gray. Sandy chert, chert matrix sand, and arenaceous dolomitic limestone occur sporadically along the trace of this interval; but no sand was detected in the line of section.	4.5	142	986 – 990.5
Base of Honeycut formation at base of interval 22. Total thickness of formation 142 feet.			
A short lateral shift is made on the Gorman-Honeycut contact, moving north to the bank of Cherokee Creek if going up in the section and south to the top of Bee Cave Bluff if going down.			
Gorman formation: 426 feet thick			
Calcitic facies: 275 feet thick			
23. Limestone of remarkable purity—sublithographic to lithographic, in part a fine pellet limestone; pearl gray to woodash gray, with occasional pinkish mottles and streaks, and in part with irregular yellowish to greenish argillaceous films; beds ranging from a fraction of an inch to 7 feet thick. The beds in this interval are characteristically massive and the greater part of its thickness is accounted for by beds over 18 inches thick, interrupted by an occasional thin sequence of very thin beds. Weathers smooth to solution pitted, medium bluish gray. Characteristically resistant to non-chemical weathering, these beds form the upper part of Bee Cave Bluff, on the southeast side of Cherokee Creek. The limestone in this interval appears to be the purest as well as the most massively bedded in the Cherokee Creek section, visible dolomite grains being a very minor constituent. Moreover, a corresponding interval of unusually thick bedded and pure limestones averaging 40 to 55 feet thick, and locally with a dolomitic interval near the middle, seems to occur at the top of the Gorman formation throughout the Llano region. A set of four chemical analyses through interval 23 shows it to average 96.5 per cent $CaCO_3$; 2.27 per cent insolubles; and 1.23 per cent Fe_2O_3, Al_2O_3, and unaccounted for.	41.5	183.5	944.5– 986

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
	Chert was seen in place in the line of section only as minor irregular inclusions at 978 feet, where it is chalcedonic to subchalcedonic and bluish gray to white. It occurs in other beds along the trace of this interval where they are better exposed to weathering, but is generally uncommon. Silicified specimens of *Xenelasma syntrophioides* Ulrich and Cooper occur on the upper surface of the top ledge of this interval at the top of Bee Cave Bluff (986 feet above base of section), and cross sections of *Rhombella* and *Lecanospira* not uncommonly occur in the same bed along its trace; but no fossils were collected at this horizon in the southeast fault block of the Cherokee area. Several partially silicified specimens of *Lecanospira* were noted in the limestone at 978 feet but not collected. *Lecanospira, Hormotoma, Ophileta,* small unidentified gastropods, and a small trilobite were collected from rough chert weathering from the middle of this interval along its trace (TF–96); and *Lecanospira* and *Rhombella* were collected from the limestone 3.5 to 4.5 feet above the base of the interval (TF–94).			
24.	Dolomite, grading laterally to limestone with irregular dolomitic inclusions—the dolomite is fine grained, in part vuggy; light gray to light pinkish gray, locally grading to rose and nutria. The limestone is sublithographic; pearl gray to woodash gray, with irregular yellowish argillaceous films. The beds range from less than 1 inch to 17 inches thick. Weathers rough, in part pitted; medium gray to iron gray where dolomite; reticulate and medium bluish gray where limestone.	7.5	191	937 – 944.5
25.	Limestone, in part with irregular dolomitic inclusions—sublithographic, grading to fine grained where dolomitic, in part a fine pellet limestone; pearl gray to woodash gray, with pinkish and brownish streaks where dolomitic, and in part with irregular yellowish argillaceous films; beds from a fraction of an inch to 25 inches thick, being very thin in the top 18 inches. Weathers solution pitted, in part reticulate, medium bluish gray.	7.5	198.5	929.5– 937
26.	Dolomite, grading to calcitic dolomite in the top few feet—very fine grained to medium grained; beige and rose beige to light pinkish, yellowish, and brownish gray; beds from less than 1 inch to 24 inches thick. Weathers smooth, medium gray to light pinkish gray and light pink. Occasional guano-like patches of chalk textured chert were seen from 921 to 923 feet; and minor interstitial chert occurs in some beds.	15.5	214	914 – 929.5
27.	Limestone—sublithographic; pearl gray, with irregular yellowish argillaceous films; beds from less than 1 inch to 10 inches thick. Weathers solution pitted, medium bluish gray.	1.5	215.5	912.5– 914
28.	Dolomite, grading to calcitic dolomite and dolomitic limestone in upper part—fine grained to sublithographic; light pinkish to brownish gray, grading to beige and lavender, with occasional pink streaks. Bedding indeterminate. Weathers rough, medium to dark gray.	3	218.5	909.5– 912.5
29.	Limestone—sublithographic, in part a fine pellet limestone; pearl gray, with irregular yellowish and greenish argillaceous inclusions and minor pink streaks; beds up to 10 inches thick. Weathers smooth to solution pitted, medium bluish gray to light gray.	5	223.5	904.5– 909.5
30.	Dolomite, with interbeds of calcitic dolomite, dolomitic limestone, and limestone—the dolomite is fine grained and	12.5	236	892 – 904.5

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
gray to light pinkish and yellowish gray; whereas the limestone is sublithographic and pearl gray grading to the colors of the dolomite where dolomitic. Beds from less than 1 inch to 24 inches thick. Weathers uneven to reticulate; medium gray to iron gray where dolomitic and medium to light bluish gray in the calcitic portions. Small nodules of chert are common in the lower foot; being semiporcelaneous, micro-oölitic to crypto-oölitic; dull gray to brownish gray and white. Interstitial chert also occurs in some beds.			
31. Limestone, with minor irregular dolomitic inclusions—sublithographic, grading to fine grained where dolomitic; pearl gray, grading to pink where dolomitic, and with irregular yellowish argillaceous films; a single ledge weathering in part slabby. Weathers reticulate, medium bluish gray to gray.	1	237	891 – 892
32. Dolomite, grading to calcitic dolomite and dolomitic limestone at the base—microgranular to fine grained; light yellowish gray to beige, with mottles of darker gray or pink; beds mostly covered in the lower half, bedding indeterminate. Weathers to irregular medium gray to iron gray ledges in the upper part. Small nodules of chert are abundant in the upper part of the interval; being semichalcedonic to porcelaneous, dull white to light bluish or brownish gray.	6	243	885 – 891
33. Limestone—sublithographic, in part a fine pellet limestone; pearl gray to woodash gray, grading to light brownish gray and flesh-colored, with occasional pink streaks and small pink specks and locally with abundant irregular greenish to yellowish argillaceous films; beds seemingly several feet thick in ledges but weathering from less than 1 inch to 18 inches thick. Weathers solution pitted, medium bluish gray. Chert occurs as scattered nodules at the base of the interval; being semichalcedonic and bluish gray to dull white. Small patches of chalk textured guano-like chert were noticed at 874 feet and scattered nodular chert floats into the interval.	25	268	860 – 885
H bed at 860 feet. Altitude 1366 feet on the southeast bank of Cherokee Creek and 1471 feet at its south end, which is about 1400 feet south-southeast of its position in the bluff segment of the section and just west of a fault. Shift 1400 feet north-northwest if going up in the section and south-southeast if going down. (The exact trace of bed H is uncertain for the south 400 feet; but a check measurement made between bed H and the sandy interval called bed F from a point 340 feet south-southeast of Cherokee Creek substantiates the approximate position determined by topographic tracing. The arenaceous bed F was traced from the line of section to the check point.)			
34. Limestone—sublithographic; pearl gray to mouse gray, grading to woodash gray, in part with pink tinges and spots and in part with abundant irregular greenish to yellowish argillaceous inclusions; beds from a fraction of an inch to 10 inches thick. Weathers solution pitted, in part platy, medium bluish gray. Upper bed of interval is bed H. Minor chert occurs as angular inclusions at 849 feet; being subporcelaneous, slightly oölitic, pinkish gray to brownish gray. Scattered small sand grains were seen in the chert and limestone at 849 feet.	18.5	286.5	841.5– 860

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
35. Dolomite, grading to calcitic dolomite in the upper foot—microgranular to fine grained; mostly light gray, grading to light brownish and yellowish gray. Bedding indistinct, beds as much as 14 inches thick. Weathers smooth, medium gray to iron gray.	7.5	294	834 – 841.5
36. Limestone, in part dolomitic in the upper 4 feet—sublithographic, grading to medium grained where dolomitic; woodash gray to pearl gray, with irregular yellowish to whitish argillaceous films and occasional pink streaks, grading to light rose pink where dolomitic; beds 2 to 10 inches thick. Weathers to discontinuous, solution pitted, medium bluish gray ledges. Chert was observed as occasional small nodules and excrescences above 813 feet, being subchalcedonic to chalcedonic, and bluish to brownish gray to white. At 822.5 to 823 and again at 827 feet are thin plates or beds of oölitic chert of a bluish to brownish gray to light brown or dull white color and containing scattered sand grains. Concentrically banded concretionary chert comes in along the trace of the beds at 812 feet and rough ropy chert along the trace of those at 811 feet. Small subrounded to rounded and frosted sand grains are abundant in limestone and oölitic chert from 822.5 to 823 feet, a 2- to 4-inch layer of arenaceous limestone and oölitic sand-bearing chert occurs at 827 feet, and scattered grains of sand were seen in the limestone at 830 feet.	24	318	810 – 834
G bed at 810 feet; shift 100 feet east-southeast if going up in the section and west-northwest if going down.			
37. Limestone, with a 4-inch arenaceous zone at the base—sublithographic; woodash gray to pearl gray, with scattered pink streaks and small pink spots, and in part with irregular yellowish to greenish argillaceous films; beds from less than 1 inch to 16 inches thick. Weathers to regular smooth to solution pitted, medium bluish gray ledges. Rough, ropy fossiliferous chert comes into the lower part of this interval along its trace to the north-northwest. The 4-inch chert matrix sandstone (bed F), which occurs at the base of this interval in the line of section, grades laterally to arenaceous chert, calcareous sandstone, and arenaceous limestone. This arenaceous zone is persistent in the southeast fault block of the Cherokee area and makes a useful datum there. The sand grains are predominately rounded to subrounded, frosted, and uniformly very small, but large grains are not uncommon and quartz granules occur sporadically. The chert matrix is oölitic, and dull white, pearl gray, flesh-colored, or even rose gray on a fresh surface; weathering to shades of yellowish tan. The limestone matrix is woodash gray to pearl gray, or mottled in pearl gray and cinnamon pink; weathering medium to light bluish gray or white. Occasional sand grains also occur in the limestone for a few feet above bed F. Poorly preserved fossils collected from the ropy chert that comes into the lower part of this interval from a point about 600 feet north-northwest of its inferred position in the measured section are *Hormotoma, Lecanospira* (?), *Chepultapecia* (?), and unidentified gastropods and cephalopods (TF–98). Also *Hystricurus* sp. (a single cephalon) was collected from the F bed along its trace to the north-northwest (TF–97).	12	330	798 – 810
F bed (arenaceous) at 798 feet; shift 150 feet east-southeast if going up in the section and west-northwest if going down.			

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
38.	Limestone—sublithographic, in part a fine pellet limestone; pearl gray to woodash gray, with sporadic pink streaks and small pink specks, and in part with irregular greenish to yellowish argillaceous films; beds from less than 1 inch to 14 inches thick. Weathers to fairly regular, smooth or solution pitted, in part platy, medium bluish gray ledges. Very minor chert occurs as insignificant excrescences on the lowest beds.	11	341	787 – 798
39.	Limestone—sublithographic, in part a pellet limestone; woodash gray to pearl gray, in part with scattered small pink spots and irregular yellowish argillaceous films; beds from less than 1 inch to 8 inches thick. Weathers smooth, medium bluish gray. Chert occurs as scattered irregular patches; being chalk textured to subporcelaneous or semichalcedonic and chalk white to bluish and brownish gray. It weathers dull white and that in the lower part especially has a guano-like appearance. *Archaeoscyphia* occurs in interval 39 (TF–99) as worn and broken fragments which ordinarily have no distinguishing external characters and are not recognizable as fossil remains until broken and wetted, when the spicular structure of the sponge wall is evident. This interval is an important datum and was traced across the main fault block of the Cherokee area as well as several minor fault blocks; the guano-like chert serving to call attention to it and the spicular structure of *Archaeoscyphia* identifying it.	3	344	784 – 787
40.	Limestone—sublithographic; pearl gray to woodash gray, locally with scattered pink streaks and small pink specks, and in part with irregular yellowish to dusty green or white argillaceous films; beds from less than 1 inch to 22 inches thick. Weathers smooth, medium to light bluish gray. Minor chert occurs as nodules and lenticles at 778 feet, as occasional large spheroidal masses at 782 feet, and as float. It is subchalcedonic to subporcelaneous or chalk textured, bluish gray to bluish white and chalk white, and weathers yellowish white. In dolomite float at the base of the interval occur lenticles of semichalcedonic to porcelaneous, in part micro-oölitic, bluish gray to white and dull carnelian chert.	16	360	768 – 784
41.	Dolomite—fine grained; light gray to light pinkish gray, beige, rose beige and rose; bedding indeterminate. Weathers to discontinuous medium to light gray ledges. Minor interstitial chert was seen. Sand grains of pin point size were seen to be abundant in one piece of dolomite float at the base of the interval. Silicified *Lecanospira* was seen and the siphuncle of *Piloceras* resembling *P. hornei* Ulrich, Foerste, and Miller was collected 700 feet southeast of the line of section (TF–90), from a limestone which is either the lateral equivalent of interval 41 or belongs to the immediately superjacent or subjacent beds.	4	364	764 – 768
42.	Limestone, with minor irregular dolomitic inclusions—sublithographic, grading to fine grained where dolomitic; in part a pellet limestone; pearl gray to woodash gray, and light brownish gray, in part with irregular whitish argillaceous inclusions; beds thin but bedding indeterminate. Weathers to discontinuous, smooth to rough, medium bluish gray ledges.	14	378	750 – 764

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
Chert occurs as ropy layers, irregular nodules, and rough excrescences; abundant in place in the upper 4 feet and in the float below. It is chalcedonic to porcelaneous, in part chalk textured, in part crypto-oölitic to oölitic, and in part apparently a chertified pellet limestone with a texture approaching that of the cannonball chert. Locally it is quartzose; and the color varies through bluish gray, to brownish gray, pearl gray, and china white. *Syntrophinella* was seen in place in chert at the top of interval 42, as were also small trilobites and gastropods; but none were collected.			
E bed at 750 feet; shift 120 feet east-southeast if going up in the section and west-northwest if going down.			
43. Dolomite, as judged from float in a largely covered interval; grading to calcitic dolomite and dolomitic limestone at the top, and apparently going laterally to limestone in the upper beds—predominantly microgranular, grading to fine or even medium grained in the upper part; mouse gray, yellowish gray, beige, and rose beige, locally grading to salmon or coral pink. The minor exposures and scattered float cobbles weather smoothly uneven, light to medium gray and tan. Minor chert float in the upper part of the interval is in part a granule breccia. It is subchalcedonic to subgranular, in part with quartzose inclusions; varies through bluish gray, brownish gray, tan, and pearl gray; and weathers dull orange or bluish white. Interstitial chert occurs in some of the dolomite.	20	398	730 – 750
44 Mostly limestone, as judged from float in a largely covered interval; in part with irregular dolomitic inclusions—mostly sublithographic, grading to medium grained where dolomitic, in part a pellet limestone; woodash gray to pearl gray and white, with sporadic small pink spots. Exposed rock weathers smooth to rough and medium bluish gray. Chert is abundant below 715 feet as large blocks, and not uncommon as excrescences, surficial coatings, and angular blocks above. It is semiporcelaneous to subgranular, commonly oölitic to crypto-oölitic, in part with drusy vugs, commonly finely drusy on broken surfaces, white to brownish gray. Some oöids are white in a brownish gray matrix and some of the so-called oölitic chert may represent chertified pellet limestone.	19	417	711 – 730
Base of calcitic facies of Gorman formation at base of interval 44 (altitude about 1485 feet). Thickness of facies 275 feet.			
Dolomitic facies: 151 feet thick			
45. Dolomite, as judged from float and poor exposures in a mostly covered interval; grading to calcitic dolomite and dolomitic limestone at top—mostly microgranular in lower 22 feet, grading to fine and medium grained in upper 11 feet; rose beige, beige, rose, rose gray, and light yellowish gray to coral pink; bedding indeterminate. Weathers to a mostly covered interval strewn with smooth, light to medium gray and yellowish gray cobbles of dolomite. Scattered to abundant chert weathers from this interval, especially in the lower 20 feet; being porcelaneous to subgranular or chalk textured, with scattered tiny dolomolds, in part quartzose, china white to bluish or yellowish gray. *"Euconia"* sp. (TF–69a) was collected from chert along the trace of this interval.	33	450	678 – 711
D bed (arenaceous) at 678 feet; shift 700 feet southeast if going up in the section and northwest if going down.			

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
46. Dolomite—mostly microgranular, in part grading to very fine grained; light yellowish and pinkish gray to beige and rose beige, with rose mottles; bedding indeterminate. Weathers to discontinuous ledges in a largely covered and rubble strewn surface; the ledges and float cobbles being smooth, medium to light gray and yellowish gray. Scattered angular inclusions, nodules, and plates of chert occur at 662 feet and in the upper 3 feet of the interval. It is subchalcedonic; in part crypto-oölitic and pseudospicular; varies through bluish gray, brownish gray, white, rose, and light pink; and weathers shiny white to pinkish white. Irregular plates and coatings of fine to medium grained quartz druse are common in the upper 3 feet. Porcelaneous, china white, in part finely dolomoldic chert may weather out of the upper part of this interval, but it more probably floats down from above. Sand occurs in the upper foot of interval 46 (bed D); constituting an arenaceous dolomite in the line of section, but grading laterally to dolomitic sandstone with tiny rounded to subrounded and frosted sand grains which in general are not well sorted within their small size limits. In color it ranges through tones of beige; varying to white where bleached or brick red to russet where oxidized, and weathering to medium tones of gray and tan. Bed D is fairly persistent and was traced the breadth of the southeast block of the Cherokee area as an arenaceous zone varying from 5 inches to about 2 feet thick. Occasional sand grains also occur for about 18 inches below bed D. Fossils were collected from chert float along the trace of the upper part of this interval, but the chert was probably derived from interval 45. They are "*Euconia*" sp., *Ophileta* sp., and *Raphistomina* (?) sp. (TF–69).	23.5	473.5	654.5– 678
47. Dolomite, in minor part grading to calcitic dolomite and dolomitic limestone in the lower 5 feet—mostly fine to medium grained, grading to microgranular from 638 to 643 feet; yellowish gray, grayish yellow, rose gray, and light rose, in part grading to medium gray; beds 1 to 12 inches thick. Weathers to uneven, medium gray ledges. Chert is abundant in the lower 5.5 feet as thin plates, angular inclusions, excrescences, and surficial coatings; varying from subgranular to subporcelaneous, white, and white weathering chert to dolomoldic and finely drusy chert or films of fine grained quartz druse. Interstitial chert is abundant in the dolomite of the lower 5.5 feet and occasional above.	22	495.5	632.5– 654.5
48. Dolomite—mostly microgranular, but with a few thin beds that are medium to fine grained; mostly beige to light yellowish gray, grading to rose beige, light rose, and cinnamon pink; bedding indeterminate. Weathers to discontinuous, medium gray ledges alternating with largely covered portions. Minor coatings of fine grained quartz druse were seen in place, and interstitial chert occurs in the medium grained beds. Angular chips of chert float of uncertain derivation occur in fair abundance; being principally porcelaneous to chalk textured, locally quartzose, and having scattered tiny dolomolds and occasional cavities lined with dolomolds. It is china white to woodash gray or pinkish white and weathers shiny white to dull tan.	27.5	523	605 – 632.5

C bed at 605 feet; shift about 210 feet north-northwest if going up in the section and south-southeast if going down. This shift is made on the basis of a zone of billowy surfaced chert lenses or plates an inch or two thick and up to 10 inches across (projected for about 50 feet at the north end of the

Description	*Thickness in feet Interval*	*Cumulative*	*Feet above base*
shift) that weather out about 5 feet above the bed marked C. This chert varies from semichalcedonic to porcelaneous, subgranular, and locally chalk textured, and is generally crowded with indistinct pin point inclusions. It is bluish to brownish gray to chalk white in color, in part concentrically banded, and weathers yellowish white to tan or white.			
49. Dolomite—microgranular to medium grained; consisting of microgranular to very fine grained dolomite (total of 10 feet) interbedded with medium to fine grained dolomite (total of 8 feet). Rose beige, beige, and rose gray, grading to pinkish and yellowish gray. Bedding indeterminate, beds poorly exposed. Weathers to alternating, thin, medium gray to light yellowish gray or tan ledges and covered portions. Coatings of fine to medium grained quartz druse are common throughout the interval, and interstitial chert characterizes the medium grained beds. Occasional nodules of chalcedonic to porcelaneous chert also were seen, and along the trace of the lower foot of the interval abundant angular pieces of chert may be found. This lower chert is mostly porcelaneous, grading to subgranular and semichalcedonic; white to bluish gray; and weathers shiny white or yellowish white.	18	541	587 – 605
50. Calcitic dolomite, in part grading to dolomitic limestone—medium grained, light pinkish gray to light gray; bedding indeterminate. Weathers rough, medium gray, poorly exposed. Interstitial chert and small patches of chalk textured chert are occasional throughout. Coatings of rough, dark weathering quartz druse were seen near the base of the interval.	5	546	582 – 587
51. Dolomite—microgranular to fine grained, locally with a few scattered vugs; beige to light yellowish gray, varying to rose gray and light grayish yellow, in part with rose to lavender streaks; bedding indeterminate. Weathers to a largely covered interval that is strewn with smooth or slightly pitted, medium to light gray weathering cobbles and has a few medium gray ledges exposed in the lower part. Chert float is abundant in the lower part of the interval and chert was seen in place between 568 and 572 feet as prominent layers, with occasional nodules above. From 570 to 572 feet the chert is chalcedonic to porcelaneous; bluish gray, brown, and china white; and weathers mostly shiny white. From 568 to 570 feet it is porcelaneous to subporcelaneous, with scattered small dolomolds and disseminated quartz, and commonly interlayered with a lesser amount of quartz druse; it is china white to woodash gray on a fresh surface except that where penetrated by oxidation in the drusy layers it is russet to dull brown. Interstitial chert occurs in the dolomite at 570 feet. *Rhombella* was found in the chert from this interval at locality TF-61. Although sand-bearing chert is fairly common near or at the base of the Gorman formation in parts of the principal fault block of the Cherokee area, none was noted at this position in or near the base of the Cherokee Creek section.	17.5	563.5	564.5– 582
52. Dolomite—fine grained in the line of described section, but going laterally to microgranular dolomite as may be seen above the Tanyard-Gorman contact in the south segment of the section and intermittently along the trace of this interval. Light yellowish or pinkish gray to beige, with	4.5	568	560 – 564.5

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
darker yellowish streaks. Bedding indeterminate. Weathers to a largely covered interval with a few thin medium gray ledges cropping out. Interstitial chert is fairly common, as well as float of blocky weathered chert in part apparently weathering from this interval and in part from above. Lateral tracing indicates that the locally derived chert is predominantly a type composed of irregularly interlayered or interlacing fine quartz druse and a lesser amount of porcelaneous china white chert with scattered small dolomolds. Generally similar chert from the interval stratigraphically above contains typical Gorman fossils. *Hystricurus* sp., "*Euconia*," and a well preserved but unidentified brevicone cephalopod were collected a foot or two above the base of this interval and the Gorman formation (TF–65) as traced beyond the line of section.			
Base of dolomitic facies of Gorman formation at base of interval 52. Total thickness of facies 151 feet, and of formation 426 feet.			
Gorman-Tanyard contact at 560 feet—altitude 1473 feet in line of section southeast of county road and 1443 feet in line of section northwest of county road. Shift 1450 feet northwest if going up in the section and southeast if going down. (Because some of the lower microgranular dolomite of the Gorman formation and possibly some of the upper limestone of the Tanyard formation in the Cherokee area goes laterally to fine to medium grained dolomite along this contact, it is not a hairline break as traced in the field; but evidence from lateral tracing closely limits its position and at no place along the 1450-foot shift are more than 4 or 5 feet of beds in question.)			
Tanyard formation: 560 feet thick			
Staendebach member (type section): 300 feet thick			
Calcitic facies: 176 feet thick			
53. Limestone; apparently pure from 540 to 556 feet, but with irregular dolomitic inclusions in the lower 10 feet and the top 4 feet—sublithographic, varying to medium grained where dolomitic, in part a fine pellet limestone; pearl gray to woodash gray, varying to flesh-colored where dolomitic, in part with minor pinkish tinges; beds 1 to 9 inches thick. Weathers uneven, reticulate where dolomitic, medium bluish gray. Chert is abundant in the lower 2.5 feet as layers or extensive lenses and plates strung out parallel to the bedding; being subchalcedonic to porcelaneous, bluish gray to china white, in part banded. Above the basal very cherty zone it occurs as occasional nodules, lenses, plates, and angular inclusions to the top of the interval, and as a thin layer at 339.5 feet; being chalcedonic to subgranular, in part oölitic to crypto-oölitic and pseudospicular, locally with quartzose inclusions and scattered dolomolds. A fresh surface is light bluish or brownish gray to brownish orange or white, in part laminated; whereas weathered surfaces are white to yellowish gray. The top few feet of the interval are marked by finely drusy and in part dolomoldic excrescences, vugs, and coatings and by oölitic to oömoldic laminar chert. *Ozarkina* was noted at several places along the trace of the upper part of this interval, locally accompanied by other fossils, but no fossils were noted or collected from these beds in the line of section.	30	598	530 – 560
54. Limestone, with irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic, locally a fine pellet limestone; gray to light brownish or pinkish	19	617	511 – 530

	Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
	gray; beds 3 to 22 inches thick. Weathers uneven, locally reticulated; medium bluish gray. Chert was seen in place only in the lower 5 feet where it occurs as occasional platy to irregular inclusions. It is semichalcedonic to chalcedonic, in part oölitic, bluish gray to white.			
55.	Dolomite, slightly calcitic and in minor part grading to limestone—medium to fine grained, pearl gray with sporadic light pinkish spots, beds up to at least 30 inches thick. Weathers uneven, in part pitted, medium to medium dark gray. Chert occurs as scattered excrescences and irregular inclusions; being dolomoldic and finely drusy to semichalcedonic, locally oölitic, bluish to brownish gray.	9	626	502 – 511
56.	Dolomitic limestone and calcitic dolomite—sublithographic to coarse grained; pearl gray to woodash gray, grading to light brownish to pinkish gray; bedding indeterminate. Weathers rough, in part reticulate, in part pitted, medium gray to medium bluish gray. Chert occurs as minor thin plates and excrescences, partly oölitic and dirty white. Fossils were collected from a subporcelaneous to granular or chalk textured dirty white chert weathering out near the trace of this interval or interval 55 about 1400 feet northwest of here (TF–49). They are cystid plates, *Ozarkina*, cf. *O. typica* Ulrich and Bridge, *Helicotoma* sp., *Chepultapecia* sp., *Ectenoceras* sp., unidentified brevicone cephalopods, and *Paraplethopeltis*.	6	632	496 – 502
57.	Limestone, with irregular dolomitic inclusions—sublithographic to fine grained; woodash gray or pearl gray, grading to light brownish gray; beds from less than 1 inch to 14 inches thick. Weathers reticulate, medium bluish gray. Oölitic laminar chert occurs from 487 to 488 feet. Above 488 feet chert is fairly abundant as excrescences, lenses, nodules, and plates; being subchalcedonic to subporcelaneous and locally crypto-oölitic or dolomoldic and quartzose, in part concentrically banded, bluish gray to pinkish white and white.	16	648	480 – 496
58.	Limestone, with minor irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic; woodash gray to pearl gray; a single ledge. Weathers rough to smooth, medium bluish gray. The minor chert present consists of subporcelaneous, dolomoldic, dirty white excrescences. Fossils collected from the limestone (TF–93) include *Ozarkina* cf. *O. complanata* Ulrich and Bridge, *O.* cf. *O. typica* Ulrich and Bridge, *Ophileta* sp., *Helicotoma* cf. *H. uniangulata* (Hall), *Clarkoceras?*, and *Paraplethopeltis*.	1	649	479 – 480
59.	Limestone, with abundant irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic; pearl gray or light brownish gray, grading to light pinkish gray where dolomitic; beds 1 to 14 inches thick. Weathers rough, reticulate; medium bluish gray. Above 474 feet chert is abundant; being mostly oölitic and laminar with holes resembling molds of flat pebbles. It is subgranular to porcelaneous, in part quartzose, breaking with a fracture like that of paraffin; brownish to bluish gray to dirty white, in part with purplish or pinkish tinges. In the lower beds scattered chert occurs as irregular nodules and ropy excrescences; being subgranular to semichal-	13.5	662.5	465.5– 479

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
cedonic, in part finely drusy, locally crypto-oölitic and pseudospicular, white to gray to purplish gray. *Ozarkina* cf. *O. typica* Ulrich and Bridge was collected from limestone in place 2.5 feet above the base of this interval (TF–93a). Fossils were also seen in chert float at 479 feet, being recorded as *Ozarkina* cf. *O. typica* Ulrich and Bridge and a small species of *Sinuopea*, but not collected. Fossils were collected from granular, dirty pinkish white, russet weathering chert about on the trace of the upper part of this interval 600 feet west-northwest from the line of section. They are *Ozarkina* cf. *O. complanata* Ulrich and Bridge, *Ophileta* sp., *Schizopea* sp., *Ectenoceras?*, a large brevicone cephalopod, and *Paraplethopeltis* (TF–47).			
60. Limestone and chert; the top 6 to 12 inches being oölitic laminar chert and the remainder limestone with abundant irregular dolomitic inclusions—the limestone is sublithographic, grading to medium grained where dolomitic; pearl gray, grading to woodash gray or light pink where dolomitic; poorly exposed. It weathers reticulate, medium bluish gray. The chert in the top foot of this interval is subgranular to subporcelaneous, oölitic and laminar, in minor part quartzose; bluish to brownish gray to white, in part banded. Besides the type described, abundant chert was seen to weather out from the lower beds where traced laterally. This lower chert is semichalcedonic to subgranular or finely granular, commonly resembling fractured paraffin on a freshly broken surface; partly crypto-oölitic, dolomoldic, and chalk textured; in part layered with holes resembling molds of flat pebbles; light gray to dirty white on a fresh surface; and weathers to light shades of russet, tan, or dirty white. Fossils collected from chert at locality TF–29 are thought to be about on the trace of this interval or immediately below it. They include *Helicotoma* cf. *H. uniangulata* (Hall), *Schizopea* sp., *Sinuopea* sp., *Ophileta* sp., *Ectenoceras* sp., and a larger brevicone cephalopod.	5.5	668	460 – 465.5
B bed at 460 feet (altitude 1420 feet at east end). Shift 680 feet south-southeast if going up in the section and west-northwest if going down.			
61. Limestone, with irregular dolomitic inclusions—sublithographic, grading to medium grained where dolomitic; pearl gray to woodash gray, with minor pinkish tinges; beds poorly exposed, bedding indeterminate. Weathers reticulate, medium bluish gray. Much chert weathers out of this interval though little was seen in place. It is irregularly blocky to nodular or concretionary with semiconcentrically banded "cabbage-head" stromatolites of the cryptozoon type, and it is especially abundant in the lower half of the interval. It is chalcedonic to porcelaneous, less commonly subgranular with a fracture like broken paraffin, locally crypto-oölitic, in minor part slightly dolomoldic, and chalk textured where penetrated by weathering; light bluish or brownish gray to white, weathering to tones of dirty white to tan or russet.	11	679	449 – 460
A bed at 449 feet (altitude 1491 feet at west end). Shift 440 feet east-northeast if going up in the section and west-southwest if going down.			
62. Limestone, with minor irregular dolomitic inclusions—sublithographic, grading in part to a fine pellet limestone;	11	690	438 – 449

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
pearl gray to woodash gray; beds 1 to 18 inches thick, poorly exposed in lower part. Weathers uneven, in part reticulate; medium bluish gray. Oölitic laminar chert weathers out from the lower few feet of this interval as abundant angular, russet to yellowish weathering blocks. At 447 feet semichalcedonic, in part crypto-oölitic gray to brownish gray to dirty white chert occurs as irregular nodules and inclusions. Abundant blocky, white weathering chert floats over the interval from above. A short lateral shift is made at 438 feet, moving east if going up in the section and west if going down.			
63. Dolomite at top and bottom, grading to limestone in the middle third—medium to fine grained, grading to sublithographic where pure limestone; woodash gray to light pinkish gray; beds 3 to 8 inches thick. Weathers smoothly uneven, reticulate, medium gray to medium bluish gray. Chert occurs as nodules and lenses at 435.5 feet: being semichalcedonic to chalk textured, oölitic to crypto-oölitic, bluish to brownish gray to white, and weathering shiny yellowish white.	3.5	693.5	434.5– 438
64. Mostly limestone, with irregular dolomitic inclusions and occasional thin dolomite beds—sublithographic, grading to medium grained where dolomitic; pearl gray to woodash gray, grading to light yellowish gray; beds 1 to 8 inches thick. Weathers reticulate, platy, medium to light bluish gray. Chert is abundant as lenses and nodules from 431 to 432 feet; being chalcedonic to semichalcedonic, banded, bluish gray to brown and white, and weathering shiny brownish white.	8.5	702	426 – 434.5
65. Dolomite—mostly medium grained, in part vuggy; light grayish brown, grading to light brownish and pinkish gray; beds 2 to 22 inches thick. Weathers uneven, pitted to smooth, medium gray. Chert is abundant as lenses, nodules, and angular inclusions from 416.5 to 418.5 feet and from 424 to 425 feet. It is chalcedonic to subchalcedonic, in part grading to porcelaneous; locally oölitic to crypto-oölitic; in part with minor quartzose inclusions; and bluish or brownish gray to china white.	15	717	411 – 426
66. Limestone, with irregular dolomitic inclusions and grading to calcitic dolomite in upper 4 feet—sublithographic, grading to medium grained where dolomitic; pearl gray to yellowish or pinkish gray; bedding indeterminate. Weathers reticulate, medium gray to medium bluish gray. Chert abundant at base as semiconcentrically banded "cabbage-head" stromatolites of the cryptozoon type. It is subchalcedonic to porcelaneous, in part quartzose, brownish or bluish gray to white, and weathers tan to shiny white. Lenticular chert is abundant from 406 to 407 feet; being subchalcedonic to chalcedonic, in part crypto-oölitic, in minor part with quartzose inclusions, bluish gray to white, and mostly weathering shiny white.	10	727	401 – 411
67. Limestone, with irregular dolomitic inclusions and grading to dolomite in lower foot—sublithographic, grading to medium grained where dolomitic; very light gray to pearl gray or light pinkish gray, grading to light pink and salmon colored where dolomitic; beds 1 to 10 inches thick. Weathers reticulate, platy, medium bluish gray. Z bed at 394 feet; shift about 150 feet east if going up in the section and west if going down, traveling parallel to and	7	734	394 – 401

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
about 70 feet north of the east-west fence between the Staendebach survey to the north and one of the Fisher and Miller surveys to the south.			
68. Limestone, with irregular dolomitic inclusions and in minor part grading to dolomite—sublithographic, grading to medium grained where dolomitic; very light gray to pearl gray, grading to pinkish gray or salmon-colored where dolomitic, with sporadic pinkish and yellowish mottles; beds from less than 1 inch to 14 inches thick. Weathers rough, reticulate, medium bluish gray. Oölitic laminar chert and excrescences and plates of ropy, granular, in part dolomoldic and quartzose chert are abundant in place and as float in the lower half of the interval; weathering spongy and russet to dull brown. Occasional irregular inclusions, nodules, and lenses of chalcedonic to porcelaneous, brownish to bluish gray to china white, white weathering chert occur on the surface of bed Z, at the top of this interval. The lowest of the so-called oölitic laminar chert known from the vicinity of the Cherokee Creek section occurs in this interval, or slightly below it where beds of interval 69 have shifted laterally to limestone. This is the chert which typically accumulates in the residual mantle of gentle slopes underlain by rocks of some parts of the upper Staendebach member of the Tanyard formation in the north half of the Llano region. *Ozarkina* sp. and *Ophileta* sp. were noted in the upper part of this interval but not collected.	10	744	384 – 394
Base of calcitic facies of Staendebach member of Tanyard formation at base of interval 68 (altitude 1516 feet). Thickness of facies 176 feet.			
Dolomitic facies: 124 feet thick			
69. Dolomite, grading laterally to limestone in upper part—medium to fine grained, in part vuggy; light gray, varying to light pinkish and yellowish gray and grayish brown; beds 10 to 15 inches thick. Weathers uneven, in part pitted, medium gray. Dolomoldic chert and mostly medium to fine grained quartz druse are abundant as surficial coatings on some ledges, weathering rough and appearing in the float as conspicuous angular blocks. Interstitial chert is abundant in most beds. Search laterally along the trace of this interval reveals blocks of chert that is porcelaneous to semichalcedonic, with scattered dolomolds, and china white to light gray; subgranular, pitted, and dull brownish gray; subchalcedonic, crypto-oölitic, and light gray; or dolomoldic and russet. The porcelaneous to subchalcedonic cherts tend to weather shiny bluish to pinkish white. Fossils were collected from subgranular chert of this interval at locality TF–46. They are *Helicotoma* cf. *H. uniangulata* (Hall), *Sinuopea* small sp., *Gasconadia* (?) sp., *Levisoceras* (?) sp.	24	768	360 – 384
70. Dolomite—fine to medium grained, in part slightly vuggy; light brownish or yellowish gray to pinkish gray, grading to nutria; beds poorly exposed and bedding indeterminate. Weathers irregular, in part pitted, medium gray. Chert is fairly abundant as nodules and irregular inclusions in place and angular blocks in the float, especially in the lower half of the interval. It is chalcedonic to porcelaneous; in part with quartzose inclusions; brownish and bluish gray to grayish white and brown, grading to pink or china white; and weathers shiny white to pinkish or brownish white. Interstitial chert occurs in some beds.	19	787	341 – 360

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
71. Dolomite—mostly fine grained, grading to medium grained; light brownish or pinkish gray to pearl gray, with scattered pinkish and yellowish streaks and mottles; beds 5 to 14 inches thick, mostly covered in lower 10 feet. Weathers irregular, in part pitted; medium gray. A 5-inch layer of chert occurs at 333 feet; being semichalcedonic to subchalcedonic, slightly quartzose, in part highly oölitic, brownish gray to dull white. Otherwise chert occurs as dolomoldic, quartzose, dirty white, russet weathering excrescences and thin surficial crusts of mostly medium to fine grained quartz druse; both weathering blocky and locally very abundant. Fossils were collected from dolomoldic chert weathering from this interval at locality TF-46a. They are *Helicotoma* cf. *H. uniangulata* (Hall), *Schizopea* cf. *S. typica* (Ulrich and Bridge), and fragments of other gastropods. Y bed (1 foot of oölitic chert) at 313 feet. Altitude 1538 feet at the south end, which is just south of the crest of a prominent strike ridge, and 1465 feet at the north end, which is near the bottom of an eastward draining draw. Shift 600 feet north-northeast if going up in the section and south-southwest if going down. (The offset indicated is a matter of convenience. The actual trace of bed Y, as inferred from its pattern in the float, and going from south to north, swings first eastward and then westward in a broad loop on a composite dip slope and then loops around the head of the eastward draining draw to the base of interval 71.)	28	815	313 – 341
72. Chert (bed Y)—conspicuously oölitic and oömoldic; shades of gray and brownish gray; weathering russet.	1	816	312 – 313
73. Dolomite—fine to medium grained; light pinkish to yellowish gray, grading to pearl gray and brownish gray; beds 6 to 30 inches thick. Weathers uneven, in part pitted, medium gray. Dolomoldic, quartzose, white, gray to russet weathering chert and mostly medium to fine grained quartz druse are abundant as excrescences, surficial coatings, and rough weathering blocks in the upper 16 feet; and thin plates of white porcelaneous chert occur near the base of the interval.	22.5	838.5	289.5– 312
74. Dolomite, except for top 4 to 6 inches which is oölitic chert—medium to fine grained; pinkish, brownish, and yellowish gray to beige, in part with pinkish and yellowish brown mottles; beds 9 to 12 inches thick. Weathers smooth to rough, in part pitted, medium gray. The 4- to 6-inch layer of chert at the top is semichalcedonic, crowded with oöids and irregular ovoid bodies, brownish to bluish gray, and weathers shiny white to russet. The beds from 283 to 285 feet display a conspicuous surface shell of finely dolomoldic, russet-weathering chert.	10.5	849	279 – 289.5
75. Dolomite—very fine to medium grained, in part vuggy; varying through light gray, pinkish gray, grayish brown, and beige, with local pinkish and purplish mottles; beds 4 to 16 inches thick. Weathers smooth to pitted, medium gray. Chert present as minor dolomoldic and quartzose excrescences or surficial coatings; in part weathering to spongy russet masses in the float. At 276 feet is minor porcelaneous, china white chert, weathering smooth and shiny white.	14	863	265 – 279
76. Dolomite—in part an intraformational conglomerate, having angular granules of chert and dolomite in a dolomite matrix; very fine grained; mouse gray to pinkish and yellowish gray, with sporadic pinkish mottles; beds poorly	5	868	260 – 265

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
exposed, seemingly 1 to 4 inches thick. Weathers to smooth, light yellowish to brownish gray plates and cobbles scattered on a conspicuous minor topographic bench. Chert is common as thin irregular plates and blocks in the float; being chalcedonic to porcelaneous, with scattered tiny dolomolds and local quartzose inclusions, bluish to brownish gray to white, and weathering shiny white. In the lower part of the interval, the chert is commonly a granule conglomerate, consisting of rounded to angular fragments of chert of the types described in a chalcedonic matrix which is typically crypto-oölitic and pseudospicular. Interval 76 was traced the breadth of the southeast block of the Cherokee area as a conspicuous and persistent minor bench; below which compact to inconspicuously dolomoldic, smooth fracturing, chalcedonic and porcelaneous chert was found only as float or as minor inclusions in predominantly dolomoldic and quartzose chert.			
Base of dolomitic facies of Staendebach member of Tanyard formation at base of interval 76 (altitude 1506 feet). Total thickness of facies 124 feet, and of member 300 feet.			
Threadgill member: 260 feet thick			
Dolomitic facies: 260 feet thick			
77. Dolomite—mostly medium grained, in part grading to fine grained, vuggy; pearl gray to light pinkish and brownish gray, in part with minor yellowish gray to pink mottles; beds irregular, about 10 to 24 inches thick. Weathers irregular; pitted; medium gray to iron gray, in part with a brownish tone. Chert occurs in the upper 2 feet as spongy surficial coatings and excrescences; being dolomoldic and quartzose, dirty white, and weathering dull white to tan or russet. Interstitial chert occurs in some beds. Minor quartz druse and a little float of granular white chert occurs in the lower part of the interval.	22	890	238 – 260
78. Dolomite—fine to medium grained in alterating zones of varying thickness, vuggy. Pearl gray to brownish gray, grading to pinkish and yellowish gray; in part with lavender, rose, and beige tinges; and with the darker colors in the lower part. Bedding indistinct, beds about 4 to 24 inches thick. Weathers rough to smooth, in large part pitted; medium brownish gray to iron gray. Dolomoldic, quartzose chert and quartz druse are common in the lower 25 feet as excrescences and surficial films; being most abundant in the upper part of this zone and occurring occasionally above it. Fossils were collected from chert thought to weather out about on the trace of the beds between 220 and 230 feet in this interval (TF–70). They are *Schizopea* sp., *Ophileta* cf. *O. supraplana* Ulrich and Bridge, *Sinuopea* large and small spp., chiton plates, *Ectenoceras* sp., *Dakeoceras* sp., and *Caseoceras* (?) sp.	50	940	188 – 238
79. Dolomite—medium to coarse grained; vuggy; mostly pearl gray to woodash gray, in part grading to darker tones; beds about 5 to 24 inches thick, indistinct in the upper part. Weathers rough, pitted, uneven, medium gray to iron gray. Minor dolomoldic chert and quartz druse occurs as excrescences.	25	965	163 – 188
80. Dolomite—mostly fine grained, in part grading to medium grained, in part vuggy; medium grayish brown to brownish or yellowish gray, grading toward nutria and pearl gray; beds 5 to 24 inches thick. Weathers uneven, medium gray to iron gray.	19	984	144 – 163

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Abundantly dolomoldic chert and quartz druse is fairly common as excrescences and surficial films in place and spongy blocks in the float, and minor compact granular chert was seen in place. The dolomoldic chert is coarsely cellular to fairly compact, commonly quartzose, white to light gray or light brown, and weathers russet to tan. The crystals of the quartz druse are milky to clear and fine to coarse grained. Fossils occur in the chert described above, and *Ozarkina* large sp., *Schizopea* large sp., *Sinuopea* large and medium sized spp., *Ophileta* sp., *"Pelagiella"* sp., and several species of brevicone cephalopods were seen in chert float immediately above bed X at its east end. Representative collections can best be obtained where the chert accumulates as a mantle, and collection TF–44 is thought to come from chert of about this interval accumulating at the foot of a hill northwest of the line of section, though it may include stratigraphically lower elements or contaminations from above. It contains *Helicotoma* cf. *H. uniangulata* (Hall), *Schizopea* sp., *Ophileta* cf. *O. supraplana* Ulrich and Bridge, *Sinuopea* large and small spp., *"Pelagiella"* sp., *Chepultapecia* sp., *Gasconadia?* sp., chiton plates, *Caseoceras* sp., and *Conocerina* ? sp.			
X bed at 144 feet. Altitude 1493 feet at the west end of its traced portion at the top of a westward-facing scarp, and 1442 feet at the east end of its traced portion, at the foot of a south-facing scarp. Shift about 2400 feet east-southeast if going down in the section and west-northwest if going up.			
81. Dolomite—mostly medium grained, in part vuggy; woodash gray to pearl gray, with lavender streaks. The upper 18 inches, however, is fine to medium grained and beige to yellowish gray, with lavender streaks. Bedding indistinct in lower part, beds 10 to 18 inches thick in upper part. Weathers smooth to uneven; in part pitted; medium gray to iron gray, in part with a brownish tinge. Quartz druse; dolomoldic, quartzose, russet to tan weathering chert; and minor granular chert occurs as local excrescences on the upper beds.	11	995	133 – 144
82. Dolomite, in part calcitic—coarse to medium grained, in part vuggy; light yellowish to brownish gray to pearl gray; beds about 1 to 18 inches thick. Weathers rough, in part pitted; medium gray to iron gray, in part with a brownish tone. Poorly exposed in lower 55 feet. Minor interstitial chert was seen in the upper part of the interval. The lower few feet of this interval shows rounded to angular inclusions of fine grained brownish dolomite in the coarse to medium grained light colored dolomite typical of the Threadgill member of the Tanyard formation in the Cherokee area. This probably represents the thin conglomerate which has been seen at the generally poorly exposed base of the Ordovician at a few other places in the Cherokee area.	133	1128	0 – 133
Base of dolomitic facies of Threadgill member of Tanyard formation at base of interval 82. Total thickness of facies 260 feet, of member 260 feet, and of formation 560 feet. Cambrian—Ordovician boundary and base of Cherokee Creek section at base of interval 82; elevation 1428 feet on flat between draw and foot of scarp. Beneath is very fine to fine grained, brownish dolomite of the Pedernales dolomite member of the Wilberns formation, with interstitial glauconite. Total thickness of the Ellenburger group (restricted) in the Cherokee Creek section = 1128 feet.			

Harris Ranch Section (Supplementary)

The supplementary Harris ranch section is located principally between points about 400 feet southeast and 500 feet east-southeast of the Julia Callahan Harris ranch headquarters, in the southeast corner of the Cherokee map area. It is about 2.6 miles airline south and slightly east from the eighth cattle guard on the road from Cherokee to the San Saba-Chappel road but is more easily reached by going east from Cherokee on the Cherokee-Chappel road (*see* Pl. 1). It supplies data on the thicknesses of Upper Cambrian strata above the *Plectotrophia* zone.

Estimates of thicknesses in this vicinity are derived from the averages of several computations based on the multiplication of paced breadths of outcrop by the sine of the average angle of dip, determined from numbers of readings. The locality is in an area of steep dips and minor faulting associated with the Little Llano River fault zone, and estimates cannot be too closely relied upon. The figures obtained for the thicknesses of the several members of the Wilberns formation above the *Plectotrophia* zone are, from below up, as follows: Point Peak shale member (incomplete thickness) above the *Plectotrophia* zone, 40 feet; San Saba limestone member, 140 feet; Pedernales dolomite member, 90 feet.

Salt Branch Section

The Salt Branch section comprises the basal part of the composite section of the Ellenburger group and Wilberns formations in the Cherokee area, furnishing information on the Wilberns strata below the zone of *Plectotrophia*. It is just south of the Cherokee map area, between the east and west forks of Salt Branch. This section was measured by Barnes and Cloud in January 1946.

The section begins 1.1 miles by speedometer south of the Cherokee-Chappel road, at the fourth cattle guard on the county road to Wilberns Glen. Stratigraphically this point is at the base of the Welge sandstone member of the Wilberns formation. It extends eastward 0.4 mile along the south side of an east-west fence across two minor strike-ridges and part way up a third ridge to the zone of *Plectotrophia* in the Peak Point shale member of the Wilberns formation. In the Cherokee area *Plectotrophia* has a maximum observed range of 5 feet and is ordinarily restricted to a single bed, so the zone furnishes an accurate tie-point with the Harris ranch section.

Structurally the Salt Branch section is located at the nose of a gentle, faulted syncline that lies between the Little Llano River fault zone and a fault that trends north-northeast to merge with the Little Llano River fault zone at or near its south end on the mapped part of the Cherokee area. This syncline plunges east-southeast into the Little Llano River fault zone, against which it is upthrown. Along the line of section the units measured are structurally uncomplicated and relatively well exposed.

This section includes, from the base of the Wilberns formation upward, 9 feet of the Welge sandstone member, 165 feet of the Morgan Creek limestone member, and 101 feet of the Point Peak shale member to the zone of *Plectotrophia*. *Eoorthis texana* Walcottt was collected 67 feet above the base (TF–462) and *Plectotrophia bridgei* Ulrich and Cooper was obtained at the top of the section (TF–73). The general stratigraphic characters of the section are graphically shown on Plate 14.

An unnamed supplementary section displaying a similar sequence of rocks to that of the Salt Branch section was measured in January 1946 by Barnes and Cloud along the west side of a north-south fence line at the south edge of the Cherokee map area and near the head of the north fork of Salt Branch. This section is just south of the geologically mapped portion of the Cherokee area. It begins at the base of the Welge sandstone member of the Wilberns formation, just south of a cattle guard by a bend in a county road, and extends upward in the section for about 0.5 mile north to the *Plectotrophia* zone in the Point Peak shale member. Although exposures are poor and attitudes of beds correspondingly un-

certain, measurements obtained essentially coincide with those from the subsequently measured Salt Branch section. This section is marked with an S on Plate 2 and TF–461 indicates the *Eoorthis* bed.

Kirk Ranch Section

The Kirk ranch section is supplementary to the Cherokee Creek section in that it gives a check on the thickness of the Threadgill member of the Tanyard formation in the Cherokee area, shows a partial lateral shift to limestone in the Threadgill member, and provides a better display of the chert types found in this lowest member of the Ellenburger group.

The top of this section is at an altitude of 1480 feet near the top of the south end of a west-facing scarp, and immediately below the traced equivalent of interval 76 of the Cherokee Creek section (base of Staendebach member of Tanyard formation). It is about 1.2 miles airline southeast from the sixth cattle guard northeast (4.5 miles by speedometer) from Cherokee on the county road from Cherokee to the San Saba-Chappel road.

Its base is at an altitude of 1420 feet on a flat at the foot of a spur and immediately above the last fine to very fine grained, interstitially glauconitic, relatively dark colored dolomite of the Pedernales dolomite member of the Wilberns formation (uppermost Cambrian). It is slightly more than 0.4 mile south-southwest from the top of the section.

The line which the Kirk ranch section follows was painted and its course marked on the geologic maps (Pl. 2 and 7) in the same manner as for the Cherokee Creek section, but it is not marked off in 5-foot intervals. This section was measured and sampled in March 1944 by R. L. Heller and L. E. Warren, after having been located and painted by Cloud and Heller. Plane-table control for adjusted thicknesses was run by Barnes and Warren. The following description is the result of condensation and rearrangement of the original description by Heller.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Ellenburger group: *273 feet described*			
Tanyard formation: 273 feet described			
Threadgill member: 273 feet thick			
Upper dolomite facies: 165 feet thick			
1. Dolomite (altitude 1480 feet at top of section)—medium to fine grained, pearl gray to light brownish gray. Weathers rough, in part pitted, medium brownish gray. Chert abundant as irregular excrescences. It is quartzose, dolomoldic, and russet weathering; or subporcelaneous to subgranular, dolomoldic, dirty white, and white weathering.	1	1	272 – 273
2. Dolomite—medium to fine grained, in part vuggy; light brownish gray to pearl gray or brown, in part with pinkish tinges; beds 8 to 30 inches thick. Weathers smooth to rough, tending to form pinnacles in upper 6 feet; medium to dark brownish gray. Minor quartz druse in place. Chert abundant in float; being dolomoldic, quartzose, and russet weathering; or semiporcelaneous to subgranular, in part quartzose, slightly dolomoldic, light gray to dirty white, and white weathering.	12	13	260 – 272
3. Dolomite—fine to medium grained, in part vuggy; light pinkish or brownish gray to pearl gray, in part with pinkish streaks; beds 10 to 18 inches thick. Weathers smooth, in part pitted, tending to develop pinnacles or rounded knobs; medium to dark brownish gray. Minor quartz druse in place. Chert float is semiporcelaneous to subgranular, slightly dolomoldic, light gray to dirty white, and white weathering.	14	27	246 – 260

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
Helicotoma cf. *H. uniangulata* (Hall) was seen in chert from about the top of this interval but not collected.			
4. Dolomite—medium to fine grained; light pinkish and brownish gray to pearl gray, light pink, or light brown with local scattered pinkish streaks and mottles; beds 8 to 30 inches thick. Weathers smooth to rough, in part pitted, in part tending to develop pinnacles; medium to dark brownish gray.	19	46	227 – 246
Quartz druse and dolomoldic, quartzose chert of a light gray or brown to white color occur as russet to dirty white weathering excrescences and irregular surficial coatings throughout interval; being abundant in upper 2 feet. Also present is semiporcelaneous to subgranular, slightly dolomoldic, light gray to dull white chert and minor subchalcedonic, quartzose, light gray or brown to white chert; both weathering dirty white to dull tan or russet.			
5. Dolomite—medium to fine grained, in part vuggy; pearl gray to light pinkish gray with local pink streaks; beds 6 to 22 inches thick. Weathers smooth to rough, in part pitted, medium to dark brownish gray.	22	68	205 – 227
Chert abundant as irregular excrescences, angular fragments, and spongy masses. It is subporcelaneous to subgranular, quartzose, dolomoldic, light gray to white, and weathering dirty white to russet. Locally drusy quartz alone is abundant.			
6. Dolomite—medium to fine grained; light brownish to pinkish gray, with pinkish mottles and streaks; beds 4 to 18 inches thick. Weathers smooth to rough, medium to dark brownish gray.	11	79	194 – 205
Chert and quartz druse are fairly abundant as irregular ropy excrescences. The chert is dolomoldic, quartzose, subporcelaneous, light gray to white, and weathers dirty white to dull tan or russet.			
Fossils collected from the basal 2 feet of interval 6 are *Ozarkina* cf. *O. complanata* Ulrich and Bridge, *Sinuopea* small sp., *Schizopea?* sp., *Gasconadia* cf. *G. putilla* (Sardeson), a chiton plate, a fragmentary brevicone cephalopod, and *Hystricurus* (TF–106).			
7. Dolomite—fine to medium grained, in part vuggy; light gray or pearl gray to pinkish or brownish gray, with sporadic pinkish and purplish mottles and streaks; beds 2 to 14 inches thick. Weathers smooth to rough, in part pitted, tending to develop pinnacles in lower 5 feet; medium to dark brownish gray.	22	101	172 – 194
Chert and quartz druse abundant as excrescences in upper 4 feet and as spongy blocks in the float throughout. The chert is dolomoldic, subporcelaneous to subgranular with minor semichalcedonic patches, quartzose, white to grayish or brownish, and weathers russet to dirty white.			
Helicotoma cf. *H. uniangulata* (Hall) was seen in chert in the upper part of this interval but not collected.			
8. Dolomite—medium grained, grading to fine grained in the upper 6 feet and to coarse grained from 160 to 166 feet, in part vuggy; pearl gray to light pinkish or brownish gray, with sporadic pinkish and purplish streaks and mottles; beds 4 to 22 inches thick. Weathers rough to smooth, in part pitted, in part tending to form pinnacles and rounded knobs; medium to dark brownish gray.	22	123	150 – 172

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Chert and quartz druse abundant as spongy blocks in float but only minor excrescences were seen in place. Chert is quartzose, dolomoldic, in part subporcelaneous, light gray to white, and weathers russet to dirty white. *Helicotoma* cf. *H. uniangulata* (Hall) was seen in chert near the middle of this interval but not collected.			
J bed at 150 feet. Shift about 500 feet north if going up in the section and south if going down. Altitude 1418 feet at south end and 1393 feet in draw at bottom of westward facing hill at north end of offset.			
9. Dolomite—medium to coarse grained, in part vuggy; pinkish gray to pearl gray, with pinkish and purplish streaks in upper 5 feet; bedding indistinct. Weathers smooth to rough, in part pitted; medium to dark brownish gray. Chert common in upper and lower parts of interval, but elsewhere minor and grading to quartz druse. It is quartzose, dolomoldic, granular to chalk textured or subporcelaneous, light to medium gray to pink or white, and weathers dirty white to light tan. Intervals 9 and 10 swing around the northwest slope of a wooded spur in order to stay with the outcrops.	20	143	130 – 150
10. Dolomite—medium grained, grading to coarse grained in upper 5 feet, in part vuggy; light brownish to pinkish gray to light gray, with streaks of pink, yellow, orange, and purple; bedding indistinct, beds up to 18 inches thick. Weathers rough to smooth, in part pitted, tending to develop pinnacles in upper part; medium to dark brownish gray. Minor excrescences of quartz druse in upper 5 feet and of quartzose, granular, gray chert in lower 10 feet. Intervals 10 and 9 swing around the northwest slope of a wooded spur in order to stay with the outcrops.	20	163	110 – 130
11. Dolomite—medium to coarse grained, light pinkish to brownish gray; beds 3 to 12 inches thick. Weathers smooth, in part pitted; medium to dark brownish gray. Minor excrescences of quartz druse on surface. *Calcitic facies: 41.5 feet thick*	2	165	108 – 110
12. Limestone, with minor dolomite—sublithographic, grading to fine grained where dolomitic; light pearl gray to woodash gray, with sporadic pinkish and yellowish mottles; beds 2 to 6 inches thick. Weathers smooth, platy; cement gray. Chert and quartz druse occurs as angular fragments and excrescences. The chert is chalcedonic with a waxy luster, quartzose, rifle gray to pearl gray or woodash gray, and weathers drab to dust or dull acorn brown. Sections of gastropods were seen in the limestone but none was identifiable.	2	167	106 – 108
13. Limestone, with about 25 per cent dolomite as irregular inclusions—sublithographic, grading to fine grained where dolomitic; limestone is pearl gray to woodash gray, dolomite is light gray to brownish gray; beds 1 to 6 inches thick. Weathers rough, in part reticulate, light gray to medium bluish and brownish gray.	6.5	173.5	99.5– 106
14. Dolomite, with minor inclusions of limestone—coarse to medium grained, in part vuggy; pinkish gray to light gray, with pinkish streaks and mottles; beds 6 to 8 inches thick. Weathers rough, slightly pitted; medium dark brownish gray.	3	176.5	96.5– 99.5

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
15. Limestone and dolomitic limestone, with irregular inclusions of dolomite and in part grading laterally to dolomite—the limestone is sublithographic, grading to fine grained where dolomitic, and light to medium gray; the dolomite is medium to coarse grained and pink. Beds 2 to 8 inches thick. Weathers rough, in part reticulate; cement gray to medium brownish gray. Minor excrescences of quartz druse were seen.	9.5	186	87 – 96.5
16. Limestone, with minor dolomite—sublithographic, grading to fine grained where dolomitic; woodash to pearl gray; beds 0.5 to 5 inches thick. Weathers smooth, platy; cement gray to light gray.	9	195	78 – 87
17. Limestone and dolomitic limestone, with about 25 per cent dolomite as irregular inclusions—limestone is sublithographic, grading to medium grained where dolomitic; woodash to pearl gray, grading to pinkish and brownish gray where dolomitic; beds 2 to 16 inches thick. Weathers rough, in part reticulate, in minor part pitted; medium bluish gray to light gray.	11.5	206.5	66.5– 78
Lower dolomitic facies: 66.5 feet thick			
18. Dolomite—mostly medium to coarse grained, grading to fine to medium grained in the lower 2 feet, in part vuggy; woodash gray or pearl gray to light brownish gray, with purplish and yellowish mottles and streaks above middle; beds 0.5 to 18 inches thick, indistinct in lower part. Weathers rough to smooth, in part pitted; medium to dark brownish gray to light yellowish gray near middle. Minor chert was seen as small angular fragments in lower 2 feet. It is quartzose, subporcelaneous to subgranular, light gray, and weathers dirty white to tan.	30	236.5	36.5– 66.5
19. Dolomite—medium to coarse grained, grading to predominantly coarse grained in the upper 5 feet, in part vuggy; pearl gray or woodash gray to light brownish gray, with yellowish mottles; bedding indistinct. Weathers rough, in part pitted, medium to dark brownish gray to light yellowish gray.	26	262.5	10.5– 36.5
20. Limestone, grading to dolomitic limestone and dolomite—limestone sublithographic, grading to medium grained where dolomitic, woodash gray to white; dolomite medium grained and light pinkish gray; beds poorly exposed. Weathers rough, reticulate; very light gray to medium gray.	3.5	266	7 – 10.5
21. Dolomite, with very minor inclusions of limestone—coarse to medium grained, in part vuggy; pearl gray to woodash gray or light brown, with scattered pinkish and yellowish mottles; beds poorly exposed. Weathers rough, in part pitted; light yellowish gray to medium gray. Very minor quartz druse is present as surficial skins.	7	273	0 – 7
Cambrian—Ordovician boundary and base of Kirk ranch section at base of interval 21; altitude 1420 feet on flat at foot of spur. Below is very fine to fine grained, light brown to brownish gray, interstitially glauconitic dolomite with excrescences of quartz druse belonging to the Pedernales dolomite member of the Wilberns formation. Total thickness of Threadgill member of Tanyard formation in Kirk ranch section, 273 feet; of which 41.5 feet belongs to the calcitic facies and 231.5 to the dolomitic facies.			

THE NORTHEASTERN AREAS

INTRODUCTORY STATEMENT

Gentle dips in combination with faulting preclude the measuring of a continuous section in the northeastern part of the outcrop area of the Ellenburger group. It was necessary to map two areas and measure three sections to obtain a composite section of the group. These sections are strung out for a distance of more than 8 miles in a line trending approximately north-northwest. A section was needed in this portion of the uplift not only because of its location in reference to the subsurface and the type locality of the original "Ellenburger limestone," but also because the names Gorman and Tanyard for two of the formations in the Ellenburger group were chosen from this part of the Llano uplift. The Ellenburger Hills extend westward from the line of this composite section in the combined Tanyard and Gorman Falls areas, and all units and facies of the Ellenburger group are well displayed in it. The composite Gorman-Tanyard section (pp. 230–249; Pl. 14, sec. no. 5) is, therefore, here designated as the type section of the Ellenburger group.

The chief disadvantage to this section is its relative inaccessibility and great length. It is situated in three counties, and segments of the sections are located on both sides of the Colorado River, which is bridged in this area only at Bend about 3 miles north of the top of the section. The Tanyard section is accessible by county and private roads from the east by way of either Lampasas or Burnet. It may also be reached by boat from Buchanan Dam or from Tow. The Spicewood Creek section is also accessible by boat from Buchanan Dam and Tow, or by automobile from Bend.

The lower part of the Gorman Falls section is in Lampasas County and is not accessible from the east. This portion of the section can be reached only through Bend, and the Colorado River must be crossed by boat. Fortunately boats are available at Malcolm Chism's Gorman Falls camp. The supplementary Smith ranch section is reached from Lampasas by the way of the Smith ranch house. The supplementary sections west of Buchanan Lake at The Tanyard are best reached by boat from The Tanyard.

The sections are marked by yellow or orange paint spots at 5-foot intervals from the bottom up, with numbers placed at 25-foot intervals; for example: 1 is 25 feet from the bottom of the section, 2 is 50 feet from the bottom of the section, and so on. The lines of offset between segments of sections are not marked on the ground since the distances in many cases are great, and the segments are accurately shown on the maps (Pls. 8 and 9; *see also* Pl. 35, fig. B) by chevrons and can be reëstablished with little work. The supplementary sections are not marked on the ground, but their positions are shown on the maps or described in the text.

The sections are described from the top down for convenience in comparing with well logs, but they are best viewed from the bottom up in the field. The descriptions may be used for tracing the sections on the ground, providing all directions given for offsets and line of sections are translated 180 degrees.

In general the rocks in these sections are well exposed except in some portions of the Staendebach member of the Tanyard formation and in the upper part of the Honeycut formation. The Tanyard section overlaps the Spicewood Creek section 280 feet. This amount of overlap is helpful in correlating the two sections. Several offsets made across faults are possibly somewhat in error, but each of these questionable offsets is discussed in the described sections. The units in this section compare very closely in thickness to those found in the Western Lampasas Oil Company No. 1 Whittenburg well which is located a few miles to the north. Most of the questionable shifts were made within the Tanyard formation, yet Cloud found 658 feet of Tanyard in the well, which is the same amount measured at the surface. Barnes' estimation of the thickness of the Tanyard in the Whittenburg well is 675 feet, which is 17 feet more than that obtained by Cloud. Both Cloud and Barnes logged 1459 feet of

section in the Whittenburg well from the top of the Point Peak shale member of the Wilberns formation to the top of the Gorman formation. The measurement obtained at the surface is 1456 feet, which is a very close comparison.

Most of the area shown on Plates 8 and 9 is in rather rough country that is rather uniformly and thickly covered with cedar. Only the alternating beds in the Honeycut formation give a consistently banded pattern. The limestones of the Threadgill member of the Tanyard formation are in part less thickly covered by cedar and appear on the photographs as somewhat lighter areas. To the west in less rough country, including the Ellenburger Hills, the dolomites of the Tanyard and the lower Gorman formation, as well as a portion of the Pedernales dolomite member of the Wilberns formation, form bald hills and prairies, whereas the calcitic portion of the Gorman and the Honeycut formations are well wooded, with the vegetational banding being more distinct in the Honeycut. To the east most ground underlain by the Tanyard formation is wooded even in fairly flat areas, but a portion of the top of the Tanyard and the dolomitic portion of the Gorman formation form a grassy prairie, known as Buffalo Prairie.

As familiarity with the lithic characteristics of the Ellenburger and underlying rocks developed, less and less use was made of fossils in mapping; and few fossil collections were made in the Tanyard and Gorman Falls areas since they were among the last areas mapped. The collections which were obtained were made during the reconnaissance examination of the areas. Some of the better collecting localities are mentioned under the descriptions of the various formations.

TANYARD AREA, BURNET AND SAN SABA COUNTIES

Upper Cambrian

Riley Formation

The Cap Mountain limestone member of the Riley formation is barely exposed above the surface of Lake Buchanan on the west shore of the lake just north of the mouth of Cedar Hollow. A complete section of the Lion Mountain sandstone member is present, and it makes up most of the flat area at the mouth of Cedar Hollow. The best exposure of the Lion Mountain sandstone is at the south side of the mouth of Cedar Hollow, but elsewhere there is little outcrop. The alluvium and colluvium which cover considerable of the area mapped as Lion Mountain sandstone are not shown because the boundary between them and the sandy soil of the Lion Mountain is not distinct.

Wilberns Formation

The positions of measured sections of the San Saba limestone and Pedernales dolomite members are shown on Plate 8, but the Welge sandstone, Morgan Creek limestone, and Point Peak shale members were measured by Cloud and Barnes in January 1946 after Plate 8 had been sent to the engraver, and their position is consequently not shown.

Welge sandstone member.—The Welge sandstone is brown and sparingly glauconitic. It is 19 feet thick, as measured in a very shallow drain west of Buchanan Lake at a point 1100 feet west-northwest of Tanyard Spring and about 200 feet northeast of a ranch road.

Morgan Creek limestone member.—The Morgan Creek limestone, measured in part along the ranch road mentioned above and in part alongside of, and in the drain just west of the road, is 131 feet thick. The *Eoorthis* zone is 71–72 feet above the base of the Wilberns formation, and a collection, 205T–1–11C, was made where the road bends eastward away from the section. A shaly zone immediately above the *Eoorthis* zone is probably about 40 feet thick. The top few feet of the Morgan Creek is reddish, a feature not noted elsewhere in the Llano region. Here as elsewhere in the Llano region the bottom portion of the Morgan Creek limestone is reddish, sandy, and is gradational upward from the Welge sandstone.

Point Peak shale member.—A section of the Point Peak shale member was measured east of the lake and 4600 feet upstream from Tanyard Spring. Measurements of thickness were made parallel

to the strike of the beds from the top of the Morgan Creek limestone to the alate-*Billingsella* bed, which is at the top of the *Plectotrophia* zone in this area. The thickness for this portion of the Point Peak shale member is 124 feet, and another 10 feet of Point Peak shale measured above the alate-*Billingsella* bed on Jim John Creek makes a total of 134 feet for the thickness of the Point Peak shale member. The lower portion of the Point Peak shale member contains little else than calcareous shale, whereas the upper portion contains several zones of small stromatolites, some intraformational conglomerate, and some limestone beds, especially in the *Plectotrophia* zone. Subchalcedonic, smooth fracturing, gray chert is rather common in the limestone of the *Plectotrophia* zone of the Tanyard area. Its presence in the Point Peak shale elsewhere in the Llano area at this level has not been noted. The *Plectotrophia* zone is about 19 feet thick, which is thicker than seen elsewhere, except in the Sudduth area of Burnet County. A collection of *Plectotrophia* from the top of the section bears locality number 27T–7–61A, which number was assigned too late to appear on the map, Plate 8.

San Saba limestone and Pedernales dolomite members.—The San Saba limestone member is thin and the Pedernales dolomite member is thick, with the boundary between the two fluctuating widely within a short distance. The total thickness for the two members is 324 feet and in the line of section the Pedernales is 277 feet thick. A coarse grained zone in the Pedernales dolomite, about 86 feet thick, is noteworthy because of its resemblance to the coarse grained dolomite in the Threadgill member of the Tanyard formation. Where the coarse grained dolomites of the two members are in contact, for example, in the Johnson City area, Blanco County, and in the subsurface to the north, it is impossible to pick the Cambrian-Ordovician boundary on direct physical evidence alone. Within the coarse grained Pedernales dolomite in the Tanyard area there are small areas of sublithographic limestone entirely similar to the sublithographic limestones of the Threadgill member. The only outcrop of this limestone noted within the map area was inadvertently left off the map. It is about 1 mile south of The Tanyard and 500 feet southeast of fossil locality TF–261. Also left off the map at this point is fossil locality 27T–7–62A, situated just above the limestone outcrop. Other small areas of limestone in the coarse grained Pedernales dolomite are situated near lake level just off the map near Poverty Hill. Similar limestones, forming larger outcrops, noted southwest of Burnet are thought to be, but have not been proved to be, in the Pedernales dolomite. Limestone in the lower part of the Seaboard No. 1 Dawson well, in Hamilton County, probably is of this type. The lower portion of the Pedernales dolomite is very fine grained to microgranular and the upper portion is very fine to fine grained, contrasting sharply with the coarse grained dolomites in the middle of the Pedernales and in the Threadgill member of the Tanyard formation. Glauconite was not seen in either the Pedernales dolomite or the San Saba limestone in the Tanyard area. Dirty white to brown chert is very abundant in the upper fine grained portion of the Pedernales dolomite, and it is mostly porcelaneous to semiporcelaneous and dolomoldic; some is granular and quartzose. The coarse grained dolomite is mostly noncherty except in the bottom few feet. In the lower very fine grained to microgranular portion of the Pedernales the chert is concentrated in a 32-foot zone, is highly dolomoldic, and in part quartzose, is porcelaneous to semiporcelaneous, and occurs as a network on weathered surfaces. West of the lake in areas which are relatively flat, the chert breaks upon weathering, freeing girvanellas and silicified *Scaevogyra* and other gastropods.

Lower Ordovician

Ellenburger Group

Tanyard formation, Threadgill member.—The Tanyard formation receives its name from "The Tanyard" situated within the map area of Plate 8. The lower member of the Tanyard formation, the Threadgill, is well exposed in this area, and, as is true in so much of the eastern part

of the Llano region, intergrades laterally between limestone and dolomite. Within the map area, dolomite predominates, forming a continuous contact with the Pedernales dolomite member of the Wilberns formation below and the Staendebach member of the Tanyard formation above. In some sections, however, limestone composes all of the member except for the top and bottom few feet, and in other sections it is dolomite from top to bottom. In a distance of a little over 2 miles there are six abrupt lateral transitions from limestone to dolomite.

The contact between the Threadgill member of the Tanyard and the Pedernales dolomite member of the Wilberns is sharp and is well exposed in a cliff 800 feet downstream from Wolf Spring. The contact between the very fine grained Pedernales dolomite and the coarse grained dolomite of the Threadgill member is only slightly irregular, not being markedly so as in the Cherokee area (Pl. 20, figs. A and B). The boundary between the Threadgill and Staendebach members of the Tanyard is not so apparent and on the basis of grain size would probably be placed approximately 26 feet higher. In this section, however, the boundary was placed beneath the first appearance of a substantial amount of porcelaneous, white weathering chert, making the Threadgill member 202 feet thick. Only a very minor amount of chert is present in the Threadgill member and that is mostly smoky gray, minutely quartzose, and in irregular pieces. Some beekite excrescences are also present.

Tanyard formation, Staendebach member.—Only 336 feet of the Staendebach member was measured in the Tanyard section, whereas its thickness as ascertained by piecing the Tanyard and Spicewood Creek sections together is 456 feet. Additional beds are present east of the top of the section but exposures are so poor in this area that a shift could not be made with enough accuracy to warrant the inclusion of these beds in the section. The Staendebach in this area is predominantly fine to medium grained dolomite which becomes coarser grained toward the top and grades to limestone. The boundary between the dolomite and limestone is exceedingly irregular, the irregularity being caused by lateral gradation.

The Staendebach member contains large quantities of porcelaneous, white weathering, mostly dolomoldic chert, and in addition quartz druse is very abundant in the lower 300 feet. Oölitic chert is fairly common throughout the Staendebach, and a persistent 2-foot bed in the lower part is used to tie the Tanyard section to the Spicewood Creek section. In the upper part of the Staendebach great chert masses such as the one shown in figure C of Plate 21 are common. Only rarely are these masses seen in section; mostly they form mounds in gently sloping areas and cap hills.

GORMAN FALLS AREA, SAN SABA, LAMPASAS, AND BURNET COUNTIES

Lower Ordovician

Ellenburger Group

Tanyard formation, Staendebach member.—On the geologic map of the Gorman Falls area (Pl. 9), most of the Staendebach member of the Tanyard formation is present. The Staendebach, as is true in much of the Llano uplift, is poorly exposed, and the only place found within the map area where fairly good exposures are present is along Spicewood Creek. The Staendebach of this area is essentially the same as it is in the Tanyard area except that the top portion, missing in the Tanyard area, is present here. Chert is distributed in about the same amounts as in the Tanyard area, except that fewer large chert masses were seen.

Gorman formation.—The contact between the Gorman formation and the underlying Tanyard formation, though apparently sharp in the line of section, is not so easy to pick elsewhere in the area. If the correct interpretation has been made for the rocks in the vicinity of the Smith ranch supplementary section (Pl. 9, east bank of Colorado River 3400 feet upstream from Yancy Creek), microgranular dolomites which grade laterally into limestone are locally present in the top 30 feet of the Tanyard formation. Some limestone is also present near

the base of the Gorman, a notable example of which is just upstream from the top of the Spicewood Creek section. The Gorman-Tanyard boundary has been mapped through a known range of 30 feet of section (*see* discussion following Smith ranch supplementary section, p. 343), and it is possible that the boundary as mapped in places is even more divergent. The boundary is well exposed in only a few places. Mostly it is in thick cedar with its attendant litter, making it almost impossible to trace the boundary once it is established or to check lateral gradation and changes in lithology above and below the boundary. The dolomitic facies of the Gorman formation in the Gorman Falls section is thinner, 81 feet, than it is in any other section measured, except the anomalous Bald Ridge section of McCulloch County. The thinness of the dolomitic facies in the Gorman Falls area holds only in the vicinity of the section and possibly in the next fault block to the east. Throughout most of the outcrop area (Pl. 9) of the Gorman formation the boundary between the dolomitic and calcitic facies is mapped only a short distance beneath the *Archaeoscyphia* zone of the Gorman, indicating that the dolomitic facies is between 200 and 225 feet thick.

The Gorman formation is considerably less cherty than the underlying Tanyard formation and, while much of the chert is similar to that of the Tanyard, a greater portion of it is chalcedonic. Sand grains are distributed in thin zones throughout most of the Gorman, which distinguishes it from the Tanyard.

Areas of collapse are common within the Gorman formation, but only three are noted on the map. The one most accessible is at Gorman Falls in the drain just north of the camp. Northeast of Colorado River at a point 1 mile southeast of Gorman Falls, in an area of very thick cedar, the *Archaeoscyphia* zone could not be followed, the boundary between the calcitic and dolomitic facies is obscure, and divergent dips suggest that this may be an area of collapse.

The calcitic facies of the Gorman formation in the Gorman Falls area, as elsewhere in the Llano uplift, displays much evidence of ground water circulation and active solution. The magnificent spring known as Gorman Spring issues from it one-half mile up Gorman Creek from Colorado River. The large travertine deposit at Gorman Falls has been built up from the waters of Gorman Spring (a similar travertine mass is shown on Pl. 30, fig. B). Bear Spring, also issuing from the calcitic facies of the Gorman, is a small spring situated on the bank of Colorado River a few hundred feet downstream from the mouth of Tie Slide Creek. Small sinks and solution openings are common in the calcitic facies of the Gorman formation and a solution crevasse behind the camp at Gorman Falls is said to lead into a large cave. Gorman Cave is located nearly 1 mile down Colorado River from Gorman Falls on its west bank near river level, but its extent is unknown to the writers.

Fossils noted are associated mostly with the *Archaeoscyphia* zone of the Gorman. Two of the better localities for making collections are located near Gorman Falls but have not been noted on the map. One locality is behind the Gorman Falls camp along the *Archaeoscyphia* zone where several species of gastropods were noted, and the other, again associated with the *Archaeoscyphia* zone, is about 500 feet east of the road one-half mile south of Gorman Falls camp, where several large cephalopods were seen. *Diaphelasma pennsylvanicum* Ulrich and Cooper was first seen in the Llano uplift at TF–251. The bed in which this brachiopod occurs has not been followed throughout the map area but has been seen in all places where it has been looked for at the proper stratigraphic position.

Honeycut formation.—The interbedded dolomites and limestones of the basal part of the Honeycut formation contrast sharply with the massive limestone sequence at the top of the Gorman formation. The basal bed of the Honeycut is a medium gray to light brown microgranular dolomite which is about 1 foot thick and is crowded with sand grains in the lower 8 inches. This bed retains its characteristics throughout the map area and in addition is situated on a narrow lightly vegetated bench, making it

easy to trace (Pl. 35, fig. B). The Honeycut of this area is an alternation of limestone and dolomites with microgranular dolomite making up most of the top 40 feet. The upper 40 feet of microgranular dolomite apparently corresponds to part of the dolomitic zone in the upper part of the Honeycut formation of the Backbone and Riley Mountain areas and the middle part of the Honeycut formation of the Honeycut Bend area.

The quantity of chert in the Honeycut formation is about the same as that in the Gorman, and texturally it is about the same as that of the Gorman except that the Honeycut contains numerous zones of cannonball cherts, whereas in the Gorman formation cannonballs are present only in the vicinity of the *Archaeoscyphia* zone.

The Honeycut formation of the Gorman Falls area is richly fossiliferous. The north valley-wall of Tie Slide Creek is an ideal collecting ground for the upper portion, and the slope above the Gorman strata in the Gorman Falls section offers good collecting for the lower part. The principal *Archaeoscyphia* zone of the Honeycut formation as mapped in the Cherokee area could probably be mapped in the Gorman Falls area, but so many well developed *Archaeoscyphia* beds are present and so many of them have Ceratopeas in them that it was difficult to pick and map consistently the *Archaeoscyphia-C. capuliformis* bed. *Xenelasma*, an index fossil of the lower part of the Honeycut formation, is present in cannonball chert in the line of section 12 feet above the base of the Honeycut. *Xenelasma* was also found in collection TF–253, which while not in the line of section, is estimated to be about 125 feet above the base of the Honeycut. This collection contains, in addition to *Xenelasma syntrophioides* Ulrich and Cooper, *Orospira* sp., *Hormotoma* sp., *Rananasus* sp., and *Jeffersonia* sp.

The Honeycut formation is 325 feet thick in the Gorman Falls section, having more than doubled its thickness from that noted in the Cherokee section. Beds of the Honeycut formation seem to be peeling out from under the Mississippian strata eastward and there might be an appreciably greater thickness of Honeycut rocks in the eastern part of the map area. Eleven miles north of the top of the Gorman Falls section, in the Western Lampasas Oil Company No. 1 Whittenburg well, the Honeycut has increased 82 feet in thickness.

Caverns, solution cavities, and springs are not as common in the Honeycut as in the Gorman formation; but along Colorado River 1 mile east of the T. S. Aylor ranch house, Sulphur Spring, flowing copiously, issues from the Honeycut formation near river level.

Carboniferous

In the Gorman Falls area the Mississippian rocks are mapped as one unit and the Pennsylvanian as another. Other than to map the boundary between the two, little attention has been paid to either. The Mississippian, so far as noted, is composed of the Chappel limestone overlain by the Barnett formation. The Chappel limestone, even though it does not outcrop continuously, is present at all localities where erosion has removed the creeping cover of shale of the Barnett formation, thus indicating that the Chappel may extend practically continuously throughout the map area. The Barnett formation, as judged from its topographic expression, must be almost entirely shale. The surface of the lower part of the Barnett formation is a treeless bench, but the upper part is heavily wooded.

A mound between 100 and 200 feet in diameter situated alongside the T. S. Aylor ranch house displays outcrops containing fossils of Morrow age. They therefore probably represent F. B. Plummer's Sloan member of the Marble Falls limestone, even though Plummer (1946, p. 66) states that "It [the Sloan] has not been identified east of Cherokee Creek in the Colorado River exposures southeast of Bend or in Lampasas County." The rock in this mound is highly fossiliferous and lithically different from the rest of the Marble Falls limestone noted in the Gorman Falls area. Its position at the outer edge of the Barnett bench suggests solution of the Ellenburger strata following the deposition of the rock of

Morrow age but preceding its erosion, and thus allowing it to collapse into the Barnett formation and be preserved. Fossils from this locality (205T–1–4A) collected by G. A. Cooper and the writers are in the U.S. National Museum. Dr. Cooper states (oral communication) that, in his opinion, there is no doubt as to the Morrow age of these fossils.

Supplementary Information, Gorman Falls and Spicewood Creek Sections

In the list below are given the intervals in which sand was noted by Cloud in an examination of the insoluble residues of the Gorman Falls and Spicewood Creek sections; as are also the intervals in which sand was noted by Barnes and Warren in their description of the sections.

Of the 25 recordings of the presence of sand, 7 (italicized) were seen by both parties. Six sands seen in the field escaped being sampled. As should be expected, more sand was seen in the residues (19) than in the field (13).

Cloud (from residues)		Barnes and Warren (from field description)
Gorman Falls section		
675–80	A*	*675–80*
465–70	S	----------
455–60	S	----------
420–25	VA	*420–25*
----------		415–20
410–15	C	----------
----------		400–05?
305–10	R	----------
----------		285–90
----------		280–85
265–70	C	----------
----------		260–65
255–60	R	*255–60*
210–15	C	----------
165–70	S	----------
95–100	R	----------
85–90	C	*85–90*
70–75	R	----------
60–65	A	*60–65*
55–60	S	----------
----------		50–55
40–45	R	----------
10–15	S	*10–15*
5–10	A	----------
Spicewood Creek section		
420–25	C	*420–25*

*VA = very abundant.
A = abundant.
C = common.
S = scattered.
R = rare.

Description of the Gorman Falls Section

The Gorman Falls section receives its name from Gorman Falls which plunges into Colorado River in southeastern San Saba County. The bottom of the section is downstream southeast from Gorman Falls 0.4 mile and the section extends to the Mississippian contact 1.25 miles north-northwest of Gorman Falls. This section ties to the Spicewood Creek section with only 3 feet of overlap. The portion of this section beneath the *Archaeoscyphia* bed of the Gorman is located east of Colorado River in Lampasas County, and the rest of the section of the Gorman formation is situated along the side of a ravine upstream 0.3 mile from Gorman Falls west of Colorado River in San Saba County. A long shift was made on the Gorman-Honeycut contact to Tie Slide Canyon and the section of the Honeycut formation is situated along the north valley-wall of Tie Slide Creek.

The section was measured and described by V. E. Barnes and L. E. Warren in March 1945.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Lower Ordovician			
Ellenburger group: 1457 feet thick (745 feet present in Gorman Falls section)			
The top of the section is located just south of the road to the T. S. Aylor ranch house at a point 0.7 mile by road east-northeast of the Bend-Gorman Falls road at a point by road 3.1 miles south of Bend. See Plate 9 for exact location.			
Honeycut formation: 325 feet thick			
1. Dolomite—microgranular, medium gray, very poorly exposed. Some blocks contain irregular, clear to milky calcite-filled vugs. (The thickness of this interval is only an estimate since the upper part is covered. A few hundred yards each way, blocks of Chappel limestone outcrop. The Chappel limestone is persistent and may extend beneath the covering materials at the top of the section. Above the Chappel limestone, and responsible for the covering on the Honeycut-Chappel contact, is the Barnett formation, here a shale, producing a flat, the lower part of which is mostly treeless.)	5	5	740 – 745
2. Limestone—sublithographic, old ivory, essentially one bed. Silicified fossils are *Ceratopea* abundant but poorly preserved.	4	9	736 – 740
3. Dolomite—microgranular, dark beige to beige, beds 2 to 6 inches thick, very poorly exposed.	14	23	722 – 736
4. Limestone—sublithographic, yellowish brown, beds 6 to 12 inches thick. Silicified fossils are *Ceratopea* sp. and large *Archaeoscyphia* sp., abundant. (Fossils collected about 0.7 mile to the southwest may be from this interval and are *Ceratopea* sp. 5, TF–260.)	2	25	720 – 722
5. Dolomite—microgranular, beige, very poorly exposed but beds seen are about 4 inches thick.	13	38	707 – 720
6. Limestone—sublithographic, mottled brown and medium gray, beds poorly exposed but appear to be about 4 inches thick. Chert at 701 and 707 feet cannonballs, semiporcelaneous, medium gray, somewhat fossiliferous. Silicified fossils, 703 feet, *Archaeoscyphia* sp., rare. (Fossils collected about 0.65 mile to the southwest may be from this interval and are *Ceratopea* sp. 4? and unidentified gastropods and trilobites, TF–259.) Silicified fossils at 707 feet are *Ceratopea* sp., abundant; *Archaeoscyphia* sp., and cephalopod siphuncles.	15	53	692 – 707
7. Dolomite—microgranular, beige, beds poorly exposed but probably about 6 inches thick.	5	58	687 – 692
8. Limestone—sublithographic, medium gray, beds 1 to 3 feet thick. Chert, 682 to 683 feet, irregular finger-sized pieces having cannonball chert texture, beige, semiporcelaneous, fossil fragments abundant. Silicified fossils are *Ceratopea* sp. (Fossils collected about 0.6 mile to the southwest are at 680 feet and are *Ceratopea* sp. 4, TF–258.)	9	67	678 – 687
9. Dolomite—microgranular, yellow beige, one bed. Chert rare and composed of small rounded objects, possibly pellets. Sand present as a few scattered grains.	4	71	674 – 678
10. Limestone, somewhat dolomitic—sublithographic, yellowish gray. Chert cannonballs, semiporcelaneous, brown, common.	6	77	668 – 674
11. Dolomite—microgranular, near nutria, beds 1 to 3 inches thick.	1	78	667 – 668
12. Limestone—sublithographic, old ivory in part mottled yellowish brown; beds at 655 to 665 feet, 1 to 3 feet thick; 665 to 667 feet, 1 to 2 inches thick.	12	90	655 – 667

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Silicified fossils at 661 to 665 feet are *Archaeoscyphia* sp., common. (Fossils collected about 0.6 mile to the southwest are at about 662 feet and are a variety of *Ceratopea robusta* Oder and *Ceratopea* sp. 4? (TF–257).			
13. Dolomite—microgranular, beige, poorly exposed but beds appear to be about 6 inches thick. Quartz nodules common at 642 to 644 feet.	15	105	640 – 655
14. Limestone—sublithographic, yellowish brown, beds about 1 foot thick. Chert skeletal cannonballs, abundant at 638 to 640 feet. Silicified fossils abundant are *Hormotoma* spp., *"Ophileta"* sp., *Archaeoscyphia* sp., *Eopteria* sp., *Ceratopea capuliformis* or young *robusta*, undetermined cephalopods and gastropods, *Euconia* aff. *E. etna* (Billings) (205T–1–17A).	5	110	635 – 640
15. Dolomite—microgranular, medium gray to beige, bottom portion thinly bedded, top portion somewhat more thickly bedded, poorly exposed.	5	115	630 – 635
16. Limestone—sublithographic, yellowish brown, one bed. Chert cannonballs up to 1 foot in diameter, contain fragments of fossils.	2	117	628 – 630
17. Dolomite—microgranular, medium to dark gray, lower 3 feet paper-thin laminae; upper 4 feet 4- to 8-inch beds. Silicified fossils at 625 feet collected about 0.6 mile to the southwest are *Archaeoscyphia annulata* Cullison and *Barnesella lecanospiroides* Bridge & Cloud (TF–255).	7	124	621 – 628
18. Limestone—sublithographic; medium gray, beige, and brownish gray; 601 to 603 feet one bed; the interval is composed of 5 zones, 3 of which are thickly bedded with beds 1 foot or more thick, and 2 thinly bedded zones with beds 1 to 4 inches thick; exposures are rather poor. Chert, 604 feet, large cannonballs, irregular and in part anastomosing, semiporcelaneous, medium gray, fossil fragments abundant, also cannonballs at 608 and 612 to 614 feet. Chert at 606 feet semiporcelaneous, brown, occurring as a network of compact chert. Chert at 620 feet subchalcedonic, caramel colored, full of spicules, occurring as a 1-inch layer. Silicified fossils at 601 to 603 feet are *Archaeoscyphia* sp., and cephalopod siphuncles; 604 and 608 feet, fossil fragments in cannonball chert; 608 to 612 feet, *Archaeoscyphia* sp. abundant. (Fossils at 609 feet collected about 0.6 mile to the southwest are *Archaeoscyphia annulata* Cullison, *Ceratopea* cf. *C. capuliformis* Oder, *Hormotoma* sp., unidentified cephalopods, *Rananasus* sp., and *Jeffersonia* sp. (TF–256); and at 612 to 614 feet *Archaeoscyphia* sp., trilobites, and gastropods.)	20	144	601 – 621
19. Dolomite—microgranular; variegated beige, browns, and purples; appears to be in about 2- to 4-inch beds, not well exposed.	1	145	600 – 601
20. Limestone—sublithographic; medium gray to brownish gray; 561 to 567 feet essentially one bed, 567 to 590 feet 2- to 12-inch beds (top few beds nutria), 590 to 600 feet thickly bedded. Chert at 561 to 564 feet small cannonballs; 576 feet porcelaneous, medium gray, fossiliferous cannonballs, 585 feet cannonball type along bedding plane with abundant fossil fragments; 595 and 598 to 600 feet cannonballs. Chert at 575.5 feet chalcedonic, medium gray, occurring as finger-sized pieces and nodules. Chert at 588 feet subchalcedonic, medium gray, smooth-fracturing, occurring as a layer of masses 6 to 8 inches thick and 1 to 2 feet long. Quartz nodules numerous at 564 to 569 feet. Silicified fossils at 561 to 564 feet are *Archaeoscyphia* sp.; 576 feet trilobites and gastropods abundant; 580 feet	39	184	561 – 600

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
cephalopod siphuncles, and indications of *Ceratopea;* at 595 feet gastropods common; and 598 to 600 feet *Archaeoscyphia* sp., abundant.			
Shift east-northeast along base of interval about 1100 feet and continue section down drain.			
21. Limestone and dolomite—in about equal parts occurring as a network to lamellar intermixture producing a nodular appearance. This zone weathers recessive and in combination with the overlying massive 6-foot limestone bed forms a distinct scarp. The limestone is sublithographic, medium gray; and the dolomite is fine grained and medium gray. Chert of cannonball texture irregularly distributed as bedding plane layers; and some chert semiporcelaneous, medium gray, compact and smooth weathering.	7	191	554 – 561
22. Dolomite—fine grained, medium gray, one poorly defined bed. Quartz nodules abundant.	1	192	553 – 554
23. Limestone—with abundant network dolomite, irregularly bedded. Chert, some flattened cannonballs.	2	194	551 – 553
24. Dolomite—microgranular to fine grained, beige, one bed. Quartz nodules ½ inch in size, rare.	5	199	546 – 551
25. Limestone—sublithographic, medium gray, one bed. Chert cannonballs, semiporcelaneous, medium gray, abundant. Silicified fossils collected about 0.8 mile to the southwest are *Archaeoscyphia annulata* Cullison and unidentified endoceratid cephalopod (TF–254).	1	200	545 – 546
26. Dolomite—microgranular to fine grained, light brownish gray, one bed.	2	202	543 – 545
27. Limestone—sublithographic old ivory to medium gray with network dolomite in limestone grading up to dolomite for the portion of interval 514 to 515 feet; bedding 517 to 525 and 538 to 541 feet, 1 inch or less, rest of interval, 2- to 12-inch beds. Chert at 507 feet subchalcedonic to semiporcelaneous, bluish gray to white, 2-inch layer. Cannonballs at 516 feet porcelaneous, white to dirty white, in part structureless and in part composed of fragments. Chert 526 to 530 feet porcelaneous, beige, structureless, compact, smooth fracturing, in spheres up to 6 inches in size; 536 to 538 feet similar chert, some with concentric banding; and top surface contains nodules and plates of similar chert.	37	239	506 – 543
Shift east-southeast about 400 feet and continue section down hill.			
28. Limestone—sublithographic, old ivory, one bed. Chert cannonballs, semiporcelaneous, medium gray; contains many interstices and fossil fragments, about 8 inches in diameter.	2	241	504 – 506
29. Limestone—sublithographic, old ivory to light gray, beds up to 4 inches thick with most being thinner nodular beds.	5	246	499 – 504
30. Dolomite—microgranular, brown and highly weathered, poorly exposed.	3	249	496 – 499
31. Limestone—sublithographic, light gray, very thinly bedded, poorly exposed.	5	254	491 – 496
32. Limestone—sublithographic, old ivory, beds 2 to 12 inches thick, lower part highly dolomitic from network dolomite. Quartz nodules with quartz at outer surface and limestone in the centers, rare.	12	266	479 – 491
33. Dolomite—microgranular, medium gray to beige with yellowish brown and purple streaks and mottles.	9	275	470 – 479
34. Limestone—sublithographic and in part pellet limestone, medium gray, one bed. Chert cannonballs semiporcelaneous, beige, 2 to 3 inches in diameter. Some quartz films are present.	5	280	465 – 470

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
35. Dolomite—fine grained, medium gray to beige and light brown, one bed. Quartz nodules (dolomite in centers) ½ inch in size.	2	282	463 – 465
36. Dolomite—microgranular, light gray to light brown, beds 6 to 12 inches thick.	3	285	460 – 463
37. Dolomite—microgranular to fine grained, beige, beds 6 inches to 2 feet thick. Chert semiporcelaneous, light gray, oölitic, occurring as 1-inch nodules and plates.	3	288	457 – 460
38. Limestone—sublithographic, old ivory, bedding paper-thin laminae.	1	289	256 – 457
39. Limestone,—sublithographic, old ivory, beds 6 inches to 2 feet thick. Chert at 448 feet subchalcedonic to semiporcelaneous, light gray, crowded with pellets. Cannonballs 3 inches in diameter and elongated masses of similar chert at 455 feet semiporcelaneous, brownish gray. Quartz nodules 1 inch in size at 452 feet.	9	298	447 – 456
Shift downstream and across gully east-southeast about 200 feet along prominent bedding joint and continue section downstream.			
40. Dolomite—microgranular, beige to medium brown, beds 4 to 12 inches thick with top 2 feet nodular and thin bedded. Chert at 437 feet semiporcelaneous, light gray, contains sand grains and rounded to flattened ⅛-inch thick pebbles, occurs as a 2-inch layer. Chert cannonballs at 438 feet semiporcelaneous, reddish brown, 2 to 6 inches in diameter.	13	311	434 – 447
41. Limestone with dolomite network—limestone sublithographic, old ivory, beds 1 to 2 feet thick. Dolomite network indicative of filled burrows. Chert cannonballs at 431 to 432 feet semiporcelaneous, beige, fossiliferous. Silicified fossils in cannonballs are *Xenelasma* sp., and gastropods.	7	318	427 – 434
42. Dolomite—fine to medium grained, dirty brown to dark gray. Chert subchalcedonic, light gray, occurring as a row of nodules near base of interval.	3	321	424 – 427
43. Dolomite—microgranular, light brown, one bed.	1	322	423 – 424
44. Limestone—sublithographic, old ivory, with upper part containing network dolomite as if it filled burrows. Sand present in the dolomite. Calcitic fossils are sections of *Hormotoma* sp. on upper surface.	2	324	421 – 423
45. Dolomite—microgranular, medium gray to light brown, one bed. Sand is present in bottom 8 inches. The bed retains its characteristics throughout the map area. This is the base of the Honeycut formation.	1	325	420 – 421
The rest of the Gorman Falls section is measured 3600 feet to the south-southwest where the exposures of the upper part are not so good as in Tie Slide Canyon. The following supplementary section was measured in Tie Slide Canyon on a bare rock surface.			
a. Limestone—sublithographic, ivory to old ivory; essentially one bed, 400 to 405 feet; beds 6 inches to 2 feet thick from 405 to 420 feet. Sand fills what appear to be burrows in top 6 inches.	20	345	400 – 420
b. Dolomite—microgranular, medium gray mottled brownish yellow, bedding indistinct. Forms a recess around canyon wall.	2	347	398 – 400
c. Limestone—sublithographic; ivory to old ivory; bedding from 365 to 372 feet thin to nodular; 372 to 376 feet a single bed; 376 to 378 feet one bed; 378 to 384 feet	33	380	365 – 398

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
one bed; and 384 to 398 feet beds 6 inches to 2 feet thick. Silicified fossils are *Diaphelasma pennsylvanicum* Ulrich and Cooper at 395 feet.			
d. Dolomite—fine to medium grained, medium gray, beds 4 to 8 inches thick. Somewhat calcareous near middle of interval.	8	388	357 – 365
e. Dolomite—microgranular, medium gray, mottled brownish yellow, bedding indistinct. Bottom of supplementary section is at water level in pool in bottom of Tie Slide Canyon.	3	391	354 – 357
Shift along the Honeycut-Gorman boundary to a point 3600 feet airline south-southwest and continue section down slope.			
Gorman formation: 474 feet thick (420 feet present in Gorman Falls section)			
Calcitic facies: 383 feet thick			
46. Limestone—sublithographic; ivory; beds 1 to 2 feet thick. Beekite excrescences are present on the surface of beds at 415 and 418 feet. (This interval as measured was 18 feet thick but in view of poorer outcrops it is made to correspond more nearly to the supplementary section in Tie Slide Canyon using the *Diaphelasma* bed as a tie point.)	19	344	401 – 420
47. Dolomite—microgranular, one bed which actually is about 6 inches thick. Some float of limestone containing sand was seen in this vicinity, not found in place.	1	345	400 – 401
48. Limestone—sublithographic, ivory, essentially one bed. Chert present in top surface as a few small rounded nodules.	5	350	395 – 400
Shift eastward about 300 feet and continue section down slope.			
49. Limestone—sublithographic; ivory; beds, 377 to 382 feet, 2 to 6 inches thick; 382 to 384 feet one bed; 384 to 385 feet probably 6-inch beds; 385 to 389 feet one bed; 389 to 393 feet 6- to 12-inch beds; and 393 to 395 feet one bed. Chert excrescences on top surface of interval. Silicified fossils are bryozoans (?) at 384 feet, *Diaphelasma pennsylvanicum* Ulrich and Cooper at 395 feet. Calcitic fossils are sections of *Rhombella* sp. and *Lecanospira* sp. at 393 feet. (Silicified fossils at 395 feet collected 900 feet to the south-southwest are *Diaphelasma pennsylvanicum* Ulrich and Cooper and *Lecanospira* sp. (TF–251).	18	368	377 – 395
50. Dolomite—bottom 17 feet microgranular, top 4 feet fine grained; medium gray with yellowish brown mottles and streaks; beds 2 to 12 inches thick. Chert at 362 to 363 feet subchalcedonic, light bluish gray to white, occurring as rounded nodules up to 6 inches in diameter and as elongated curved plates. Chert at 374 to 375 feet subchalcedonic, light gray, with some pieces containing straight spicules, occurring as plates and nodules up to 2 inches thick.	21	389	356 – 377
51. Limestone—sublithographic, dark ivory, one bed. Calcitic fossils are *Lecanospira* sp. in top surface.	2	391	354 – 356
52. Dolomite—microgranular, dark gray mottled and streaked yellowish brown. Chert porcelaneous, white, cloudy from rounded pebble-like objects, occurs as a 4-inch bed near top. Silicified fossils are *Rhombella* sp. and *Lecanospira* sp., seen in chert.	2	393	352 – 354
53. Limestone and dolomite—intergrading laterally.	2	395	350 – 352
54. Limestone—sublithographic; ivory; at 335 to 341 feet beds 1 to 3 feet thick; 341 to 344 feet nodular thin bedded; 344 to 350 feet 1 to 2 feet thick. Chert at 342 to 343 feet subchalcedonic, bluish gray, abundant as irregular branching nodules and plates. Calcitic fossils at 350 feet are *Rhombella* sp., *Lecanospira* sp., and cephalopods.	15	410	335 – 350

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
55. Dolomite—microgranular, beige somewhat mottled brownish gray.	2	412	333 – 335
56. Limestone—sublithographic, ivory, one bed.	4	416	329 – 333
57. Dolomite—fine grained. A few hundred feet east this interval grades to limestone having a stromatolitic structure.	1	417	328 – 329
58. Limestone with network dolomite.	1	418	327 – 328
Shift along bluff downstream about 150 feet east and continue section down bluff.			
59. Dolomite—microgranular, beige and brownish gray somewhat mottled, beds 6 inches to 2 feet thick. Chert porcelaneous, white, chalky weathering, occurs as thin plates in top 2 feet of interval.	6	424	321 – 327
60. Limestone—sublithographic; ivory; at 302 to 312 feet beds irregular, 1 inch or less thick, having a nodular appearance and with shaly material between; at 312 to 321 feet, 1 to 2 feet thick. Chert at 318 to 319 feet subchalcedonic to semiporcelaneous, white to bluish gray, occurring as irregular plates, and as a discontinuous network of finger-sized pieces.	19	443	302 – 321
61. Dolomite—microgranular, medium gray to nutria, beds 1 to 2 feet thick. Chert at 294 to 296 feet subchalcedonic, white to bluish gray, contains straight white spicules, very abundant as nodules.	8	451	294 – 302
62. Limestone—sublithographic, beige, oölitic, beds 4 inches to 2 feet thick.	4	455	290 – 294
63. Dolomite—microgranular, beige, one bed. Chert subchalcedonic, white to brownish gray, oölitic, contains sand grains, occurs as a layer up to 6 inches thick. Sand is disseminated throughout bed.	1	456	289 – 290
64. Limestone—sublithographic, ivory, splits into thin layers.	5	461	284 – 289
65. Dolomite—microgranular, light to medium gray, beds 6 inches to 2 feet thick. Chert at 263 feet subchalcedonic, dull brownish gray, oölitic, sandy, occurs as elongated nodules. Chert at 267 to 270 feet subchalcedonic to semiporcelaneous, medium gray to dirty white, occurs as 1- to 2-inch thick flattened nodules. Chert at 283 to 284 feet subchalcedonic, dark bluish gray, rounded objects possibly oölites or pellets, sandy, occur as 2-inch thick beds. Sand is present at 263 and 283 to 284 feet.	21	482	263 – 284
Shift downstream about 500 feet along north valley wall of ravine using the chert matrix sand at 259 feet as the principal bed for making the shift.			
66. Limestone—sublithographic; ivory; 232 to 235 feet one bed; 235 to 237 feet beds about 1 inch thick; 237 to 239 feet one bed; and 239 to 263 feet beds 1 to 4 inches thick. Chert at 253 to 255 feet porcelaneous, dirty white to medium gray, occurring as bedding plane lenses and layers 1 to 2 inches thick. Chert at 259 feet semiporcelaneous to granular, the granular appearance due to sand grains and other objects, one bed 1 to 2 inches thick. Sand at 259 feet in chert and 2-inch limestone bed above it.	31	513	232 – 263
67. Limestone—sublithographic, ivory, with paper-thin bedding. Chert dull porcelaneous, brownish white, present as a 2-inch thick bed at top of interval.	1	514	231 – 232
68. Dolomite—microgranular, beige, one bed. Chert subchalcedonic to porcelaneous, medium gray and white mottled, one bed at bottom of interval is 2 inches thick.	1	515	230 – 231
69. Limestone—sublithographic; ivory; somewhat stylolitic; at 200 to 202 feet beds 6 to 12 inches thick; 206 to 213 feet	30	545	200 – 230

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
2 beds; 213 to 218 feet 1 to 4 inches thick; 218 to 223 feet thickly bedded; 223 to 228 feet 1- to 4-inch beds; and 228 to 230 feet 6- to 8-inch beds. Chert at 202 feet semiporcelaneous, medium gray, has a surface of raised designs, present as an inch-thick layer. Chert at 213 to 216 feet porcelaneous, white, occurring as plates. Chert at 223 feet similar but occurring as inch-thick lenses.			
Shift on top of *Archaeoscyphia* bed across Colorado River into Lampasas County and downstream to a point about 2700 feet airline southeast and continue section down slope.			
70. Limestone—sublithographic, ivory, beds 1 to 3 feet thick with a massive bed from 192 to 195 feet. Chert at 197 to 200 feet skeletal cannonballs grading into flattened skeletal outlines and finally into compact, porcelaneous, white, chert layer having a surface of raised designs. Silicified fossils at 183 to 185 feet are *Archaeoscyphia* sp., structure in chert nodules; and 197 to 200 feet *Archaeoscyphia* sp., *Rhombella* cf. *R. umbilicata* Ulrich and Bridge, undetermined gastropods, and cephalopods in cannonballs (141T-6-43A). West of river and north of ravine north of Gorman Falls, silicified brachiopods from this bed are *Syntrophinella* (TF-250).	20	565	180 – 200
71. Dolomite—microgranular, beige and darker, very poorly exposed. Chert porcelaneous, white, with micro-oölitic (?) structure, occurs as plates in top of interval.	7	572	173 – 180
72. Limestone—sublithographic, ivory, irregularly bedded, bedding planes 1 to 6 inches apart in lower portion becoming less distinct toward top, with one 5-foot bed at top.	14	586	159 – 173
73. Dolomite—medium grained beige, weathers saccharoidal, poorly exposed. Chert porcelaneous to subchalcedonic, medium gray to white, oölitic, occurs in upper part as long masses up to 6 inches thick.	7	593	152 – 159
74. Limestone—sublithographic, ivory, one 2-foot bed at bottom and 6-inch beds at top.	4	597	148 – 152
75. Dolomite—medium grained, beige, one bed. Chert porcelaneous, white, occurs in bottom half of interval as spherical nodules and irregular smooth forms.	3	600	145 – 148
76. Limestone—sublithographic, ivory, one bed.	3	603	142 – 145
77. Limestone—sublithographic, ivory, beds ¼ to 1 inch thick.	5	608	137 – 142
78. Dolomite—microgranular, beige and yellowish brown mottled with dull reds in bottom 2 feet and with light gray above. Chert weathered chalky white, occurs near bottom as thin plates.	8	616	129 – 137
Shift along bluff downstream about 75 feet and continue section down side of bluff.			
79. Dolomite—fine grained, light gray, poorly bedded. Chert porcelaneous, light gray, abundant as nodules and irregular forms.	2	618	127 – 129
80. Limestone and dolomite—a mixture ranging from pure limestone to pure dolomite grading in an erratic manner both vertically and laterally.	4	622	123 – 127
81. Limestone—poorly exposed but appears to be thinly bedded, 1 inch or less, weathers recessive.	4	626	119 – 123
82. Limestone—sublithographic, ivory, stylolitic, contains some dolomite rhombs, beds 1 to 3 feet thick. Chert at 112 feet porcelaneous, white, somewhat dolomoldic, occurring as a fairly continuous 2- to 6-inch layer.	12	638	107 – 119
83. Dolomite—microgranular to fine grained, white to light gray with some beige, beds 6 inches to 3 feet thick.	18	656	89 – 107

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
84. Dolomite—fine to medium grained, beige, one bed. Sand is disseminated in middle foot of interval.	2	658	87 – 89
85. Limestone—sublithographic, ivory, extremely thin bedded becoming thicker bedded at top. Chert porcelaneous to chalky, occurring in middle portion of interval as ellipsoids.	7	665	80 – 87
86. Dolomite—medium grained, beige, one bed.	3	668	77 – 80
87. Dolomite—microgranular, beige mottled with yellowish brown. Chert chalky, white, occurring as very thin plates.	2	670	75 – 77
88. Dolomite—medium grained, beige, beds 4 inches to 3 feet thick.	5	675	70 – 75
89. Dolomite—microgranular, beige with brown mottles.	1	676	69 – 70
Shift along bluff downstream about 100 feet and continue section down cliff.			
90. Dolomite and limestone—medium grained dolomite, brownish as if stained, grading to limestone below which contains dolomite network.	2	678	67 – 69
91. Limestone—sublithographic, old ivory with numerous brown and yellow lined stylolites, beds up to several feet thick. Chert at 61 feet porcelaneous to subchalcedonic, bluish gray to white, occurring as one layer up to 2 inches thick. Sand disseminated at 50, 61, and 65 feet.	30	708	37 – 67
Shift along base of cliff downstream about 150 feet and continue section down slope.			
Dolomitic facies: 91 feet thick (37 feet present in Gorman Falls section)			
92. Dolomite—microgranular; mostly light gray, some beige with yellowish brown mottles.	24	732	13 – 37
93. Dolomite—fine grained, light gray, one bed. Sand disseminated in bottom 6 inches of interval.	3	735	10 – 13
Continue section downstream along edge of flood plain.			
94. Dolomite—microgranular, light gray at bottom becoming slightly mottled toward top, bedding indistinct. Chert porcelaneous, white, concentrically banded nodules, occurring in bottom 2 feet of interval.	7	742	3 – 10
95. Limestone—yellowish brown, contains numerous dolomite rhombs, beds 1 to 6 inches thick. Chert present as a few thin excrescences.	1	743	2 – 3
96. Limestone—sublithographic, extremely thin bedded and cusped as if ripple marked, splits into very thin layers.	2	745	0 – 2
The bottom of the Gorman Falls section is located at the edge of a narrow alluvial strip just upstream from a drain on the east side of Colorado River at a point 2100 feet southeast of Gorman Falls.			

DESCRIPTION OF THE SPICEWOOD CREEK SECTION

The Spicewood Creek section receives its name from Spicewood Creek in southeastern San Saba County. The bottom of the section is about 600 feet upstream from the mouth of Spicewood Creek and continues along the northeast valley-wall for about 0.7 mile.

This section overlaps the Tanyard section 280 feet and displays the upper 400 feet of the Staendebach member of the Tanyard formation. It continues up into the dolomitic facies of the Gorman formation 57 feet and overlaps the Gorman section 3 feet. The upper portion of the Staendebach member is poorly exposed almost everywhere in the northeastern part of the uplift, but the exposures on Spicewood Creek are sufficient to allow a section to be measured. Faulting is present and some of the offsets are questionable as indicated in the description of the section.

The Spicewood Creek section was measured and described by V. E. Barnes and L. E. Warren in March 1945.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Ellenburger group: 1457 feet thick (456 feet present in Spicewood Creek section)			
Gorman formation: 474 feet thick (57 feet present in Spicewood Creek section)			
Dolomitic facies: 91 feet thick (57 feet present in Spicewood Creek section)			
The top of the section is located 200 feet north of Spicewood Creek 8.9 miles by road south of Bend. To reach the top of the section, follow the road from Bend toward the head of Lake Buchanan 7.9 miles, turn south on a dim cedar cutters' road 0.8 mile to Spicewood Creek roughly following a north-south fence, and thence downstream 0.2 mile. *See* Plate 8 for exact location.			
1. Limestone—containing some dolomite rhombs, grayish brown, one bed. Chert similar to skeletal cannonballs is present.	1	1	456 – 457
2. Limestone—sublithographic, extremely thin bedded and cusped as if ripple marked. Splits into layers 1/16 inch or less in thickness.	1	2	455 – 456
3. Dolomite—microgranular, medium gray to beige in part mottled with yellowish brown, beds 6 to 12 inches thick.	4	6	451 – 455
4. Dolomite—fine grained, mottled dark to medium gray with yellowish browns, beds 6 to 12 inches thick.	4	10	447 – 451
5. Dolomite—microgranular, medium gray to beige in part mottled with yellowish brown, beds 6 to 12 inches thick. Chert porcelaneous, white, occurs as nodules, rare.	4	14	443 – 447
6. Dolomite—fine grained, medium gray, one bed.	2	16	441 – 443
7. Dolomite—microgranular, medium gray to beige in part mottled with yellowish brown, beds 6 to 12 inches thick. Chert nodules at 436 feet are porcelaneous and white.	11	27	430 – 441
8. Dolomite—fine grained and dark gray containing areas which are microgranular and medium gray, one bed.	2	29	428 – 430
9. Dolomite—microgranular, predominantly light gray and in part mottled medium gray with yellowish browns, beds 6 to 12 inches thick.	2	31	426 – 428
10. Dolomite—microgranular as in interval 9. Quartz druse occurs as a network, and porcelaneous, white dolomoldic chert is common.	1	32	425 – 426
11. Dolomite—microgranular as in interval 9, beds 6 to 12 inches thick. Chert porcelaneous, white, occurring as an occasional flat plate with a row of plates at 415 to 416 feet. Sand at 420 feet is disseminated through 2 inches of dolomite.	15	47	410 – 425
12. Dolomite—fine grained, medium gray, somewhat mottled, one bed.	2	49	408 – 410
13. Dolomite—microgranular, mottled medium gray with yellowish browns, bedding indistinct, beds 1 foot or more thick. Chert at 403 feet porcelaneous, white, mixed with quartz druse. Chert at 407 to 408 feet porcelaneous to subchalcedonic, white to medium gray, slightly dolomoldic.	8	57	400 – 408
The bottom of this interval marks the base of the dolomitic facies of the Gorman formation. Shift about 1000 feet southeast downstream along Gorman-Tanyard contact and continue section down slope to bluff.			
Tanyard formation: 658 feet thick (400 feet present in Spicewood Creek section)			
Staendebach member: 456 feet thick (400 feet present in Spicewood Creek section)			
Calcitic facies: 163 feet thick			
14. Limestone—sublithographic, off white, considerable network dolomite. Chert at 384 to 386 feet chalcedonic bluish gray, forms an almost continuous layer.	11	68	389 – 400

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
15. Limestone—sublithographic, off white, one bed.	5	73	384 – 389
16. Limestone—sublithographic, off white, contains considerable network dolomite, beds 1 to 3 feet thick. Chert at 358 to 359 feet and 362 feet, porcelaneous, white, occurs as layers of small irregular nodules. Chert at 379 feet subchalcedonic to semiporcelaneous, banded, bluish gray, white. Chert at 384 feet subchalcedonic to semiporcelaneous, oölitic, in a layer 4 to 6 inches thick.	36	109	348 – 384
17. Limestone—sublithographic, off white, contains small amount of network dolomite, beds 6 inches to 3 feet thick. Chert at 339 feet subchalcedonic to semiporcelaneous, white to medium gray, oölitic, forming an almost continuous layer. Similar chert layers but mostly not oölitic are abundant throughout interval.	9	118	339 – 348
Shift about 200 feet southeast across two small faults on chert layer and continue section down bluff.			
18. Limestone—sublithographic, off white, with abundant network coarse grained dolomite, beds 1 to 3 feet thick. Chert at 307 to 309 feet subchalcedonic to semiporcelaneous, white to medium gray, occurs in layers. Chert at 310 feet similar but occurring as nodules.	33	151	306 – 339
19. Dolomite—coarse grained, medium gray, beds 1 to 4 feet thick. A zone from 297 to 301 feet is calcareous. Chert subchalcedonic to semiporcelaneous, dark gray to white, somewhat quartzose, dolomoldic, occurs as an almost continuous bed from 279 to 281 feet and as masses up to 295 feet. Chert subchalcedonic to semiporcelaneous, white to medium gray, oölitic, occurs as a 6-inch bed at 300 feet.	27	178	279 – 306
Shift southeastward about 600 feet along bottom of chert across several small faults and continue section down bluff. This shift is not satisfactory since chert of similar character is distributed through about 16 feet of section, and without other recognizable beds to trace, an error could easily have been made in shifting.			
20. Limestone—sublithographic, white to light gray, contains abundant network of coarse grained dolomite, beds 1 to 2 feet thick. Some of the beds grade rapidly laterally to coarse-grained dolomite.	16	194	263 – 279
Dolomitic facies: 293 feet thick (237 feet present in Spicewood Creek section)			
21. Dolomite—coarse grained, beige, poorly exposed; a few limestone patches surrounded by dolomite are located at 242 to 243 feet. Chert rubble abundant, but none seen in place.	26	220	237 – 263
22. Dolomite—medium grained, nutria to yellowish gray, mottled. Chert porcelaneous to subchalcedonic, white to bluish gray, occurring as a few nodules near middle of interval.	7	227	230 – 237
23. Dolomite—coarse grained, beige, beds about 2 feet thick. Chert at 224 to 225 feet porcelaneous to subchalcedonic, white to bluish gray, occurring as small nodules.	6	233	224 – 230
24. Dolomite—medium grained, medium brown to nutria, beds 6 to 12 inches thick. Chert particles in bottom 5 feet of interval are disseminated as 0.1- to 0.3-inch sized particles. Chert at 221 to 224 feet porcelaneous to subchalcedonic, white to bluish gray, abundant as nodules and plates up to 6 inches thick.	14	247	210 – 224
25. Dolomite—coarse grained, beige, beds about 2 feet thick. Interstitial chert common at 205 to 209 feet. Chert at 209 to 210 feet porcelaneous to subchalcedonic, white to bluish gray, abundant.	5	252	205 – 210
26. Dolomite—medium grained, medium brown, beds 6 to 12 inches thick.	2	254	203 – 205

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Chert subchalcedonic to semiporcelaneous, bluish gray to white, oölitic, very abundant.			
27. Dolomite—coarse grained, beige, bedding indistinct but beds probably 1 to 4 feet thick.	18	272	185 – 203
Chert at 185 to 186 feet semiporcelaneous to quartzose, dirty white to dark gray, dolomoldic. Chert at 194 to 196 feet semiporcelaneous, dark brownish gray, contains large dolomolds, abundant. A layer of 1-inch spherical, subchalcedonic chert nodules is situated at 195 feet.			
28. Dolomite—medium grained, medium gray to beige, bedding indistinct but beds probably 1 to 2 feet thick.	20	292	165 – 185
Chert semiporcelaneous to quartzose, dirty white to dark gray, dolomoldic, occurs as masses up to 1 foot thick and as a network, abundant. Considerable quartz druse is present.			
29. Dolomite—medium grained, medium gray to beige, bedding indistinct but beds probably 1 to 2 feet thick.	20	312	145 – 165
Chert semiporcelaneous, dirty white, dolomoldic, common. Some quartz druse is present.			
Shift downstream southeast about 900 feet along bluff and continue section down bluff. The beds actually followed to make this shift are somewhat beneath the offset and a few feet error in making the shift is possible.			
30. Dolomite—medium grained, dark gray mottled beige, beds 2 to 3 feet thick.	6	318	139 – 145
Chert semiporcelaneous, white, dolomoldic, common as small irregular nodules. A small amount of quartz druse is present.			
31. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct but probably about 1 foot thick.	11	329	128 – 139
Chert semiporcelaneous to subchalcedonic, white to medium gray, mostly oölitic, occurs as nodules and plates 3 to 6 inches thick and 1 to 3 feet long. A small amount of quartz druse is present.			
32. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct.	12	341	116 – 129
Chert quartzose to porcelaneous, white to medium gray, very abundant as an irregularly distributed network. Abundant quartz druse. Considerable subchalcedonic to semiporcelaneous, white to medium gray or bluish gray, dolomoldic chert is also present, with one bed from 123 to 124 feet nearly continuous. The chert from 125 to 128 feet is in thin, highly dolomoldic, quartzose, bedding plane layers.			
33. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct.	9	350	107 – 116
Chert subchalcedonic to semiporcelaneous, white to medium gray or bluish gray, dolomoldic, abundant. From 110 to 111 feet forms an almost continuous layer.			
34. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct.	7	357	100 – 107
Chert quartzose to porcelaneous, white to medium gray, highly dolomoldic, very abundant throughout interval as a network.			
35. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct, but beds probably about 1 foot thick.	10	367	90 – 100
Chert semiporcelaneous to subchalcedonic, in part slightly quartzose, bluish gray and medium gray to white, dolomoldic, abundant as 6-inch thick lenses up to several feet in length. Quartz druse at 90 to 91 feet abundant and common elsewhere in interval.			

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
36. Dolomite—fine to medium grained, dark gray in part mottled medium gray, bedding indistinct. Chert porcelaneous, white, dolomoldic, abundant as irregular plates and masses.	5	372	85 – 90
37. Chert—semiporcelaneous to subchalcedonic, white to medium gray or bluish gray, white weathering, lamellar, oölitic, and in part dolomoldic. Forms a continuous bed. This chert is probably the same as in the Tanyard section from 638 to 640 feet and is used as a tie between the Tanyard section and the Spicewood Creek section. There is considerable latitude for error in this correlation, but to obtain a complete Ellenburger section in this portion of the uplift some such tie has to be made.	2	374	83 – 85
38. Dolomite—fine grained, dark gray, mottled medium gray, bedding indistinct. Chert subchalcedonic to semiporcelaneous, bluish gray to white and in part medium to dark gray, in part oölitic, abundant as nodules.	3	377	80 – 83
39. Dolomite—fine grained, brown stained, beds about 1 foot thick.	2	379	78 – 80
40. Dolomite—medium grained, dark gray stained brown, beds about 1 foot thick. Quartz druse abundant.	3	382	75 – 78
41. Dolomite—fine grained, mottled dark gray and medium gray, beds 4 to 12 inches thick. Chert, one 2-inch concentrically banded nodule seen.	4	386	71 – 75
42. Dolomite—medium grained, mottled medium gray and dark gray, essentially one bed.	6	392	65 – 71
43. Dolomite—fine to medium grained, medium to dark gray with beige mottles, beds about 1 foot thick. Chert porcelaneous, in part oölitic, common as ½-inch plates and angular nodules from 60 to 65 feet. Quartz druse abundant at 58 to 60 feet.	8	400	57 – 65
44. Chert—subchalcedonic to semiporcelaneous, bluish gray to white, in part micro-oölitic, forming practically a continuous bed.	1	401	56 – 57
45. Dolomite—fine to medium grained, poorly exposed.	4	405	52 – 56
46. Dolomite—fine to medium grained, medium gray stained brown, bedding indistinct, but beds probably up to 4 feet thick. Chert at 27 to 28 feet quartzose to semiporcelaneous, white, occurring as plates. Chert at 30 to 32 feet porcelaneous, white, faintly banded nodules. Chert at 38 to 39 feet porcelaneous to subchalcedonic, bluish white, occurring as fractured nodules. Quartz druse irregularly distributed at 17 to 25 feet; abundant at 48 to 52 feet.	35	440	17 – 52
47. Dolomite—medium grained, stained brown, one bed. Chert semiporcelaneous to subchalcedonic, slightly banded, light grayish blue to brown, occurring in masses up to 1 foot in size. Considerable quartz druse present.	2	442	15 – 17
48. Dolomite—fine grained, light brown with grayish mottles, beds about 2 feet thick. Quartz druse irregularly distributed throughout interval.	7	449	8 – 15
49. Dolomite—medium grained, medium gray with light brown stains, beds 1 to 2 feet thick. Quartz druse, 4 to 8 feet, irregularly distributed.	8	457	0 – 8
The bottom of the Spicewood Creek section is along the east side of Spicewood Creek 600 feet upstream from its mouth. About 20 to 30 feet of fine to medium grained cherty dolomite in sporadic exposures is present beneath the section to lake level. A small fault may be present about 100 feet downstream from the bottom of the section.			

DESCRIPTION OF SMITH RANCH SECTION (SUPPLEMENTARY)

A supplementary generalized section was measured corresponding to the lower portion of the Gorman Falls section about 3400 feet northwest of the mouth of Yancy Creek, on a bluff on the east side of Colorado River. The purpose of this section was to check the tie between the Spicewood Creek and the Gorman Falls sections.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
1. Dolomite—microgranular.	8	8	88 – 96
Chert at 88 feet porcelaneous, white, in layers. Sand 2 inches thick at 88 feet and 3 inches of disseminated sand grains at 96 feet.			
2. Limestone—fine grained, one bed.	2	10	86 – 88
Cannonball type chert at 86.5 feet. Sand grains at 87 feet.			
3. Limestone—sublithographic, paper thin laminae.	1	11	85 – 86
4. Dolomite—microgranular.	5	16	80 – 85
5. Dolomite—fine to medium grained.	5	21	75 – 80
6. Dolomite—microgranular.	2	23	73 – 75
7. Dolomite—medium grained.	1	23	72 – 73
8. Dolomite—microgranular.	12	36	60 – 72
Chert at 69 feet quartzose, dolomoldic, occurs as a network 6 inches thick.			
9. Dolomite—medium grained.	1	37	59 – 60
10. Dolomite—microgranular.	1	38	58 – 59
11. Limestone and dolomite—gradational, dolomite medium grained.	3	41	55 – 58
12. Dolomite—microgranular.	1.5	42.5	53.5– 55
13. Dolomite—medium grained.	1	43.5	52.5– 53.5
14. Dolomite—microgranular.	23.5	67	29 – 52.5
Chert porcelaneous, white at 34 and 41 feet. Approximate base of Gorman formation as chosen in the Spicewood Creek section.			
15. Dolomite—medium grained.	1	68	28 – 29
16. Dolomite—microgranular.	6	74	22 – 28
Chert white, layered at 25 feet.			
17. Dolomite—medium grained.	7	81	15 – 22
18. Dolomite—essentially microgranular.	15	96	0 – 15
Base of Gorman formation as it would be chosen on basis of lithology.			

Beneath this section is 4 feet of coarse to medium grained dolomite, below which is limestone containing chert in which *Ozarkina* sp. is present.

When the section was measured the contact between the Tanyard and Gorman formations was thought to be at the base of interval 18, but in tracing the contact southeastward along the side of the bluff the lower 15 feet of microgranular dolomite appears to grade to limestone. Where this interval is limestone the contact would be picked on the basis of lithology 22 feet higher in the section. It appears, therefore, that, using lithologic evidence only at any one place and without impractically detailed lateral tracing, the Gorman-Tanyard contact as mapped would fluctuate through at least 22 feet of section. Fossils, of course, if found would settle the position of the boundary at any one locality, but fossils are scarce and for the most part the contact was mapped using intermittently determined lithologic evidence for it. The original reason for measuring this section was to check the tie between the Spicewood Creek and the Gorman Falls sections, by checking the distance between the base of the Gorman formation and the contact between the sublithographic limestone with paper-thin laminae and the overlying brownish granular limestone. In the Spicewood Creek section this point is 56 feet above the supposed base of the Gorman formation, whereas it is 86 feet above the point

originally picked, on the basis of lithology, as the base of the Gorman in the Smith ranch supplementary section. If the check point is at the same stratigraphic level in the two places then there is a fluctuation of 30 feet of the Gorman-Tanyard boundary as mapped within the Gorman Falls area.

DESCRIPTION OF THE TANYARD SECTION

The Tanyard section includes Cambrian rocks down to the San Saba limestone member of the Wilberns formation and Ordovician rocks up to near the top of the Tanyard formation in an unfaulted sequence. Unfortunately the section does not reach the top of the Tanyard formation, but this is not serious since all the facies of the Tanyard formation are well displayed in the section. The rest of the formation can be seen about 4 miles up the Colorado in the Spicewood Creek section. The Tanyard section was measured and described by Barnes and L. E. Warren in February 1945.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Ellenburger group: 1457 feet thick (538 feet present in Tanyard section)			
Tanyard formation: 658 feet thick (538 feet present in Tanyard section)			
Staendebach member: 456 feet thick (336 feet present in Tanyard section)			
Calcitic facies: 137[1] feet thick (17 feet present in Tanyard section)			
The top of the section is about 1200 feet east of Tanyard Spring. The top 197 feet of the section is measured approximately along the strike in a direction about S. 80° W.			
1. Limestone—sublithographic, light gray, with small network of dolomite having a wide range of colors such as pinks and yellows. The top 4 feet of limestone is not exposed, the surface being made up of angular blocks of chert. Chert subchalcedonic to semiporcelaneous, white to bluish gray, in part compact, in part dolomoldic, and some of it is oölitic, occurring as angular blocks a foot or more in size and very abundant in the top portion of the interval.	17	17	818 – 835
Note: Somewhat higher beds are present to the east but to include them in the section requires lateral tracing over areas with very poor outcrops and with no recognizable key beds on which to shift. The possibility of error in making a shift makes it inadvisable to try to place these beds in the section. Furthermore these beds are described in the Spicewood Creek section, located about 4 miles to the north.			
Dolomitic facies: 319 feet thick			
2. Dolomite—coarse grained, medium gray, beds 1 to 2 feet thick, not well exposed. Chert porcelaneous, white, clouded, not abundant, occurring as irregular masses.	23	40	795 – 818
3. Dolomite—medium grained, dark gray, not well exposed. Chert porcelaneous, brown, oölitic, occurring as irregular masses.	2	42	793 – 795
4. Dolomite—medium to coarse grained, medium gray, not well exposed. Chert porcelaneous, white, occurring as irregular masses.	3	45	790 – 793
5. Dolomite—coarse grained, medium gray, not well exposed.	4	49	786 – 790
6. Dolomite—medium grained, dark gray, 1-foot beds.	3	52	783 – 786
7. Dolomite—coarse grained, medium gray, 1- and 2-foot beds. Chert porcelaneous, dolomoldic, occurring as irregular masses. Considerable quartz druse is also present.	3	55	780 – 783
8. Dolomite—medium grained, beige, in 1-foot beds.	12	67	768 – 780

[1]Position of calcitic and dolomitic contact varies; consequently a different value is given for the Spicewood Creek section.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
9. Dolomite—medium grained, dark gray, one bed. Quartz druse abundant, and some porcelaneous highly dolomoldic chert is also present.	2	69	766 – 768
10. Dolomite—medium grained, beige to dark gray, beds about 1 foot thick. Chert porcelaneous, white, occurring as irregular nodules and masses.	4	73	762 – 766
11. Dolomite—fine grained, dark gray to brown, 6-inch beds. Chert porcelaneous, white, occurring as irregular nodules and masses.	2	75	760 – 762
12. Dolomite—medium grained, beige to yellow beige and some nutria, beds 6 to 12 inches thick. Quartz druse as a network is associated with highly dolomoldic, porcelaneous chert, very abundant.	8	83	752 – 760
13. Dolomite—medium grained, nutria at bottom ranging to beige at top, beds about 1 foot thick. Chert porcelaneous, white, somewhat dolomoldic, occurring mostly as small, angular fragments, sparse.	11	94	741 – 752
14. Dolomite—fine grained, beige with pink mottles, one bed.	1	95	740 – 741
15. Dolomite—medium grained, nutria, beds about 6 inches thick, not well exposed in line of section. Chert at 740 feet subchalcedonic to semiporcelaneous, light gray, occurring as small irregular nodules. A small amount of quartz druse is present.	5	100	735 – 740
16. Covered—probably medium grained dolomite.	3	103	732 – 735
17. Dolomite—medium grained, beige to medium brown, beds about 1 foot thick. A chert network, highly dolomoldic, occurs as a few irregular masses.	2	105	730 – 732
18. Dolomite—medium to coarse grained, medium gray to rose, beds 1 to 2 feet thick. Chert porcelaneous, white, dolomoldic, occurring as irregular masses.	6	111	724 – 730
19. Dolomite—medium grained, medium gray, beds 1 to 4 feet thick. Quartz druse is abundant as an irregularly distributed network, and a minor amount of porcelaneous, white, dolomoldic chert is present.	29	140	695 – 724
20. Dolomite—medium grained, beige to medium gray and light gray, beds 1 to 2 feet thick. Chert and quartz druse are about equally common. Chert porcelaneous, white, dolomoldic.	8	148	687 – 695
21. Dolomite—fine grained, beige to dark gray. Chert porcelaneous, white, occurring as ellipsoids up to 2 inches thick.	2	150	685 – 687
22. Dolomite—medium grained, dark gray, beds about 2 feet thick. Quartz druse is abundant as a network and along bedding planes. In top foot chert is porcelaneous, white, dolomoldic, and layered.	7	157	678 – 685
23. Dolomite—medium grained, light brown, beds 1 to 2 feet thick. Chert in bottom foot porcelaneous, white, dolomoldic to oömoldic, and oölitic, up to a 6-inch thick layer. Quartz druse masses are irregularly distributed throughout rest of interval, and some highly dolomoldic, porcelaneous chert is also present.	13	170	665 – 678

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
24. Dolomite—medium grained, beige to medium brown, in beds 2 to 3 feet thick. Quartz druse very abundant along bedding planes and as network masses, and some porous, porcelaneous, dolomoldic network chert is associated with the quartz druse.	11	181	654 – 665
25. Dolomite—medium grained, dark gray, beds about 2 feet thick. Quartz druse, a small amount, and a few nodules of porcelaneous white chert are present.	14	195	640 – 654
26. Chert—porcelaneous, lamellar, oölitic.	2	197	638 – 640
Shift along this distinctive chert bed southward up ravines and around spurs to a point about 3000 feet distant in a direction about S. 10° E. and continue section down hill in a direction about S. 60° W.			
27. Dolomite—fine grained, dark gray to beige, beds 4 to 6 inches thick. Chert varied with some porcelaneous, white, in part dolomoldic plates, and some highly porous, dolomoldic masses. Quartz druse occurs from 637 to 638 feet.	4	201	634 – 638
28. Dolomite—medium grained, medium to dark gray and in part with purplish splotches, beds about 1 foot thick. Some quartz druse is present.	4	205	630 – 634
29. Dolomite—fine grained, dark gray with purplish splotches. Chert porcelaneous, white, dolomoldic, occurring as nodules and plates.	1	206	629 – 630
30. Dolomite—medium grained, dark gray, beds 6 to 12 inches thick. Quartz druse is present in bottom foot.	4	210	625 – 629
31. Dolomite—fine grained, dark gray, beds about 1 foot thick. Quartz druse abundant as a network. Chert in top foot dolomoldic and lamellar with occasional plates of slightly oölitic, white porcelaneous chert.	5	215	620 – 625
32. Dolomite—fine grained, dark gray to beige, beds 6 to 12 inches thick. Quartz druse present from 611 to 615 feet, with some indication of its presence in the rest of the interval. Chert in top 2 to 3 feet porcelaneous, somewhat quartzose and oölitic, occurring as flat plates, suggesting lamellar structure.	9	224	611 – 620
33. Dolomite—medium grained, medium gray to beige, beds about 1 foot thick, weathers pitted. Quartz druse from 599 to 600 and 605 to 611 feet.	12	236	599 – 611
34. Dolomite—fine to medium grained, dark gray, 6-inch beds.	2	238	597 – 599
35. Dolomite—fine to medium grained, beige, one bed. Chert porcelaneous and dolomoldic associated with abundant quartz druse.	3	241	594 – 597
36. Dolomite—fine grained, dark gray, 6-inch beds.	1	242	593 – 594
37. Dolomite—medium grained, medium gray, beds 1 to 2 feet thick. Chert porcelaneous and dolomoldic associated with considerable quartz druse.	5	247	588 – 593
38. Dolomite—fine grained, beige, beds 6 to 12 inches thick.	2	249	586 – 588
39. Dolomite—medium grained, medium to dark gray, one bed. Chert porcelaneous and dolomoldic associated with considerable quartz druse.	2	251	584 – 586
40. Dolomite—fine grained, beige, one bed.	1	252	583 – 584
41. Dolomite—medium grained, medium to dark gray, one bed. Chert porcelaneous and dolomoldic associated with considerable quartz druse.	1	253	582 – 583

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
42. Dolomite—microgranular to fine grained, medium gray with very light purplish splotches, beds 6 to 12 inches thick.	4	257	578 – 582
43. Dolomite—medium grained, medium gray, one bed. Chert porcelaneous and dolomoldic associated with considable quartz druse.	2	259	576 – 578
44. Dolomite—medium grained, medium gray, beds about 2 feet thick.	5	264	571 – 576
45. Dolomite—fine grained, mottled purple or light gray and beige, beds 6 to 12 inches thick.	3	267	568 – 571
46. Dolomite—medium grained, beige, two beds.	3	270	565 – 568
47. Dolomite—fine grained, beige with purplish splotches, beds 6 to 12 inches thick.	3	273	562 – 565
48. Dolomite—medium grained, beige, one bed. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse.	2	275	560 – 562
49. Dolomite—fine grained, purplish gray, one bed.	1	276	559 – 560
50. Dolomite—medium grained, medium gray, one bed. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse.	2	278	557 – 559
51. Dolomite—fine grained, light beige, one bed.	1	279	556 – 557
52. Dolomite—medium grained, beige, beds up to 2 feet thick. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse.	5	284	551 – 556
53. Dolomite—fine grained, purplish gray, two beds.	1	285	550 – 551
54. Dolomite—medium grained, beige, one bed. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse.	2	287	548 – 550
55. Dolomite—fine grained, beige, beds 6 inches thick.	2	289	546 – 548
56. Dolomite—medium to coarse grained, beige, beds about 2 feet thick. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse.	6	295	540 – 546
57. Dolomite—medium grained, medium gray, beds about 2 feet thick.	6	301	534 – 540
58. Dolomite—fine grained, beige, beds 2 to 6 inches thick, poorly exposed. Chert porcelaneous, white, finely dolomoldic, occurring as thin plates along bedding, rare.	7	308	527 – 534
59. Dolomite—fine to medium grained, pinkish gray, beds 6 to 12 inches thick. Chert porcelaneous, white, dolomoldic, associated with abundant quartz druse, occurring as a network.	2	310	525 – 527
60. Dolomite—coarse grained, medium gray, essentially one bed, weathers pitted.	5	315	520 – 525
61. Dolomite—medium grained, light gray. Chert semiporcelaneous, highly dolomoldic, associated with a preponderance of quartz druse forming network masses a foot or more in thickness, irregularly distributed but abundant in bottom 2 feet of interval, and occurring as abundant somewhat more continuous layers from 514 to 520 feet. It is present in the intervening portion of the interval but is not abundant.	13	328	507 – 520
62. Dolomite—coarse grained, medium gray, beds 1 to 2 feet thick, weathers with a pitted surface.	7	335	500 – 507
63. Dolomite—coarse grained, medium gray, one bed, weathers with a pitted surface. Chert porcelaneous, white, dolomoldic, occurring as irregular nodules.	1	336	499 – 500
Shift southeastward around hillside about 300 feet and continue section southward down slope.			

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Threadgill member: 202 feet thick			
Upper dolomitic facies: 41 feet thick[8]			
64. Dolomite—coarse grained, medium gray, beds 2 to 12 inches thick.	18	354	481 – 499
65. Dolomite—medium grained, medium gray, one bed.	1	355	480 – 481
66. Dolomite—coarse grained, light gray, essentially one bed.	4	359	476 – 480
67. Dolomite—fine grained, mottled purplish gray to brownish gray, one bed.	1	360	475 – 476
Shift westward 100 feet along side of gully and continue section down slope southward to bottom of gully.			
68. Dolomite—coarse grained, light gray, beds 1 to 4 feet thick, weathers with a pitted surface.	17	377	458 – 475
Limestone facies: 138 feet thick			
69. Limestone—sublithographic, very light ivory, abundant network and bedding plane, coarse grained dolomite, one or two beds.	8	385	450 – 458
70. Dolomite—coarse grained, light gray, one bed.	5	390	445 – 450
71. Limestone—sublithographic, very light ivory, abundant network and bedding plane, coarse grained dolomite, essentially one bed.	8	398	437 – 445
72. Dolomite—coarse grained, light gray, one bed. Chert in top subchalcedonic, cloudy, light brown, weathering dirty white, occurring as irregular masses along bedding plane.	2	400	435 – 437
73. Limestone—sublithographic, very light ivory, abundant network and bedding plane, coarse grained dolomite, beds about 3 feet thick.	13	413	422 – 435
74. Dolomite—microgranular, purplish gray to beige, one bed. Laterally to the south this bed changes by degrees to coarse grained dolomite and then to limestone. Chert porcelaneous, white, occurring as nodules, rare.	2	415	420 – 422
Shift from bottom of gully southward about 150 feet along hillside and continue section southwestward down slope.			
75. Limestone—sublithographic, white to very light ivory, beds about 3 feet thick alternating with zones having beds 1 to 3 inches thick. The thin bedded zones are about 3 feet thick in lower part of interval becoming thicker upward, with top 13 feet having no beds over 1 foot thick and mostly ranging between 1 to 6 inches in thickness. Coarse grained dolomite as a network and along bedding planes common throughout interval. Chert minutely quartzose and smoky gray, sparingly present at a few places in interval. None seen is persistent for an appreciable distance along the strike. Fossils as cross sections on bedding surfaces are common. No collections were made but fossils can be broken out of the limestone.	55	470	365 – 420
76. Limestone—sublithographic, white, one bed, contains network of coarse grained dolomite. Chert minutely quartzose, dark smoky gray, occurring as irregular pieces up to 1 by 6 inches in size, rare.	6	476	359 – 365
77. Limestone—sublithographic, white, beds 2 to 4 inches thick.	3	479	356 – 359
78. Limestone—sublithographic, white, beds up to 2 feet thick. Beekite excrescences ¼ inch in size are present but scarce.	4	483	352 – 356
79. Limestone—sublithographic, white, beds up to 5 feet thick with a zone from 333 to 334 feet composed of 1- to 2-inch beds. Coarse grained dolomite is present as a discontinuous network and in places along bedding. Fossils are round-headed trilobites at 335 feet.	32	515	320 – 352
Shift along bedding plane southward for 75 feet and continue down slope to Cambrian boundary. Note laterally gradational boundary between the limestone and dolomite.			

[8]In both directions from the line of section the entire Threadgill member is dolomite. *See* Plate 8.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Lower dolomitic facies: 23 feet thick			
80. Dolomite—coarse grained, light gray with red, purple and yellow weathering stains, beds 1 to 4 feet thick, weathers with a pitted surface. Chert quartzose and black, occurs sparingly in bottom foot of interval.	23	538	297 – 320
Shift along Cambrian-Ordovician contact near top of bluff about 700 feet to the southeast and continue section S. 30° W. using a 6° dip in line of section. Actual dip is about 9° to the north.			
Upper Cambrian			
Wilberns formation: 297 feet measured to bottom of section			
Pedernales dolomite member: 277 feet thick			
81. Dolomite—fine to very fine grained, pinkish gray, platy, in beds 2 to 6 inches thick.	10	548	287 – 297
82. Dolomite—fine to very fine grained, mottled dark gray to light brown and nutria, beds 4 to 12 inches thick. Chert semiporcelaneous, minutely quartzose, dolomoldic to compact, light brown weathering dirty white, abundant as network aggregates.	17	565	270 – 287
83. Dolomite—fine to very fine grained, light brown to dark gray and nutria, beds 6 to 12 inches thick. Chert very scarce.	9	574	261 – 270
84. Dolomite—fine to very fine grained, nutria to light brown and dark gray and from 250 to 261 feet mostly beige, beds 6 inches to 4 feet thick. Chert at 216 to 245 feet common and at 245 to 261 feet abundant as quartzose, highly porous, dirty white layers along the bedding. Chert oölitic, semiporcelaneous, light brown and 6 inches thick is present at 227 feet. Conical fossils on bedding surface at 228 feet.	45	619	216 – 261
85. Chert—semiporcelaneous, white, faintly micro-oölitic, somewhat dolomoldic, occurs as a rather continuous layer.	2	621	214 – 216
86. Dolomite—fine to very fine grained, light brown to dark gray, somewhat mottled, beds 6 inches to 2 feet thick. Chert quartzose, highly porous, dirty white, very abundant as layers along the bedding.	14	635	200 – 214
Shift along top of coarse grained dolomite along bluff about 500 feet and continue section down spur to the south.			
87. Dolomite—coarse grained, light gray, seldom with mottles having a very light purplish tint, beds 1 to 4 feet thick, weathers pitted. Chert at 139 feet to 155 feet common; at 155 to 175 feet scattered and in smaller pieces, chalky textured to semiporcelaneous and minutely quartzose, in part chalcedonic.	75	710	125 – 200
88. Dolomite—coarse grained, mottled medium to dark gray and beige, beds about 2 feet thick, weathers pitted. Chert chalky textured to semiporcelaneous and minutely quartzose, in part chalcedonic, occurring as irregular finger-like to flattened nodules.	11	721	114 – 125
89. Dolomite—medium grained, beige with some medium gray mottles. Chert at 111 to 113 feet semiporcelaneous, minutely quartzose, slightly dolomoldic, occurring as irregular ½-inch sized pieces.	3	724	111 – 114
90. Dolomite—very fine to fine grained, mostly purplish with dark gray and beige mottlings, beds 6 to 12 inches thick, slightly pitted on weathered surfaces.	19	743	92 – 111

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Shift across drain and along hillside about 400 feet to the south. This shift is unsatisfactory. The chert does not hold a constant level and nothing could be traced without question. The dip of the rocks in this area averages 10° and this value was used along the flood plain to help establish the tie point. A median point was chosen between the points obtained by lateral tracing and by instrument. The error in this shift is probably within 10 feet.			
91. Dolomite—microgranular to fine grained, mottled and streaked mostly light purplish and light olive green to beige, beds irregular and about 1 to 2 feet thick. Chert porcelaneous to semiporcelaneous, in part quartzose, highly dolomoldic, dirty white, and occurring as network excrescences on weathered surface which cannot be seen on freshly broken surfaces. In upper part much of the chert is in curved layers as if deposited with or concentrated along growth surfaces of stromatolites. Fossils are silicified *Scaevogyra* seen at 78 and 81 feet.	32	775	60 – 92
92. Dolomite—microgranular to very fine grained, somewhat mottled beige and medium gray with some yellowish and purplish streaks and mottles, beds 1 to 2 feet thick.	15	790	45 – 60
93. Dolomite—microgranular to very fine grained; mottled medium gray to dark gray, beige and purplish gray; beds 1 to 4 feet thick, weathers pitted. Some calcite is present in the rocks as bodies about as large as the surface pits.	15	805	30 – 45
94. Dolomite—microgranular to very fine grained, medium to dark gray with some yellow and purple streaks; beds in bottom 7 feet, 6 inches to 2 feet thick; in top 3 feet, 2 to 4 inches thick; weathers blocky and smooth. *San Saba limestone member: 20 feet measured to bottom of section*	10	815	20 – 30
95. Limestone somewhat dolomitic—mottled light to medium and dark gray, sparingly dolomitic at bottom becoming progressively more dolomitic upward until only the girvanellas remain limestone. The dolomitic portion of the rock forms a raised network on weathered surfaces. The bottom 9 feet is essentially one bed as is also the portion of the interval from 11 to 17 feet. From 9 to 11 feet 1- to 2-inch beds and from 17 to 20 feet 4- to 18-inch beds. On gentler slopes the bedding joints are more closely spaced, forming parallel sided slabs. This section was measured when the water in Lake Buchanan was low. When the lake is full a portion of the bottom part of the section as measured will be under water. The bottom of the Tanyard section is about 6000 feet south of Tanyard Spring and about 2800 feet downstream from Wolf Spring.	20	835	0 – 20

DESCRIPTION OF SUPPLEMENTARY SECTIONS IN THE TANYARD AREA

An attempt was made to estimate the interval between the base of the Tanyard section and the alate-*Billingsella* bed. The following section is described from the vicinity of a small tributary of Jim John Creek about 2200 feet due west of the mouth of Jim John Creek (Cedar Hollow). The top of the section is about 1500 feet north of Jim John Creek and 400 feet east of the tributary.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
1. Dolomite—very fine grained to microgranular, poorly exposed. Chert of the type described in Tanyard section, interval 91, very abundant. Fossils are *Scaevogyra sweezeyi* Whitfield, *S. elevata* Whitfield, *Sinuopea* sp., and *Proplina* or *Archinacella*. Silicified girvanellas are abundant (205T-1-11A).	14	14	101 – 115
2. Dolomite—very fine grained to microgranular, beds range up to 2 feet thick.	42	56	59 – 101
3. Dolomite—limestone transition. Ints. 1–3 = Pedernales dol. Shift from the upper boundary of an inlier of San Saba limestone downstream and continue section southward. Shifting on the boundary between limestone and dolomite is not satisfactory since this boundary fluctuates. The amount of error in this shift cannot be estimated on the ground but it appears by comparison with another section that about 16 feet of beds was not measured.	16	72	43 – 59
4. Limestone—mottled, medium gray with yellow and brown wavy streaks, beds 6 to 18 inches thick. San Saba ls.	28.5	100.5	14.5– 43
5. Shale—with thin beds of fine grained, medium gray, dolomitic limestone.	10	110.5	4.5– 14.5
6. Limestone—oölitic, brown, glauconitic, one bed. Fossils are alate *Billingsella* on the top surface of the bed.	3	113.5	1.5– 4.5
7. Limestone—oölitic, white, contains pebbles. The next bed beneath contains *Plectotrophia*. Ints. 5–7 = Point Peak sh.	1.5	115	0– 1.5

One thousand feet northwest of the mouth of Jim John Creek, 68 feet of section was measured between the alate-*Billingsella* bed and the bottom of the Pedernales dolomite. The base of the dolomite in this section is roughly 29 feet higher than it is 1700 feet to the west-southwest.

About 1000 feet west of Lake Buchanan and about 4200 feet north-northeast of Tanyard Spring the base of the dolomite is 57 feet above the alate-*Billingsella* bed and the first chert is 47 feet up in the dolomite. The latter figure is apt to be in error since the dips of the rock and the slope of the surface of the ground are both gentle.

The best interval measured is located about 6000 feet north-northeast of Tanyard Spring, along an east-west fence about 200 feet east of the lake. The alate-*Billingsella* was not found but the same sequence of beds as measured near Jim John Creek was present with *Plectotrophia* just below a 1.5-foot white pebbly oölite, above which was a 3-foot brown oölite, the top of which should contain the alate *Billingsella*. The interval between the postulated alate-*Billingsella* bed and the first chert in the Pedernales dolomite member of the Wilberns formation is 97 feet. The contact between the San Saba limestone and the Pedernales dolomite is in a covered zone about 25 feet above the postulated alate-*Billingsella* bed. Using this section for comparison on the assumption that it is the best and that the chert holds a constant horizon, then there should be 37 feet of beds beneath the Tanyard section to the alate-*Billingsella* bed.

These measurements show a marked though not unusual fluctuation (43 feet) of the boundary between the San Saba limestone and the Pedernales dolomite members of the Wilberns formation in a relatively short distance.

THE MOORE HOLLOW AND WARREN SPRINGS AREAS, RILEY MOUNTAINS, LLANO COUNTY

INTRODUCTORY STATEMENT

The Moore Hollow and Warren Springs areas lie on the south and north limbs, respectively, of the faulted Honey Creek basin in southeastern Llano County, 10

to 14 miles airline southeast to south-southeast of the town of Llano. Both are reached via the Llano-Round Mountain road, on the turnoff to Click, and the south edge of the Moore Hollow area is only a little north of Click. Altogether about 7 square miles was mapped geologically between the latitudes of 30° 34′ to 30° 39′ north and longitude of 98° 32′ to 98° 34′. Plate 10 shows the geology of the areas involved at a scale of 1:10,000, and figure B of Plate 33 is a stereogram, at the approximate scale of 1:20,000, of part of the Moore Hollow area.

Control for the base maps of the Moore Hollow and Warren Springs areas was taken from tape and Brunton compass traverses along the Llano-Click road by Cloud and local residents. The base was plotted and adjusted by L. E. Warren from data recorded by Cloud on aerial photographs of the U.S. Department of Agriculture.

On its east side the Honey Creek basin is dropped by the Riley Mountain fault against the pre-Cambrian Packsaddle schist, which underlies the eastern half of the Moore Hollow and Warren Springs areas. In fact, the presence of Ellenburger rocks in this part of the Llano uplift is due to the fact that the Honey Creek basin is structurally the deepest part of the region, the Pennsylvanian Smithwick shale being faulted against the Packsaddle schist at the middle of the basin.

Due to subsidiary east-west faulting associated with the structural adjustment of the basin, it was not possible to obtain a complete section of Ellenburger rocks on either limb of the Honey Creek basin. Strata below the Gorman formation were therefore measured and described from the Moore Hollow area, whereas the Gorman and Honeycut formations were measured and described from the Warren Springs area. Rocks mapped and described include a complete sequence of the rocks known to occur between the pre-Cambrian and the Pennsylvanian of the Llano uplift, except for Devonian strata and the basal Mississippian Ives breccia. Unusually steep dips for the Llano region combine with topography to make possible the observation of a thick sequence of strata in a relatively short horizontal distance in the sections here described.

With local exceptions, and disregarding artificial clearings, the Riley Mountains are thickly wooded throughout. Cedar is the dominant type of tree and its growth seems to be more closely related to topography than to geology, being very dense on north slopes and more scattered on south slopes of hills. Vegetational banding is prominent and useful in the Cambrian and Carboniferous rocks, and in spite of control being primarily topographic the dolomites of the Tanyard formation are relatively sparsely wooded. Dendrologic patterns, however, are less helpful to mapping in the outcrop area of the Ellenburger group of the Riley Mountains than in areas of more gentle topography.

The Warren Springs, Moore Hollow, and East Canyon sections, comprising the composite Riley Mountain section, are described on pages 260–287 and diagrammatically represented on Plate 14. Table 3 presents a summary of physical and chemical data for samples from the Warren Springs and Moore Hollow sections, prepared by Barnes from data furnished by Dr. S. S. Goldich and Mr. E. B. Parmelee of the Argicultural and Mechanical College of Texas.

On balancing accessibility, completeness, compactness, percentage of exposure, and "normality" of expression, the composite Riley Mountain section is seen to include the best section of Ellenburger rocks now known or likely to be discovered. Adding the work of Goldich and Parmelee to that of the present authors, it is also the most intensively studied. For these reasons the Lower Ordovician part of the combined Moore Hollow and Warren Springs sections is here designated the *standard section* for the Ellenburger group. The composite Tanyard-Gorman section (pp. 230–249), adjoining the Ellenburger Hills 25 miles north-northeast from here, is a preferable type section, but its widespread and relative inaccessibility make it unsuitable as a standard.

UPPER CAMBRIAN

Riley Formation

In upward succession the three members of the Riley formation are the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone members. They are easily mapped in the Riley Mountains because of their characteristic topographic and photographic expression (Pl. 33, fig. B). The total thickness of the Riley formation in the East Canyon section, which may be taken as representative of the type area, was computed as 780 feet.

Hickory sandstone member.—The Hickory sandstone member rests nonconformably on the varied but mostly dark and schistose metasedimentary rocks of the pre-Cambrian Packsaddle schist. At or near its base through most of the Moore Hollow area is a conspicuous breccia bed a foot to 30 inches thick and comprised of subangular to angular phenoclasts of white vein-quartz in a sandstone matrix. Upward it consists predominantly of noncalcareous, nonglauconitic, largely cross-bedded sandstones wherein the grains are angular to subrounded, poorly sorted, and display a wide range in size. Its thickness varies but is about 335 feet in the East Canyon section. Fossils were not observed in the Hickory sandstone of the Moore Hollow area.

For the most part the Hickory sandstone member is topographically and dendrologically distinct. It rises in low bluffs above the Packsaddle schist and is separated from the bluffs of the Cap Mountain limestone member above by a bench on the dip-slope of its upper beds. This bench is the site of residual and colluvial accumulations and is so prominent that it was once locally cleared and cultivated to form a landmark known as "halfmoon field" (Pl. 33, fig. B, southwest corner). The Hickory sandstone supports a growth of deciduous oaks, whereas mesquite and bee-brush are prominent on the Packsaddle schist below and cedar on the Cap Mountain limestone above. Clumps of live oak are a feature of the bench at the top of the Hickory sandstone.

Cap Mountain limestone member.—The Cap Mountain limestone member is arenaceous in the lower part and slightly so in the upper part, grading to the Hickory sandstone member below and the Lion Mountain sandstone above, but topographically and dendrologically distinct from both. Characteristically it is a granular, brownish gray to grayish brown or brown, markedly glauconitic limestone. It is about 420 feet thick in the East Canyon section. Trilobites and acrotretid brachiopods were noted locally, but none were collected.

The Cap Mountain limestone member expresses itself as a cedar-covered, south-facing scarp between the broad flat at the top of the Hickory sandstone and the narrow but conspicuous flat underlain by the Lion Mountain sandstone member. In the Moore Hollow area the lithologic boundary between the Cap Mountain limestone and Lion Mountain sandstone members of the Riley formation was placed at the top of the highest of several prominent limestone beds containing many white-weathering *Lingulella.* This boundary splits the *Aphelaspis* zone and includes the lower sparsely vegetated part of the "Lion Mountain bench" in the Cap Mountain limestone.

Lion Mountain sandstone member.—At the top of the Riley formation is the highly glauconitic and locally calcareous Lion Mountain sandstone member. Weathering of this 24-foot sandstone has produced a narrow but prominent bench at the top of the Riley formation, separating it topographically from the scarp-forming Welge sandstone and Morgan Creek limestone members of the Wilberns formation above. Lenses of granular limestone that weather out of the Lion Mountain sandstone are crowded with *Aphelaspis* and other trilobites. The lower part of the *Aphelaspis* zone, however, and the more sparsely vegetated part of the "Lion Mountain bench" were mapped with the Cap Mountain limestone in the Moore Hollow area.

Wilberns Formation

All five named members of the Wilberns formation are represented in the

Moore Hollow area, and the total thickness of the formation in the East Canyon and Moore Hollow sections is about 560 feet.

Welge sandstone member.—The basal member of the Wilberns formation is a sparingly glauconitic, brown to brownish yellow sandstone about 17 feet thick that forms a low scarp adjacent to the Lion Mountain flat and grades upward into the Morgan Creek limestone member. A single specimen of *Lingulepis* was found in the Welge sandstone of the Moore Hollow area by Dr. Leo Hendricks (TF–414).

Morgan Creek limestone member.—The Morgan Creek limestone member consists of granular, ordinarily glauconitic limestone that is pink to reddish brown at the base and greenish gray to gray above. The basal few feet are arenaceous, grading to the Welge sandstone below, and the manner of weathering of the beds above the *Eoorthis* zone suggests local shaly partings in the upper half of the member. In the East Canyon section the Morgan Creek limestone is 110 feet thick, with *Eoorthis texana* Walcott 48 feet above its base. *Pterocephalia, Elvinia,* and other trilobites are abundant immediately below *Eoorthis,* and *Billingsella* is very abundant above it, in both calcitic and silicic preservation. *Huenella* occurs through 50 feet of beds above *Eoorthis,* in calcitic preservation.

In the western part of its outcrop in the Moore Hollow area the Morgan Creek limestone member is wholly within a prominent, south-facing scarp separated from that of the Cap Mountain limestone member of the Riley formation below by the Lion Mountain flat and distinct from it in being steeper and in having a thick growth of black persimmon interspersed with the cedar. In the eastern part of its outcrop, however, the *Eoorthis* zone is at the crest of the scarp, with the upper beds of the Morgan Creek limestone coming in on the steep north-facing dip-slope that forms the south slope of Moore Hollow.

Point Peak shale member.—The Point Peak shale member, 216 feet thick in the Moore Hollow area, lies above the Morgan Creek limestone member. It consists of green shale with interbedded granular glauconitic limestone in the lower half and mostly sublithographic, stromatolitic limestones with local shale partings in the upper half. On the north limb of the Honey Creek basin, a little over 4 miles north of Moore Hollow and about 1.3 miles north of Warren Springs, the Point Peak shale member consists mostly of green shales with interbedded granular limestones, and the stromatolitic limestones are reduced to local thin beds. Although this difference in facies was recognized from the beginning of work in the area, and the upper 115 feet of mostly stromatolitic limestones in the Moore Hollow area were actually mapped as a separate unit, they are included with the San Saba limestone member on Plate 10. This resulted from an application of member lithologies that is defensible on some grounds but which obscures the actual stratigraphic associations of the zones of stromatolitic bioherms with the upper Point Peak shale in many parts of the Llano region. A restudy of the problem of the bioherm associations by the authors in January 1946, after the geologic map had gone to the engravers, resulted in a decision to include the biohermal or biostromal limestones at this position with the Point Peak shale member, except where they are mapped as a separate unit or can be shown to go laterally into limestones like those of the San Saba limestone member. This interpretation for the Moore Hollow area is shown on Plate 33, figure B.

The Point Peak shale member is separated from the Morgan Creek limestone member below on the basis of the first appearance of the crinkly-surfaced, platy, green, micaceous limestones characteristically associated with the more shaly zones of the Point Peak member; and the same type of crinkly-surfaced limestones occur in its uppermost shaly zone between the biohermal limestones at its top and the San Saba limestone member. The lower shaly part of the Point Peak shale member is mostly on the south slope of Moore Hollow and is more thickly wooded than the Morgan Creek

limestone below; whereas the upper stromatolitic limestones are on the north slope of Moore Hollow and are sparsely cedared or almost barren, in contrast to the thicker growth of cedar on the San Saba limestone above.

Characteristic fossils of the Point Peak shale member are species of silicified *Billingsella, Plectotrophia,* and occasional trilobites. *Plectotrophia,* which occurs in association with a characteristic large alate-*Billingsella* about 30 feet below the top of the normal facies of the upper Point Peak shale in the north limb of the Honey Creek basin, probably occurs 20 to 25 feet below the top of the stromatolitic facies in the south limb (p. 285).

San Saba limestone member.—In the Moore Hollow area the San Saba limestone member is sublithographic to medium grained, being generally less granular than in other parts of the Llano region. It is brownish to greenish gray, grading to pearl gray, with yellowish to buff mottles and streaks. Thin oölite beds occur locally near the base and top of the member, but glauconite is scarce except in the upper part. The San Saba limestone weathers to a darker tone of gray and is darker on a fresh surface than the Ellenburger limestones above it. It grades laterally and vertically to the Pedernales dolomite member, with consequent variation in thickness from the 144 feet measured in the Moore Hollow section.

Locally it is difficult to be sure whether apparent lateral transition between the Pedernales dolomite and San Saba limestone members is due to actual transition or to collapse. A curious feature of the areas interpreted as collapse of the Pedernales into the San Saba is that the trace of the upper boundary of the biohermal limestone facies of the underlying Point Peak shale does not in any way reflect participation in the event.

The highest *Billingsella* known from the Llano region occurs in silicic preservation 63 feet below the top of the San Saba limestone member or 136 feet below the top of the Wilberns formation in the Moore Hollow area (TF–366). A few trilobites and hexactinellid sponge spicules were also noted, but fossils are generally scarce in the San Saba limestone of this area.

Pedernales dolomite member.—The Pedernales dolomite member in the Moore Hollow area is mostly very fine grained to microgranular and yellowish to brownish gray, olive gray, or rose gray. It is 73 feet thick in the Moore Hollow section. It stands in sharp contrast to the much coarser grained and lighter colored dolomite of the basal Ellenburger beds that rest on it.

Interstitial and possibly globular glauconite occurs locally in the Pedernales dolomite member, and subporcelaneous to subgranular, partly drusy and finely dolomoldic, white to yellowish or brownish dolomite is locally abundant in the upper part.

Finkelnburgia and *"Hyolithes"* were found in dolomite 67 feet below the top of the member, but fossils are generally uncommon.

LOWER ORDOVICIAN

Ellenburger Group

The 1512 feet of Ellenburger rocks in the composite Riley Mountain section include representatives of all three formations of the Ellenburger group, with their various member and facies divisions as described below.

It is of interest that a petrographic study by Dr. S. S. Goldich and Mr. E. B. Parmelee (1947, fig. 7) revealed detrital quartz in hydrochloric acid residues from 5 places in the Tanyard formation of the Moore Hollow section. These were at 339, 445, 512, 845, and 880 feet above the base of the section, or 7, 113, 180, 513, and 548 feet above the base of the formation. At 180 feet above the base of the Tanyard subrounded sand grains averaging 0.19 mm. in diameter are said to be common in the residues, but at the other places they are rare, and their size is not given. These grains were found under such intensely close examination that they need not be considered to affect general stratigraphic applications, but they serve to warn

against a too close reliance on sand grains *per se.*

Tanyard formation, Threadgill member.—In the Moore Hollow area the Threadgill member is about 250 feet thick and is divisible into three nearly equal parts. These are a lower facies of coarse to medium grained, vuggy, woodash gray to white dolomite; a middle facies of sublithographic, woodash gray to pearl gray limestone that is in part reticulated with dolomite and grades laterally to dolomite; and an upper facies of mostly medium grained, locally vuggy woodash gray to light brownish gray dolomite.

The dolomites of the Threadgill member in the Riley Mountains average distinctly coarser grained and less clearly bedded than those of the overlying Staendebach member of the Tanyard formation and much coarser grained and more massively bedded than those of the underlying Pedernales dolomite member of the Wilberns formation. The cherts of the Threadgill are characteristically drusy, coarsely dolomoldic, and less in quantity than the porcelaneous to chalcedonic and oölitic cherts of the Staendebach member. Locally they contain the characteristic Tanyard gastropods and cephalopods.

Tanyard formation, Staendebach member.—The Staendebach member is about 353 feet thick in the Moore Hollow section and is there divisible into two parts. The lower two-thirds consists of dolomite that is fine to medium grained and light gray to brownish gray with local pinkish mottles, streaks, and tinges. This dolomite grades laterally and vertically to an upper facies of mostly sublithographic pearl gray to woodash gray or light brownish gray limestone.

The contact between the Threadgill and Staendebach members of the Tanyard formation in the Riley Mountains is marked by a break in granularity of the dolomites from predominantly medium grained in the upper Threadgill to fine to very fine grained in the basal Staendebach. This coincides with the lowest appearance of laterally persistent porcelaneous to chalcedonic, locally oölitic, white-weathering chert, and such chert is quite abundant in higher beds of the Staendebach member, along with other types. In the calcitic facies the chert is predominantly chalcedonic to semichalcedonic and occurs as lenses, nodules, and irregular layers.

Gorman formation.—Measurements in the Warren Springs section give 456 feet of Gorman strata, about equally divided into a dolomitic facies below and a calcitic facies above. The dolomitic facies contains a little limestone near the top, and the calcitic facies contains a large amount of dolomite near the middle. The dolomites are predominantly microgranular, grading to fine grained. In color they are rose beige to beige, rose gray, gray, or rose. The limestones are predominantly sublithographic and pearl gray to woodash gray. Chert is porcelaneous to chalcedonic and in general uncommon throughout the formation. Scattered to locally abundant sand grains occur intermittently though not commonly throughout the formation. *Archaeoscyphia* occurs in a thin zone about 243 feet above the base of the Gorman formation in the Riley Mountains and is so close to the boundary between the dolomitic and calcitic facies that it furnishes a horizon against which vertical fluctuations in lithology can be compared.

Although the Tanyard-Gorman contact is essentially a limestone-dolomite contact for much of its mapped extent in the Riley Mountains, the uppermost beds of the Tanyard formation are commonly dolomitic and limestone occurs locally at or near the base of the Gorman formation. Where the contact is not located on faunal evidence, it was placed below the lowest recognized occurrence of sand and the lowest conspicuous microgranular dolomite in the Ellenburger group. Locally the evidence is obscure and at such places the boundary was located on the basis of lateral tracing.

The unusually pure and thickly bedded character of the upper limestones of the Gorman formation is well displayed in the Riley Mountains. In the Warren Springs area, however, 9.5 feet of dolomite occurs at the middle of a 56.5-foot interval consisting otherwise of such limestone. This interval of pure limestones

is topographically prominent in both the Warren Springs and Moore Hollow areas.

Honeycut formation.—Of the approximately 453 feet of the Honeycut formation in the Warren Springs section, the lower 308 feet consists of thinly interbedded or intergrading limestone and dolomite, and the upper 145 feet is predominantly microgranular to very fine grained dolomite with minor limestone intervals. The dolomites are almost equally divided between microgranular and very fine grained, and are light yellowish to brownish gray, grading to grayish brown, beige, and rarely rose beige and nutria. The limestones are predominantly sublithographic and pearl gray to woodash gray or light brownish gray. Cannonball chert occurs intermittently throughout the Honeycut formation in the Riley Mountains, and chalcedonic to semichalcedonic and locally porcelaneous chert is locally abundant as nodules, plates, and lenses. Sand is rare but was noticed at the top and base of the Warren Springs section and at a few intermediate points.

Archaeoscyphia occurs in a number of beds in the lower half of the Honeycut formation, but is nowhere so persistently abundant that it forms a good zone marker, and *Ceratopea capuliformis* Oder is so excessively rare in the areas mapped that it and *Archaeoscyphia* cannot be taken together to mark a zone as they were taken in the Cherokee area. Zones of *Ceratopea robusta* Oder and *Ceratopea* sp. 5 were mapped, however, at 216 and 291 feet respectively above the base of the formation. The brachiopod *Xenelasma* marks the base of the Honeycut formation, but seems to be rarer than in other areas and is not known to range as high in the section.

The thinly interbedded limestones and dolomites of the lower beds of the Honeycut formation express themselves as a topographic sag at the foot of a dip-slope on the top of the topographically prominent massive limestones that cap the Gorman formation. The higher beds have no particularly characteristic topographic or dendrologic expression, simply extending over cedar-covered slopes to the overlapping Carboniferous rocks.

CARBONIFEROUS

Through much of the Moore Hollow and Warren Springs areas a thin belt of Mississippian rocks is present, and at such places a narrow bench separates the Ellenburger rocks from the Marble Falls limestone.

The basal Mississippian formation is the Chappel limestone, no representative of the Ives breccia having been found. The Chappel limestone ranges from about 3 feet thick to a feather-edge, contains crinoidal fragments in a finer grained matrix, and is gray to olive gray in color. Residues from its dissolution in acetic acid contain a conodont assemblage comparing closely with that from the Chappel limestone in other areas.

No exposures of the Barnett formation were found in the Riley Mountains, but the bench that forms where the Barnett strata should be indicates a range in thickness from about 8 feet to a feather-edge. That Barnett rocks actually underlie this bench is proved by the occurrence of characteristic Barnett fossils in pieces of petroliferous limestone found on the bench. The very presence of the bench, as well as the character of the limestone float, suggests that the formation is largely shale in the Moore Hollow and Warren Springs areas. *Leiorhynchus carboniferum* Girty, *Eumorphoceras bisulcatum* Girty, *Goniatites*, *Girtyoceras* cf. *G. meslerianum* (Girty), and two species of *Cravenoceras* were obtained from a single piece of limestone float at the northeast corner of the Moore Hollow area (TF–429).

At places Mississippian beds are absent and the Marble Falls limestone directly overlaps the Honeycut formation. Outcrops of the Marble Falls limestone seen

were mostly fine grained and putty-colored to dark gray or black. Nodules and concretions of black or speckled black and gray chert are common in the lower part, and where it overlaps the Barnett formation the basal bed is earthy, markedly glauconitic, and contains pebbles of limestone of which some resemble limestones from the Barnett formation. Fusiform fusulines were noted locally, but no evidence was seen to indicate the presence of a Morrow equivalent in the Marble Falls limestone of the Moore Hollow or Warren Springs areas.

The Marble Falls limestone and Smithwick shale are shown under a single symbol on Plate 10 and neither was measured or studied in detail. However, good dip-slope exposures of the Marble Falls limestone may be seen along a southwesterly continuation of the Warren Springs section toward the R. B. Siler ranch headquarters. Alluvium conceals the Smithwick shale at most places, but good exposures may be seen in the bed of Honey Creek between Honey Creek Falls and the Riley Mountain fault.

Table 3. Physical and chemical data for samples from the Moore Hollow and Warren Springs sections, by S. S. Goldich[9] and E. B. Parmelee[10]

*Moore Hollow Section**

Sample No	Interval	Feet above base of section	Dolomite grain size, mm., approximate	Density[a]	Bulk density[b]	Total porosity[c] Per cent	Composition[d] Insoluble	Calcite	Dolomite
1	23	313	0.1	(25.8°/4°), 2.847	2.723	4.4	2.4	2.9	94.7
2	23	330	0.35	(26.8°/4°), 2.839	2.740	3.5	0.4	13.0	86.6
3	22	339	1.0	(23.7°/4°), 2.846	2.722	4.3	0.7	6.9	92.4
4	22	374	1.4	(25.5°/4°), 2.837	2.694	5.0	0.2	13.0	86.8
5	21	445		(23.1°/4°), 2.707	2.703	0.1	1.4	97.4	1.2
6	20	512	1.3	(23.3°/4°), 2.839	2.765	2.6	0.6	11.9	87.5
7	19	570	0.6	(26.0°/4°), 2.833	2.709	4.4	0.4	15.9	83.7
8	18	605	0.4	(24.3°/4°), 2.829	2.629	7.1	10.2	2.7	87.1
9	16	643	0.5	(25.7°/4°), 2.845	2.676	5.9	1.7	5.9	92.4
11	15	703	0.5	(24.2°/4°), 2.845	2.765	2.8	1.7	5.9	92.4
12	15	713	0.8	(25.1°/4°), 2.825	2.748	2.7	1.9	18.6	79.5
13	14	727	0.4	(25.8°/4°), 2.811	2.746	2.3	2.8	27.2	70.0
14	13	776	0.9	(25.0°/4°), 2.823	2.752	2.5	1.5	20.7	77.8
15	12	817		(25.7°/4°), 2.762	2.740	8.0	1.4	61.1	37.5
16	11	823	0.7	(24.4°/4°), 2.807			0.6	32.8	66.5
17	10	834	0.6	(22.4°/4°), 2.793	2.751	1.5	0.5	40.8	58.7
18	9	845		(24.6°/4°), 2.708	2.696	0.4	0.9	97.1	2.0
19	8	880		(25.8°/4°), 2.705	2.688	0.6	1.6	98.4	
21	7	907		(21.8°/4°), 2.708	2.688	0.7	1.4	97.6	1.0
23	5	932		(25.8°/4°), 2.707			2.7	96.3	1.0
24	4	938	0.4	(25.9°/4°), 2.822	2.776	1.6	2.4	20.5	77.1
25	4	939	0.3	(25.4°/4°), 2.824	2.759	2.3	3.0	18.4	78.6
26	3	950	0.55	(24.9°/4°), 2.812	2.776	1.3	5.7	20.8	73.5

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[10]Graduate student in geology, Agricultural and Mechanical College of Texas.

*Stratigraphic data for sample numbers are as follows (*see* Pl. 14 for interpretation): 1–2, ewp; 3–4, Ott(mg) lower; 5, Ott(ca); 6–7, Ott(mg) upper; 8–14, Ots(mg); 15–23, 27, Ots(ca); 24–26, 28–34, Og(mg); 36–38, Og(ca) lower; 40–44, Og(ca) dolomitic parvafacies; 46–47, Og(ca) upper; 49–75, Oh facies of alternating limestone and dolomite; 76–78, Oh dolomitic facies.

Table 3. Physical and chemical data for samples from the Moore Hollow and Warren Springs sections, by S. S. Goldich and E. B. Parmelee—Continued

*Warren Springs Section**

Sample No.	Interval	Feet above base of section	Dolomite grain size, mm., approximate	Density[a]	Bulk density[b]	Total porosity[c] Per cent	Composition[d] Insoluble	Calcite	Dolomite
27		—2		(25.3°/4°), 2.709	2.696	0.5	3.2	93.9	2.9
28	58	+4	0.12	(23.6°/4°), 2.847	2.788	2.1	2.2	3.9	93.9
29	57	21	0.7	(25.6°/4°), 2.828	2.774	1.9	4.0	13.4	82.6
30	56	46	—0.05	(24.4°/4°), 2.848	2.818	1.1	2.6	2.9	94.5
31	56	99	0.7	(25.1°/4°), 2.818	2.755	2.2	3.9	20.2	75.9
32	56	133	—0.05	(24.7°/4°), 2.848	2.793	1.9	2.2	4.1	93.7
34	54	192	m*	(24.6°/4°), 2.842	2.718	4.4	4.1	4.8	91.1
36	52	230.5	0.7	(22.9°/4°), 2.824	2.776	1.7	2.6	18.5	78.9
37	51	231.5		(25.3°/4°), 2.705	2.687	0.7	2.0	98.0	
38	50	242	0.2	(23.0°/4°), 2.828	2.786	1.5	1.3	17.8	80.9
40	48	311	0.1	(25.3°/4°), 2.842	2.652	6.7	3.2	4.8	92.0
42	46	356	—0.05	(25.4°/4°), 2.840	2.754	3.0	3.4	6.8	89.8
43	45	360		(26.3°/4°), 2.705	2.693	0.4	0.4	99.6	
44	44	385	0.05	(23.3°/4°), 2.834	2.752	2.9	5.6	6.6	87.8
46	41	428	0.2	(25.2°/4°), 2.831	2.684	5.2	2.1	13.7	84.2
47	39	443		(24.2°/4°), 2.705			1.7	98.3	
49	37	473	0.12	(26.6°/4°), 2.835	2.704	4.6	3.7	9.6	86.7
50	36	482		(25.2°/4°), 2.702	2.690	0.4	4.6	94.5	0.9
51	35	485	0.05	(24.8°/4°), 2.823	2.784	1.4	3.7	15.4	80.9
52	33	490	0.10	(25.5°/4°), 2.834	2.775	2.1	2.9	8.7	88.4
54	29	512	0.10	(24.2°/4°), 2.822	2.689	4.7	2.9	19.4	77.7
55	28	520		(25.1°/4°), 2.698	2.687	0.4	19.5	74.9	5.6
56	27	526	0.05	(25.1°/4°), 2.827	2.637	6.7	7.0	9.3	83.7
58	23	564.5		(23.8°/4°), 2.705	2.695	0.4	4.1	94.6	1.3
59	23	604.5	m	(25.5°/4°), 2.836	2.771	2.3	2.1	10.8	87.1
61	21	620	m	(25.5°/4°), 2.830	2.710	4.2	4.2	11.5	84.3
63	17	636	0.05	(24.1°/4°), 2.826	2.735	3.2	3.4	15.5	81.1
64	16	646		(25.0°/4°), 2.704	2.696	0.3	1.9	98.1	
65	15	660	0.04	(23.6°/4°), 2.827	2.470	12.6	5.5	12.3	82.2
67	13	675		(24.8°/4°), 2.699			3.3	96.7	
69	11	697	0.05	(25.1°/4°), 2.842	2.775	2.4	2.3	6.8	90.9
71	9	723	0.10	(24.6°/4°), 2.834	2.723	3.9	2.9	10.7	86.4
72	7	738	—0.05	(25.6°/4°), 2.836	2.552	10.0	5.1	7.2	87.7
73	6	752		(25.2°/4°), 2.704	2.694	0.4	3.4	96.6	
74	5	759	0.05	(25.2°/4°), 2.832	2.647	6.5	3.1	12.6	84.3
75	4	763		(25.3°/4°), 2.704			2.1	97.9	
76	3	807	0.10	(24.8°/4°), 2.837	2.714	4.3	2.2	10.8	87.0
77	2	854		(24.4°/4°), 2.706	2.688	0.7	2.5	96.5	1.0
78	1	886	0.25	(24.4°/4°), 2.831	2.737	3.3	2.1	14.7	83.2

[a]Grain density (gm./cc.) is listed in the following form: (25.8°/4°), 2.847. This expression indicates that the determination was made at a temperature of 25.8° C. and referred to water at 4° C.

[b]All bulk densities were made at a room temperature of 25° C. and referred to water at 4° C.

[c]Total porosity was calculated using the formula:

$$\frac{D_g - D_b}{D_g} \times 100 = P_t\ (\%)$$

in which D_g is the grain density and D_b is the bulk density.

[d]Rock composition was calculated from the grain density of the sample after correcting for content of insolubles.

*m = microgranular.

DESCRIPTION OF THE RILEY MOUNTAIN SECTIONS

The Warren Springs and Moore Hollow sections, measured in a zone of relatively steeply dipping strata adjacent to the faulted east front of the Riley Mountains, constitute a composite section displaying the full thickness of the Ellenberger group, as well as the Pedernales dolomite and San Saba limestone members of the Wilberns formation. For the Paleozoic rocks below these measured sections, thicknesses were computed from geometric data along a supplementary line of section called, for convenience, the East Canyon section. The composite section thus derived may be summarized as follows:

Stratigraphic unit	*Thickness in feet*
Mississippian (0 to 12 feet of Barnett formation and Chappel limestone)	
Lower Ordovician—Ellenburger group (1512 feet)	
Honeycut formation	453
Gorman formation (456 feet)	
Calcitic facies	242
Dolomitic facies	214
Tanyard formation (603 feet)	
Staendebach member (353 feet)	
Calcitic facies	121
Dolomitic facies	232
Threadgill member (250 feet)	
Upper dolomitic facies	96
Calcitic facies	76
Lower dolomitic facies	78
Upper Cambrian (1340 feet)	
Wilberns formation (560 feet)	
Pedernales dolomite member	73
San Saba limestone member	144
Point Peak shale member (including a 100-foot zone of stromatolitic limestones)	216
Morgan Creek limestone member	110
Welge sandstone member	17
Riley formation (780 feet)	
Lion Mountain sandstone member	24
Cap Mountain limestone member	421
Hickory sandstone member	335
Pre-Cambrian (Packsaddle schist)	
Approximate total thickness of Lower Ordovician and Upper Cambrian rocks	2850

The Moore Hollow and Warren Springs sections are separated by the structurally deep Honey Creek basin, but they present the most complete and best exposed section of Ellenburger rocks that could be found in the Riley Mountains. They are individually described below, but on the local correlation chart they are presented graphically, along with some data from the supplementary East Canyon section, as a single composite section.

The two principal sections were measured, painted, and described by Cloud in March 1945. They are marked at approximately 5-foot intervals with yellow paint spots, and a number showing actual feet above the base of each section is painted every 50 feet or less. Control for computed measurements was taken from large scale (approximately 8 inches to 1 mile) aerial photographs and intersecting vertical traverses made with a Paulin precision altimeter to determine elevations based on a number of readings averaged to the nearest 5 feet for each point of determined elevation. The computed measurements checked closely with field measurements made with a Brunton compass and no adjustment was made.

The lower half of the Warren Springs section is on the property of Will Stribling and the upper half is on the Roy B. Siler ranch, the Gorman-Honeycut contact falling at the property line. The lower third of the Moore Hollow section is also on the property of Will Stribling, the middle part on the Ben Wallace ranch, and the upper fourth follows a north-south fence between the Ben Wallace ranch and the T. J. Wadkins (Wadkins and Tuberville) ranch. The supplementary East Canyon section traverses the Hickory sandstone member of the Riley formation on the property of Will Stribling, following a north-south fence between the Stribling property and the Woodrow Wilson ranch through the remainder of its computed thickness.

The locations of the measured sections in the Warren Springs and Moore Hollow areas are shown on the geologic map (Pl. 10) by lines of narrow chevrons whose apexes point up in the section. Offsets are indicated by dotted lines except where self-evident. The supplementary East Canyon section is shown with the same symbol interrupted by the letter *S.*

Warren Springs Section

The Warren Springs section, as described below, includes 453 feet of the Honeycut formation and 456 feet of the Gorman formation, full thicknesses for both units in the Warren Springs area.

The top of this section is at an altitude of approximately 1380 feet at the crest of a northwest-trending strike ridge, and about 0.2 mile airline southeast of Warren Springs. Stratigraphically it is at the top of the Honeycut formation in the Warren Springs area. It is overlain by a 15-foot rubble strewn interval of which probably the basal 10 feet belongs to the Barnett formation and Chappel limestone and the upper 5 feet to the Marble Falls limestone (unrestricted). A supplementary section 250 feet northwest of the top of the Warren Springs section shows 20 inches of Chappel limestone with an 8-foot covered interval between it and a ledge of abundantly glauconitic, dark gray to black limestone that is probably the basal ledge of the Marble Falls limestone (unrestricted). Beyond reasonable doubt this bench-forming 8-foot covered interval represents the Barnett formation, whose presence in the vicinity is demonstrated by goniatites from locality TF–429 in the northeast corner of the Moore Hollow area. An apparently complete sequence of the Marble Falls limestone (unrestricted) succeeds the measured Warren Springs section southwestward down a "dip-slope" to the alluvially concealed Smithwick shale in the bottom of the Honey Creek basin.

The base of the Warren Springs section is at an altitude of about 1260 feet, about 100 feet west of the Riley Mountain fault, and about 0.9 mile airline north of Honey Creek in the north-central part of the Warren Springs area. It is about 0.4 mile airline northeast of the top of the section and stratigraphically at the Tanyard-Gorman contact.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Ellenburger group: 909 feet described			
Honeycut formation: 453 feet thick			
1. Dolomite in the line of section; in part grading laterally to limestone, especially toward the top of the interval (altitude approximately 1380 feet at top of section)—very fine grained to microgranular, being mostly microgranular from 890 to 898; light gray to pale rose beige to brownish gray to grayish brown, grading to brownish olive and nutria; in part mottled; beds 2 to 48 inches thick. The upper and lower portions of the interval weather to discontinuous, rough, rather dark gray ledges with a brownish cast; but the microgranular middle portion weathers smoothly uneven and medium gray. Chert nodules occur in the lower foot; being chalcedonic, light bluish to brownish gray to white, in part with rose streaks. Excrescences and anastomosing bundles and surface films of finely dolomoldic chert and fine grained quartz druse occur at 872 to 880 feet. Scattered sand grains occur at the top of interval 1.	39	39	870 – 909
2. Limestone and dolomite, with limestone in the lower 7 and upper 4 feet and mostly dolomite from 860 to 866 feet—the limestone is sublithographic, grading in occasional patches to a pellet limestone; pearl gray, grading to wood-ash gray or light brownish gray, in part with pinkish streaks and with yellowish to greenish yellow irregular argillaceous films. The dolomite is fine grained, light brownish olive with rose mottles. Bedding indistinct. Weathers to intermittently exposed, smoothly uneven to solution pitted ledges, which, except where discolored by fire, are rather dark gray to iron gray where dolomite and medium to light bluish gray where limestone.	17	56	853 – 870

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Partially to fairly well chertified, rough, russet-weathering cannonballs occur in the lower limestone. Otherwise chert occurs throughout the interval as nodules and irregular inclusions; being chalcedonic to semichalcedonic, in part quartzose, bluish to brownish gray to paraffin white, and weathering with darker stains. Occasional unidentified cross sections of gastropods were seen in the limestone.			
3. Dolomite; grading to limestone from 777 to 780 and 796 to 802 feet, and possibly from 821 to 823.5 and 828 to 833 feet—the dolomite is microgranular to very fine grained, locally finely laminated; predominantly light gray to light yellowish gray, grading to a brownish gray that approaches nutria, with rose beige an important color from 817 to 828 feet; beds from a few inches to 25 inches thick, for the most part not well displayed and with several largely covered intervals. The limestone is sublithographic, grading to a pellet limestone in patches; pearl gray to wood-ash gray. Away from the white burned-over ground along the line of section the dolomites weather to their usual darker brownish gray colors in contrast to the medium to light bluish gray of the limestone intervals. Chert nodules occur from 770 to 776 feet; being subchalcedonic to semichalcedonic, bluish to brownish gray to carnelian, and commonly banded and streaked in variegated colors. A few small nodules of similar chert were seen from 792 to 793 feet. From 796 to 802 feet occasional partially to largely chertified cannonballs and shattered lenses of nondescript chert occur. Between 805 and 806 feet finely dolomoldic, buff-weathered crusts of chert are present. From 806 to 808 feet are scattered nodules and lenticles of chert that is chalcedonic to subchalcedonic; carnelian, tan, grayish brown and white; white-, pale orange-, and cream-weathering. A few nodules of chert occur at 815 to 815.5 feet, and at 827 to 828 feet bluish gray chert nodules were seen. Occasional nodules, plates, and irregular inclusions of chert and a few partially to largely chertified cannonballs occur between 828 and 833 feet. Quartz druse occurs from 770 to 776 feet, as fine to medium grained rosettes and excrescences. Sand grains are present in the dolomite at about 818 feet. Very large *Hormotoma* and fragmentary specimens of *Ceratopea* were seen in cannonballs at 800 feet and silicified *Ceratopea* sp. 5 was collected from limestone at 800 feet (TF–383). Silicified *Hormotoma* and flat-ended, slightly tapering siphuncles of the *Mcqueenoceras* type were seen in limestone at 828 to 833 feet. Fossil fragments also occur in the cannonballs and unidentifiable fragments of brachiopods were seen in one between 828 and 833 feet.	89	145	764 – 853
4. Limestone—sublithographic; pearl gray, in part with faint greenish yellow to whitish, irregular argillaceous films; bedding indeterminate. Weathers solution pitted, medium to light bluish gray, poorly exposed. Chert occurs as nodules and irregular inclusions; being semichalcedonic to subchalcedonic, in part crypto-oölitic and pseudospicular, light brownish to bluish gray to bluish white, and weathering dull white.	4	149	760 – 764
5. Dolomite—microgranular to very fine grained; light yellowish gray to light gray with darker yellowish tinges; bedding indeterminate in the line of section, but lateral tracing indicates that this interval is essentially a single heavy bed, grading at places in its lower part to limestone.	4.5	153.5	755.5– 760

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
Weathers to a smoothly uneven, medium to light gray ledge, grading into a covered zone at the base. Chert nodules are fairly abundant in the upper part of the interval. They are subchalcedonic to semichalcedonic, bluish gray to bluish white and locally carnelian, grading to chalk textured and chalk white where penetrated by weathering, and weathering dull white. This heavy bed of dolomite with its rather abundant chert concretions resembles the heavy bedded dolomite of interval 7, and the two serve to aid tracing of the intervening limestone zone of *Ceratopea* sp. 5.			
6. Limestone, apparently grading laterally to dolomite in the upper part—sublithographic, in large part a fine pellet limestone; pearl gray to light grayish brown and brownish gray, with irregular greenish yellow argillaceous films; bedding indistinct, lateral tracing shows that the lower part of the interval tends to form a single heavy bed. Poorly exposed in the line of section, the projecting ledges and float both weathering solution pitted, medium to light bluish gray. Chert occurs as nodules, being most abundant in the upper part of the interval. It is subchalcedonic to porcelaneous, brownish to bluish gray to pale orange to white, and weathers mostly dull white. *Ceratopea* sp. 5 may be seen in a large float block at 747 feet in the line of section and specimens were collected (TF–364) along the trace of the beds intervening between 745 and 750 feet. This is the key zone of *Ceratopea* sp. 5 that, in connection with the chert-bearing massive dolomite below, was traced through the Warren Springs area as a structural datum. Other fossils seen were fragments of unidentifiable silicified gastropods and calcitic cross sections of gastropods in the limestone.	14.5	168	741 - 755.5
7. Dolomite—microgranular; light gray to light yellowish gray or flax colored, with darker yellowish spots; bedding indeterminate in the lower part, but with at least the upper 2½ to 3 feet forming a single heavy ledge traceable laterally and marked by abundant chert nodules. Mostly covered in the lower part, weathering at the top to a prominent though discontinuously exposed, thick, smoothly irregular, medium gray ledge. Chert is abundant as nodules and lenticles in the upper half of the interval; being semichalcedonic to subchalcedonic, brown to dull carnelian, in part grading to bluish gray, and weathering dull white.	8	176	733 - 741
8. Limestone—sublithographic, grading to a granular-looking pellet limestone in which the individual pellets are sublithographic; pearl gray to brownish gray, with irregular cream colored argillaceous films; bedding indistinct. Poorly exposed; weathers solution pitted and medium to light bluish gray. Chert is abundant as cannonballs and nodules; the latter being subchalcedonic to chalcedonic, bluish to brownish gray to white to dull carnelian, and weathering white to cream. Abundant straight sponge spicules occur in some of the nodules. Cross sections and fragments of fossils are abundant both in the limestone and the cannonball chert, but are for the most part poorly preserved. *Ceratopea* sp. 5, *Archaeoscyphia*, and a poorly preserved ventral valve of a spondylium-bearing gently convex brachiopod were seen. Calcitic *Archaeoscyphia* was noted in the limestone and chertified *Archaeoscyphia* was collected (TF–382).	5.5	181.5	727.5- 733

	Description	Thickness in feet: Interval	Cumulative	Feet above base
9.	Dolomite—microgranular to very fine grained, light gray to light yellowish or brownish gray; beds 2 to 13 inches thick. Weathers to discontinuous smoothly uneven, medium gray ledges. Chert is abundant as nodules and lenses that are semichalcedonic to subchalcedonic, bluish gray to grayish brown to carnelian, and weather cream to yellowish white with darker blotches.	5.5	187	722 – 727.5
10.	Limestone—sublithographic, in minor part grading in patches to a fine pellet limestone; pearl gray to woodash gray; beds from less than 1 inch to 17 inches thick, being thicker bedded in the upper half and mostly quite thin bedded in the lower half. Weathers discontinuous, in part slabby, solution-pitted, medium to light gray ledges (white where burned). Chert is abundant in the lower beds as small nodules that are semichalcedonic to porcelaneous, woodash gray to white, and weather yellowish white. At the middle of the interval are angular blocks of conspicuously oölitic laminar chert which weather free and are seen only in the float. The oöids in this chert have thin dark skins that surround porcelaneous to chalk textured and in part hollow interiors, and the matrix bearing them grades from subgranular and quartzose to conspicuously chalk textured. In the upper beds a few largely chertified to slightly calcareous cannonballs and irregular excrescences and rosettes of fine grained quartz druse occur. *Hormotoma* and the free cheek of a large trilobite were noted among the many fossil fragments in the cannonballs.	19.5	206.5	702.5– 722
11.	Interbedded and laterally intergrading dolomite and limestone, with dolomite apparently predominating—similar to interval 13 and, like it, largely covered. Chert present as occasional nodules and lenticles that are semichalcedonic to subchalcedonic, bluish gray to pale carnelian and white, in part concentrically banded, and weather white. Fine grained quartz druse is locally abundant as rosettes and irregular excrescences.	7.5	214	695 – 702.5
12.	Limestone—sublithographic, grading in patches to a fine pellet limestone; woodash gray to pearl gray; beds form 2 massive ledges which in part weather thinner bedded. Weathers to fairly regular smooth to solution pitted and channelled, medium to light bluish gray ledges. Partially chertified, small to large, rough, russet-weathering cannonballs having the usual texture of a silicified fossiliferous pellet limestone are scattered through the interval. Fine grained quartz druse occurs as grape-sized rosettes and irregular excrescences. Flat-ended, slightly tapering silicified siphuncles of the *Mcqueenoceras* type were seen throughout this interval.	8	222	687 – 695
13.	Interbedded and laterally intergrading limestone and dolomite—the dolomite is microgranular to very fine grained and light brownish to yellowish gray to grayish brown, grading in part toward nutria. The limestone is sublithographic, grading in patches to a fine pellet limestone, and pearl gray to woodash gray. Beds from less than 1 inch to 18 inches thick, for the most part poorly exposed. Weathers to a largely covered interval, with the intermittent exposures displaying the normal weathered characters of the limestone and dolomites in this part of the section. Chert occurs as scattered nodules and extensive plates, mostly in the dolomite. It is semichalcedonic to chalcedonic and light bluish to brownish gray to white. Fine grained quartz druse is scattered through the interval in grape-sized rosettes and excrescences.	15	237	672 – 687

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
Ceratopea robusta bed at 672 feet. Offset about 580 feet airline northwest if going up in the section and southeast if going down (altitude about 1390 feet at southeast and 1310 feet at northwest end of offset).			
14. Limestone—sublithographic; pearl gray to woodash gray, in part with irregular pale greenish yellow argillaceous films; beds 3 to 30 inches thick. Weathers to solution-pitted and channelled, medium to light bluish gray ledges, the upper 30 inches being essentially a single continuous ledge that is traceable laterally. Chert occurs as occasional, slightly calcitic cannonballs with a marked pellet texture and numerous fragments of fossils; as well as occasional plates of chalcedonic to subchalcedonic, bluish gray to white chert that weathers white with darker stains. Fine grained quartz druse occurs as scattered to fairly abundant, irregular, grape-sized rosettes and larger excrescences. *Ceratopea robusta* Oder marks the top of interval 14 (TF–363).	9.5	246.5	662.5– 672
15. Dolomite—microgranular, light gray to light yellowish gray, bedding indeterminate. Weathers to discontinuous, smooth, thick, rather dark gray to iron gray ledges. Mostly covered in upper 3 feet. A single nodule of chert with a texture like that of the typical cannonball chert was seen in a block of float near the middle of the interval.	13.5	260	649 – 662.5
16. Limestone, in minor part grading to dolomite near the middle—sublithographic, in part a pellet limestone with pockets and irregular layers crowded with tiny ovoid inclusions; pearl gray; beds about 1 to 12 inches thick, bedding not well displayed. Weathers to discontinuous, uneven, solution pitted, medium to light bluish gray ledges. Chert is conspicuous in the upper foot of interval 16 as a zone of large, rough, russet-weathering, partially chertified cannonballs. Below these are occasional subchalcedonic to semichalcedonic, in part oölitic, light bluish to brownish gray to bluish white, white-weathering nodules. Occasional excrescences of fine grained quartz druse were also seen.	6.5	266.5	642.5– 649
17. Dolomite, in minor part grading to limestone near the middle of the interval—the dolomite is microgranular to very fine grained, light yellowish gray to light brownish gray and grayish brown grading toward nutria, in beds 5 to 12 inches thick. Weathers to a rubble-strewn interval displaying intermittent, fairly smooth ledges of a dark to medium gray color with a slight brownish cast. The limestone is sublithographic and in part a pellet limestone. Chert is moderately abundant as nodules, especially at 640 feet. These are semichalcedonic to chalcedonic, in part with scattered ovoid inclusions and locally crowded with microscopic oöidlike bodies, and light to dark bluish gray to brownish gray to white to yellowish white. A conspicuously oölitic chert in which the oöids appear to have formed as concentric shells around small ovoid pellets, occurs in the limestone.	7.5	274	635 – 642.5
18. Limestone in the line of section, grading laterally to dolomite at the top—sublithographic, in part with small irregular to ovoid pelletlike inclusions; pearl gray, in part with light yellow to greenish irregular argillaceous films; one or more beds. Weathers rough, solution pitted, medium to light bluish gray. Chert occurs as irregular, in part ropy inclusions and occasional cannonballs, the inclusions having either a can-	6	280	629 – 635

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
	nonball texture or being semiporcelaneous and dull grayish brown to tan and bluish gray. Impressions of snails were seen and *Ceratopea* that could be either a young *C. robusta* Oder or *C. capuliformis* Oder was collected at 630 feet from a large float block almost certainly derived from this interval (TF–381).			
19.	Dolomite—very fine grained to microgranular, locally with a few small vugs; light brownish gray to grayish brown; one or more beds, in part very thinly laminated. Weathers to uneven, discontinuous, rather dark gray to brownish gray ledges or a single interrupted ledge. Chert similar to that in interval 21, but with the nodules averaging slightly larger and not so abundant.	5	285	624 – 629
20.	Limestone, in part grading to dolomite—lithologically similar to the limestone and dolomite described in the intervals above and below. Chert occurs as nodules, irregular inclusions, and small cannonballs; the nodules and inclusions being subchalcedonic to chalcedonic and bluish to brownish gray to bluish white.	1.5	286.5	622.5– 624
21.	Dolomite—microgranular to very fine grained, grayish brown to nutria, consisting of two 2-foot beds. Weathers to a prominent, uneven, dark brownish gray ledge. Chert is abundant as mostly small shattered nodules that, on a fresh surface, are chalcedonic to subchalcedonic; light bluish gray to grayish brown or dull carnelian, grading to chalk white to dull tan where penetrated by weathering; and weathers mostly white. Some of the nodules are crowded with straight sponge spicules.	4	290.5	618.5– 622.5
22.	Limestone, in part grading to dolomite in the upper half—the limestone is sublithographic; pearl gray, with putty white to dusty green irregular argillaceous films; beds less than 1 inch to 30 inches thick, mostly thickly bedded. Where the minor dolomite beds intervene they are very fine grained and brownish gray to nutria. Weathers to discontinuous, uneven, smooth to solution pitted and channelled, medium to light bluish gray ledges. Chert occurs as scattered small to medium sized cannonballs and occasional nodules, the latter being chalcedonic to subchalcedonic and bluish to brownish gray. The cannonballs weather rough and dull brown to russet, the nodules white with darker stains. A small horn-shaped *Ceratopea* was collected from *Archaeoscyphia*-bearing limestone apparently along the trace of this zone at about 612 feet (TF–384) judged from measurement to the *C. robusta* bed at 672 feet.	12.5	303	606 – 618.5
23.	Limestone and dolomite, interbedded and laterally intergrading; beginning and ending with dolomite, with the limestone probably slightly exceeding the dolomite in volume—the limestone, where pure, is sublithographic, pearl gray to light brownish gray, in minor part with scattered to moderately abundant pelletlike inclusions. The dolomite is very fine grained and light gray to light brownish gray. Beds range from a fraction of an inch to 30 inches thick, the top 30 inches being a single massive bed of dolomite with abundant nodular chert. Weathers to alternating, solution-pitted, medium to light bluish gray ledges of limestone and smooth to uneven, rather dark brownish gray beds of dolomite. Chert is abundant in the limestone from 564.5 to 566 feet as small scattered inclusions and larger lenslike aggregates of chert and limestone, being chalcedonic to subchalcedonic and mostly bluish to brownish gray. It is also	45	348	561 – 606

	Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
	generally abundant from 575 to 582 and 599 to 606 feet, where it occurs as nodules, plates, irregular inclusions, and lenses. At these levels it is chalcedonic to semichalcedonic, in part slightly quartzose and locally concretionary, bluish to brownish gray to bluish white, and weathers white to dull yellowish or brownish. Straight sponge spicules are abundant in much of this chert and locally the spicular structure of *Archaeoscyphia* may be detected. Scattered small rosettes and irregular inclusions of fine grained quartz druse occur from 570 to 572.5 and at 582.5 feet. Occasional and locally abundant specimens of *Archaeoscyphia* may be seen between 570 feet and the top of interval 23 by working along the trace of the beds, and at places it is accompanied by flat-ended siphuncles of *Mcqueenoceras* type and other fossils. It is particularly common at some places along the trace of the beds between 575 and 600 feet (TF–380); but is not persistently localized stratigraphically so as to form marked *Archaeoscyphia* beds. A single specimen of *Ceratopea* cf. *C. capuliformis* Oder was collected a little west of the line of section at a point estimated to be near 595 feet (TF–380a).			
24.	Limestone—sublithographic, in part a fine pellet limestone; pearl gray to woodash gray; bedding indeterminate, apparently mostly thin. Weathers to poorly exposed, uneven, medium to light bluish gray ledges. Chert occurs in upper and lower parts of interval as scattered nodules and angular inclusions; being subchalcedonic to semichalcedonic, in part laminated and micro-oölitic, and bluish gray to pale tan.	6.5	354.5	554.5– 561
25.	Dolomite—very fine grained, light yellowish gray to beige; bedding indeterminate. Weathers mostly covered, with a few fairly smooth medium gray ledges. Chert occurs along the trace of this interval as occasional chalcedonic to subchalcedonic, bluish to brownish gray to white, white-weathering nodules.	3.5	358	551 – 554.5
26.	Limestone—sublithographic, in part a pellet limestone with sublithographic pellets in a matrix of clear calcite; pearl gray to woodash gray, grading to light brownish to yellowish gray; beds from a fraction of an inch to 14 inches thick, being mostly thin with the heavier beds weathering slabby. Weathers to discontinuous, smoothly uneven to solution-pitted and channelled, medium to light bluish gray ledges which are mostly platy, with the heavier beds tending to weather platy. Chert occurs at 549.5 to 551 feet as nodules that are partly calcitic, semichalcedonic to subchalcedonic, pearl gray to pale yellowish brown to white, and weather yellowish white to brownish yellow. Fine grained quartz druse occurs as minor excrescences at 546 feet.	15	373	536 – 551
27.	Dolomite—very fine grained to almost microgranular; beige to pale rose beige or very light gray, in part banded or streaked; bedding indeterminate. Weathers to a mostly covered interval in which a few discontinuously projecting ledges and loose plates and cobbles indicate the character of the underlying rock. The weathered ledges seen were mainly smooth and medium gray. Chert occurs as scattered nodules and angular inclusions in the upper part of the interval; being semichalcedonic, grayish yellow to dull white, and weathering white. This poorly exposed, mostly covered interval is at the upper stratigraphic limit of a topographically low area separating the pure, heavy bedded, ledge-forming limestones of	11.5	384.5	524.5– 536

	Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
	the upper Gorman formation from the relatively well exposed *Archaeoscyphia*-bearing limestones and interbedded dolomites of the Honeycut formation on the hillslope above.			
28.	Limestone, in part slightly dolomitic and with thin interbeds of dolomite above 520 feet—sublithographic, grading to fine grained where dolomitic; pearl gray to woodash gray to light tan, grading to beige to pale grayish lavender where dolomitic; beds from a fraction of an inch to 10 inches thick, being thicker bedded in the lower part and very thinly bedded above 520 feet. Weathers to discontinuous, solution-pitted and channelled, medium to light bluish gray ledges where the limestone is pure and slightly darker gray surfaces with a yellowish to brownish cast where dolomitic. Chert occurs in the lower 7 feet of interval 28 as scattered, partially to completely chertified cannonballs, as well as nodules and fairly abundant irregular excrescences. The nodules and excrescences are semichalcedonic to subchalcedonic, light yellowish gray to pearl gray to rose and pale carnelian, and weather rough and dull brown to shiny white and pinkish white. *Ophileta* and *Jeffersonia* (?) were collected from cannonball chert in place at 515 to 516 feet (TF-379).	11.5	396	513 – 524.5
29.	Dolomite—very fine grained, in part with scattered vugs; light grayish brown to brownish gray, grading toward nutria; one or more beds. Weathers to one or more rough, in part pitted, rather dark gray ledges. Fine grained quartz druse is abundantly scattered over the weathered surface as small irregular inclusions and thin plates and rosettes.	4.5	400.5	508.5– 513
30.	Limestone—sublithographic; pearl gray to woodash gray, with dusty green to light greenish yellow irregular argillaceous films; one or more beds. Weathers solution pitted and grooved to smooth, medium to light bluish gray.	2	402.5	506.5 – 508.5
31.	Dolomite—very fine grained, light brownish gray, one or more beds. Weathers uneven, medium gray. The chert in this interval is chalcedonic and light brownish to bluish gray on a fresh surface, grading to chalk textured and chalk white where weathered.	2.5	405	504 – 506.5
32.	Limestone—sublithographic, in part a fine pellet limestone; pearl gray; beds 8 to 19 inches thick. Weathers to discontinous, solution-pitted and channelled, medium light bluish gray ledges. Chert occurs as scattered small nodules and small angular inclusions. It is semichalcedonic to chalcedonic, cryptooölitic to micro-oölitic or pelleted, bluish gray to pale carnelian, and weathers dull brown.	8	413	496 – 504
33.	Dolomite—very fine grained; light gray to light yellowish gray, in part with mottles and streaks of beige and rose beige; beds from 1 to 22 inches thick. Weathers to uneven, discontinuous, dark to medium gray ledges in the lower part and to occasional ledges and scattered medium to light gray slabs in the upper part. A few rosettes of quartz druse were seen in the lower part, and near the middle are irregular inclusions of porcelaneous to subchalcedonic china white to bluish gray, white-weathering chert.	9	422	487 – 496
34.	Limestone—sublithographic, pearl gray to woodash gray; a single bed. Weathers solution pitted, medium to light bluish gray.	1.5	423.5	485.5– 487
35.	Dolomite—very fine grained, light brownish gray to grayish brown with beige streaks; beds as much as 7 inches thick. Weathers to discontinuous iron gray ledges in a partly covered zone.	2.5	426	483 – 485.5

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
36. Limestone—sublithographic, pearl gray to woodash gray; apparently a single bed. Weathers solution pitted, medium bluish gray. Contains scattered irregular inclusions and nodules of chert that is semichalcedonic to chalcedonic, bluish gray to white, and weathers dull brown.	3	429	480 – 483
37. Dolomite, grading to calcitic dolomite, dolomitic limestone and limestone between 465 and 472 feet—the dolomite is mostly very fine grained to microgranular; light grayish brown and brownish gray to brownish beige, in minor part grading to beige or light rose beige. The limestone is sublithographic and pearl gray to woodash gray. The rock that is gradational between the limestone and the dolomite has in part the characters of both but is mostly at the upper limit of grain size described as fine grained and is ordinarily conspicuously mottled with rose to lavender blotches. Bedding indeterminate. Weathers to a relatively depressed, rubble strewn break in slope which stands in marked contrast to the ledgy dip-slope maintained by the thickly bedded limestone of the upper Gorman formation below. The few projecting ledges are discontinuous, uneven, and medium brownish gray where dolomite. Where limestone they grade to lighter bluish gray, and where both dolomite and limestone they weather reticulate. Chert occurs from 465 to 472 feet as scattered angular inclusions that are semichalcedonic to subchalcedonic, in part highly quartzose, locally oölitic, in part with scattered sand grains, of a white to brownish gray color, and weather white to rough and russet. A few small cannonballs appear to be weathering out along the trace of interval 37, and some of the chert seen in place has a granular structure approaching that of cannonball chert. Small, well rounded, frosted sand grains were seen at a few places in the calcitic interval from 465 to 472 feet. A complete, silicified *Xenelasma syntrophioides* Ulrich and Cooper was collected from limestone in place at 466 feet, and *Hormotoma* and other poorly preserved gastropods were obtained from chert in place as well as from cannonballs apparently weathering out in the vicinity of 466 feet (TF–378). Poorly preserved syntrophid brachiopods possibly referable to *Xenelasma* were seen about 150 feet northwest of the line of section at the base of interval 37, as well as on the upper surface of the upper bed of the Gorman formation at one locality in the Moore Hollow area south of here. At no place in central Texas has *Xenelasma* been seen below the Honeycut formation except on the upper surface of the top bed of the Gorman formation.	23	452	457 – 480
38. Limestone—sublithographic; pearl gray, in part with pinkish streaks and dusty green to yellow irregular argillaceous films; one to several beds. Weathers solution pitted, medium bluish gray. Minor chert occurs as small nodules and excrescences which are chalcedonic, in part crypto-oölitic and pseudospicular, locally with a few sand grains, bluish or rose gray to whiskey brown. Small, well rounded, frosted sand grains, poorly sorted within their small size-limits, are scattered to abundant in interval 38.	1	453	456 – 457
Base of Honeycut formation at base of interval 38 (altitude approximately 1350 feet). Total thickness of formation 453 feet. *Gorman formation: 456 feet thick* *Calcitic facies: 242 feet thick*			

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
39. Limestone, relatively quite pure—sublithographic, in part with scattered to crowded pelletlike inclusions of similar sublithographic material; pearl gray to light brownish gray to woodash gray, with minor pinkish tinges and brownish olive to nutria streaks, and locally with irregular dusty green to yellowish argillaceous films. For the most part thickly bedded, with beds ranging from less than 1 inch to 40 inches thick. Weathers to fairly regular, solution-pitted and channelled, medium to light bluish gray ledges. Quartz druse and granular silica occur as scattered rosettes and irregular surficial coatings in the upper 7 feet of interval 39. Sand grains are common locally near the middle of interval 39. The intervals described from 399.5 to 456 feet (56.5 feet) together comprise the predominantly heavy bedded, markedly pure limestone zone which marks the top of the Gorman formation at most places in the Llano region. The presence of dolomite beds near the middle of this zone in the Warren Springs section is an anomalous feature, shared with a few other sections.	22.5	475.5	433.5– 456
40. Dolomite—microgranular, beige to light gray to rose, beds from less than 1 inch to 10 inches thick. Weathers poorly exposed, and, with the interval below, forms a rubble strewn bench between prominent limestone ledges. The exposed ledges in interval 40 weather medium gray to light yellowish gray, whereas the loose plates of dolomite are mostly light yellowish gray on a weathered surface. Sand grains are scattered to abundant throughout the interval, being sufficiently concentrated in small pockets to form a truly arenaceous dolomite. The grains are small, generally well rounded, and frosted, but they are poorly sorted within the size limits displayed.	3.5	479	430 – 433.5
41. Dolomite, in part grading laterally to calcitic dolomite and dolomitic limestone—fine grained, in part with scattered small vesicles; brownish to pinkish gray, with rose to nutria streaks and mottles; beds 2 to 17 inches thick. Weathers to irregular, in part pitted, medium gray ledges with a brownish tone. Fine to medium grained quartz druse occurs as scattered rosettes ranging from size of an English pea to the size of an ordinary Concord grape.	6	485	424 – 430
42. Limestone, relatively quite pure—sublithographic; in part composed of grain to granule sized, closely crowded, pelletlike to oöidlike bodies of sublithographic limestone. Pearl gray to woodash gray, in minor part grading to light brownish gray or olive gray, and in part with whitish gray to faint dusty green irregular argillaceous films. For the most part thickly bedded, with beds ranging from less than 1 inch to 60 inches thick, but with the heavier beds weathering thinner. Weathers to fairly regular ledges, pitted and channelled by solution, and of a medium to light bluish gray color. The ledges in this interval coalese to form a conspicuous terracelike break in slope which is traceable laterally and readily detectable on the aerial photographs. Chert occurs from 418 to 424 feet as irregular, nodular growths and rough, russet-weathering, partially chertified, crudely spheroidal to lobate inclusions resembling the cannonball chert in their weathered state. This chert is subporcelaneous to semichalcedonic, with scattered irregular quartzose inclusions, pearl gray to light bluish or brownish gray, and weathers russet to dirty white. Rare sand grains occur at about 412 feet.	24.5	509.5	399.5– 424

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Lecanospira was collected from the chert from 418 to 424 feet (TF–377) and may be seen at the same position along the trace of these beds northwest from the line of section.			
43. Dolomite, with one 6-inch bed of limestone at the middle and with the upper 6 inches grading to calcitic dolomite and dolomitic limestone—the dolomite is very fine grained to microgranular and beige to light brownish gray, grading in part toward nutria. The limestone is sublithographic and pearl gray, with pink specks and streaks where dolomitic. Beds 1 to 18 inches thick. Weathers to a rubble-strewn bench with projecting irregular and uneven ledges of a medium gray color.	14.5	524	385 – 399.5
B bed at 385 feet; a conspicuous arenaceous zone. Offset about 470 feet airline south-southeast if going up in the section and north-northwest if going down (altitude approximately 1400 feet at north and 1340 feet at south end of offset).			
44. Dolomite, except between 373.5 and 376 feet which is limestone—the dolomite is very fine grained to microgranular; light gray to light yellowish gray to beige or rose beige, grading to light rose, olive gray, grayish olive; beds 2 to 18 inches thick. Weathers to uneven, in part slightly pitted ledges of medium gray color with light yellowish gray blotches. The limestone noted between 373.5 and 376 feet is similar in both fresh and weathered character to that described in interval 45. Chert occurs from 371 to 372 feet as nodules and angular inclusions which are subchalcedonic, bluish to brownish gray with small pink splotches, grading to chalk textured and chalk white on the weathered edges, and weathering dull white with darker stains. From 380 to 382.5 feet are lenses of chalk textured and chalk white chert with scattered to fairly abundant dolomolds, grading to subgranular and semichalceodnic chert that is in part crowded with small subrounded to subangular pelletlike inclusions and light brownish gray to faintly pink in color. At 385 feet are nodules and plates of chert which is chalcedonic to subchalcedonic, carnelian to bluish gray, and locally contain scattered sand grains and an external coating of small, well rounded, frosted sand grains. Sand occurs as small, well rounded, frosted grains in dolomite and chert at the top of the interval, being scattered to abundant in the upper 5 inches and locally constituting the sandy element of an arenaceous dolomite.	23.5	547.5	361.5– 385
45. Limestone—sublithographic, in part a fine pellet limestone; pearl gray, in part with a faintly pinkish tinge and locally with pink streaks; bedding indistinct. Weathers to dislocated solution-pitted blocks of a medium to light bluish gray color. Chert is fairly common as rough, russet-weathering excrescences, which locally aggregate to resemble weathered cannonball chert, but which on a freshly fractured surface are subchalcedonic to semichalcedonic and light bluish to brownish gray.	3.5	551	358 – 361.5
46. Dolomite—microgranular to very fine grained, mostly light rose beige; bedding indistinct. Weathers to uneven, poorly exposed, medium gray ledges, in part with a slightly pinkish cast.	4	555	354 – 358
47. Limestone—sublithographic, in minor part with oölitic or pelletted inclusions; pearl gray to woodash gray, with chalky white to yellowish irregular films of argillaceous material; beds from a fraction of an inch to 12 inches thick. Weathers to fairly regular, solution-pitted, medium to light bluish gray ledges. Chert occurs from 351 to 353 feet as shattered nodules that are chalcedonic and subporcelaneous, brownish to blu-	17	572	337 – 354

Description	Thickness in feet: Interval	Cumulative	Feet above base
ish gray to light brown and white, and weather brown to yellowish white. Scattered to abundant sand grains, at places grading to a thin calcareous sandstone, occur intermittently along the trace of the top of interval 47. The individual grains are small, well rounded, and frosted, and are not uncommonly accompanied by small pellets and nodules of chalcedonic, bluish white to bluish gray chert.			
48. Dolomite, grading laterally to limestone in the lower and upper 3 feet—predominantly microgranular, grading to fine grained; light rose beige to beige, grading to light gray, rose, rose gray, light yellowish gray, and in minor part to nutria or brownish olive; beds 2 to 48 inches thick. Weathers to irregular, uneven, in part hackly ledges and smooth blocks which are mostly medium gray and in part with a yellowish to pinkish tinge. Chert occurs at 293 feet as scattered small angular inclusions, surficial coatings, and plates which are semichalcedonic to chalcedonic; locally chalk textured, crypto-oölitic, and pseudospicular; light brownish to pinkish gray to white; and white weathering. At 305, 318 to 323, and 328 to 332 feet chert occurs as shattered lenses, nodules, lenticles, and smaller angular inclusions which are chalcedonic to semichalcedonic, in part crypto-oölitic and pseudospicular, grading to chalk textured on weathered margins, bluish to brownish gray to whiskey brown to chalk white, and weather yellowish to bluish white with darker stains. Interstitial chert occurs in some of the fine grained dolomite beds. Sand grains are fairly abundant at about 317 feet.	44.5	616.5	292.5– 337
49. Limestone—sublithographic, locally grading to a micro-oölitic or fine pellet limestone, in minor part with scattered dolomite rhombs; pearl gray to woodash gray; beds from a fraction of an inch to 45 inches thick, with the thicker beds commonly weathering slabby. Weathers to fairly regular, solution-pitted to smooth, medium to light bluish gray ledges. The beds from 265 to 285 feet comprise a prominent ledgy break in slope that is traceable laterally and readily detectable on the aerial photographs. Chert was seen at 257 feet as small, flat, nodule like inclusions that are chalk textured to semiporcelaneous and white. Scattered sand grains occur in some beds of interval 49. The spicular wall structure of externally poorly preserved *Archaeoscyphia* occurs in nodular subchalcedonic chert in the basal 3 feet of the interval (TF–376), and occasional poorly preserved calcified snails were seen in some beds. The lower 3 feet of interval 49 constitutes the principal and only known *Archaeoscyphia* zone in the Gorman formation in the Riley Mountains. It is 243 feet above the base and 210 feet below the top of the Gorman formation in the Warren Springs section.	49.5	666	243 – 292.5
A bed at 243 feet, base of the principal *Archaeoscyphia* zone of the Gorman formation. Offset about 200 feet airline south-southeast if going up in the section and north-northwest if going down. (Altitude approximately 1380 feet at north and 1360 at south end of offset.)			
50. Dolomite and calcitic dolomite in lower 2 feet, limestone in upper 3 feet—the dolomite is mostly medium to fine grained and the limestone is sublithographic; the dolomite is light yellowish gray and the limestone pearl gray; bedding indeterminate. Weathers to a bench strewn with thin plates of limestone and thicker, less regular blocks of dolomite.	5	671	238 – 243

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Chert occurs at 239 feet as lenses which are chalcedonic and concentrically laminated or irregularly blotched in tones of brownish gray, bluish gray, carnelian, and light tan. A few poorly preserved calcitic fossil snails were seen in the upper part of the interval.			
51. Limestone—sublithographic; pearl gray to woodash gray, in part with irregular yellowish argillaceous films; beds from less than 1 inch to 24 inches thick. Weathers to fairly regular, smooth to solution-pitted, medium to light bluish gray ledges.	7	678	231 – 238
52. Dolomite, partly calcitic in the line of section and grading laterally to limestone—very fine grained to coarse grained, beige to light gray, bedding indeterminate. Weathers to a rubble-covered bench with a few projecting ledges. Chert occurs as a few irregular inclusions and thin plates that are chalcedonic, bluish to brownish gray, cream weathering.	4	682	227 – 231
53. Limestone, in minor part with abundantly scattered small dolomite rhombs but for the most part quite pure—sublithographic, pearl gray to woodash gray, beds from less than 1 inch to 24 inches thick. Weathers to fairly regular, smooth to solution-pitted, medium to light bluish gray ledges. This interval forms a conspicuous ledge or set of ledges traceable laterally as a marked break in slope and showing distinctly on the aerial photographs.	13	695	214 – 227
Base of calcitic facies of Gorman formation at base of interval 53. (Altitude approximately 1370 feet.) Total thickness of facies 242 feet.			
Dolomitic facies: 214 feet thick			
54. Dolomite, in part grading laterally to limestone in upper 8 to 10 feet—predominantly microgranular in lower 11 feet, and fine to medium grained in part grading to microgranular in upper 17 feet. Light gray to rose gray, rose beige, or light brownish beige, in part weakly mottled or streaked in the varying tones named. Bedding indeterminate. Weathers to irregular, uneven, medium gray to iron gray ledges below 200 feet; forming a rubble-covered bench with generally poor exposures in the upper half. Chert occurs at 190 feet as a few scattered excrescences that are subchalcedonic, bluish gray to white, and white weathering. From 200 to 202 feet are large shattered blocks of chert that are chalcedonic to porcelaneous, in minor part chalk textured, in part with scattered to moderately abundant dolomite rhombs or dolomolds, and locally with quartzose inclusions: bluish to brownish gray, grading to tan, light tan, bluish white, china white, and carnelian; and weather mostly shiny white. At 204.5 feet are a few similar scattered nodules of chert. At 209 to 209.5 and 212 to 214 feet chert occurs as plates and angular inclusions.	28	723	186 – 214
55. Limestone in the line of section, in minor part with irregular inclusions of dolomite and grading laterally to dolomite—sublithographic, in part oölitic or pelletted; pearl gray to woodash gray; beds from less than 1 inch to 36 inches thick. Weathers to irregular, uneven, smooth to solution-pitted medium bluish gray ledges where the limestone is pure, but rough to reticulate and darker where dolomitic. Occasional sand grains occur near the top of interval 55.	17	740	169 – 186
56. Dolomite, in part grading laterally to limestone from 150 to 155 and 165 to 169 feet—predominantly microgranular, in minor part grading to fine grained, except at 70 to 77 and 90 to 101 feet where it is fine to medium grained. Rose beige to rose, beige, light gray, rose gray, and locally dark red; in part streaked and mottled, and in part with lavender tinges. Beds 4 to 34 inches thick. Weathers to irregular, uneven to hackly, mostly fairly thick, medium	140	880	29 – 169

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
gray to iron gray, in part pinkish gray, and locally brick red ledges. Chert occurs from 59 to 60 and 88 to 90 feet as scattered angular inclusions, shattered lenses, and surficial coatings that are chalcedonic to subchalcedonic, bluish to brownish or pinkish gray, and weather dull to shiny white with darker stains. Abundant chert occurs at 110 to 122 feet as angular inclusions and shattered nodules that are oölitic and brownish gray or semichalcedonic to subgranular, white, and dull white weathering; or as darker stained drusy and in part dolomoldic excrescences and surficial coatings. At 129 feet a few angular inclusions of chalcedonic, in minor part, oölitic, pinkish to brownish or bluish gray chert were seen. From 146 to 147 feet a thick lens of chert was seen immediately northwest of the line of section, disrupting into thin plates and lenticles in the line of section and being semichalcedonic to chalcedonic; badly shattered; light bluish gray to rose gray, light rose, and bluish white; and weathering white and shiny with darker stains. At 152 feet are minor plates and angular inclusions of chalcedonic to subchalcedonic, in part micro-oölitic, pinkish gray to bluish white chert that weathers yellowish to dirty white. Siliceous residues show scattered coarse silt grains and very small sand grains between 45 and 85 feet, and sand grains are scattered to moderately abundant in some beds between 90 to 115, 125 to 140, and 150 to 156 feet. Some of the chert at 59 feet contains sand grains, and it grades in part to a chert-matrix sand.			
57. Dolomite—fine grained, grading to medium grained; light brownish gray to rose gray; beds 2 to 24 inches thick. Weathers to uneven, medium gray to iron gray ledges. Chert occurs at 25 feet as angular inclusions that are chalcedonic to subchalcedonic, bluish to pinkish gray to white, and weather dull white. Scattered small sand grains occur in the lower 5 feet of interval 57 with occasional very small sand grains above.	9	889	20 – 29
58. Dolomite—predominantly microgranular, in minor part grading to fine grained; rose beige, grading to rose, dusty rose, beige, and light rose gray; beds 4 to 24 inches thick. Weathers to irregular, uneven, in part hackly, medium gray to iron gray ledges, in part with a brownish tinge. Chert occurs at 8 and 13 feet as surface coatings and angular inclusions that are chalcedonic to porcelaneous, in part with scattered dolomite rhombs, and weather dull white. Scattered small sand grains occur about 5 feet above the base of interval 58, with occasional very small grains in the upper 5 feet.	20	909	0 – 20
Base of dolomitic facies of Gorman formation at base of interval 58. Total thickness 214 feet and of formation 456 feet. North from the line of section and west of the Riley Mountain fault 100 or more feet of thickly bedded limestone of the Staendebach member of the Tanyard formation come in stratigraphically below the measured section; and from these limestones at the ridge-crest above interval 58, and at a point about 25 feet stratigraphically below the Tanyard-Gorman contact, were collected *Ozarkina* cf. *O. complanata* Ulrich and Bridge, *Paraplethopeltis*, and other fossils (TF–204).			
Base of Warren Springs section, a segment of the composite Riley Mountain section at base of interval 58. Altitude approximately 1260 feet. About 100 feet west of the Riley Mountain fault from a point about 0.9 mile airline north of Honey Creek. Total thickness of section 909 feet, of which 453 feet belongs to the Honeycut and 456 feet to the Gorman formation.			

Moore Hollow Section

The Moore Hollow section, as described below, includes a total of 965 feet of Ellenburger and Upper Cambrian rocks extending from 30 feet above the Tanyard-Gorman boundary to 332 feet below the Cambrian-Ordovician boundary. It displays full thicknesses of the Tanyard formation (603 feet) and of the Pedernales dolomite (73 feet) and San Saba limestone (144 feet) members of the Wilberns formation. The lower 30 feet of the Gorman formation and the upper 115 feet of mostly biohermal limestones of the Point Peak shale member of the Wilberns formation comprise the remainder of the section.

The top of this section is at an altitude of approximately 1430 feet at the crest of a north-south ridge, about 1100 feet airline west of the Riley Mountain fault, and 0.65 mile airline northwest from benchmark 1176.3 on the Llano-Click road (Pl. 10). Stratigraphically it is 30 feet above the base of the Gorman formation and is overlain by microgranular to very fine grained dolomites extending northward into a zone of minor faults.

The base of the Moore Hollow section is at an altitude of about 1245 feet, about 800 feet up Moore Hollow from the Riley Mountain fault. It is about 0.6 mile airline south-southwest from the top of the section and stratigraphically at the base of the principal biohermal limestone zone of the Point Peak shale member of the Wilberns formation.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Ellenburger group: 965 feet described *Gorman formation: 30 feet described* *Dolomitic facies: 30 feet described*			
1. Dolomite (altitude approximately 1430 feet at top of section)—microgranular, in very minor part grading to fine grained; rose beige, grading to rose and light pinkish gray, in minor part with lavender mottles; bedding indistinct. Weathers uneven to hackly, smooth, medium gray to iron gray, with the smoothly weathered cobbles on the surface being very light gray. Very minor chert occurs as occasional nodules that are chalcedonic, bluish gray to white, and white weathering. A few very small but nevertheless well rounded and frosted sand grains occur in the rocks of interval 1.	7	7	958 – 965
The top of interval 1 is at the juncture of a short east-west fence with the north-south fence which the section follows from the X bed at 716 feet to the top of the section at 965 feet.			
2. Limestone with irregular inclusions of dolomite, grading laterally to dolomite—sublithographic, grading to medium grained where limestone; pearl gray, with pinkish streaks where dolomitic; bedding indistinct. Weathers rough, reticulate, light to medium bluish to slightly yellowish gray. Poorly exposed. Grades laterally to microgranular dolomite. Sand was seen as scattered to fairly abundant grains in some of this limestone.	2	9	956 – 958
3. Dolomite—predominantly microgranular, in minor part grading to fine to medium grained dolomite that appears to be oölitic. Rose beige, in part with darker rose mottles and irregular reddish purple spots where microgranular; tending to be light pinkish to yellowish gray with darker pink mottles where fine to medium grained. Bedding indeterminate. Weathers hackly to sphenoidally jointed, smooth, and medium gray with lighter faintly pinkish gray blotches where ledges are in place, but the smoothly weathered cobbles scattered over the surface are much lighter gray. Minor chert is present in a few beds, occurring as scattered small angular inclusions, lenticles, and nodules	13	22	943 – 956

Description	Thickness in feet: Interval	Cumulative	Feet above base
that are mostly chalcedonic, light bluish to yellowish gray or white, and white weathering. The lowest sand seen (in the field) in the Ellenburger rocks of the Moore Hollow section consists of rare and very small sand grains near the middle of interval 3.			
4. Dolomite—fine to medium grained, appears to be conspicuously oölitic with the oöids replaced by individual dolomite rhombs, grades laterally to microgranular dolomite. Light pinkish gray to light gray, in part with lavender mottles; the microgranular dolomite to which it grades laterally being light rose to beige, with dull reddish mottles. Bedding indistinct apparently ranging from about 2 to 24 inches thick. Weathers irregular, hackly, medium gray to light yellowish gray. Minor chert is present at the top of the interval as small lenticles that are chalcedonic to subchalcedonic, in part with scattered oöids, white to light bluish gray, and white weathering.	8	30	935 – 943
Base of dolomitic facies of Gorman formation at base of interval 4 (altitude approximately 1430 feet). Incomplete described thickness of facies and formation 30 feet.			
Tanyard formation: 603 feet thick			
Staendebach member: 353 feet thick			
Calcitic facies: 121 feet thick			
5. Limestone, grading in part to dolomitic limestone in upper 2 to 3 feet—the limestone is sublithographic, grading to medium grained where dolomitic; pearl gray to woodash gray, in minor part with pinkish streaks, and grading to pink where dolomitic. Beds from a fraction of an inch to about 14 inches thick, for the most part poorly exposed. Weathers slabby, light bluish gray, reticulated with darker weathering dolomite in upper part, and grading to light yellowish gray where most dolomitic. Chert is abundant in the lower 8 feet, occurring as thin, irregular, somewhat ropy-surfaced layers that are chalcedonic to subchalcedonic, bluish to brownish gray to white, mostly streaked and mottled, and weather dull white with darker stains. It is commonly dead white and chalk textured where deeply weathered. At 929 feet the chert is a granule conglomerate composed of granule-sized chert inclusions, irregular chert pellets, in part laminar. Above 929 feet are scattered nodules, lenses, and thin extensive plates of chalcedonic to semichalcedonic, in part micro-oölitic to crypto-oölitic, bluish to pinkish gray chert that weathers yellowish white. Small *Ophileta* was noted at 922 feet; poorly preserved gastropods and unidentified *Hystricurus*-like trilobites were collected from chert float at 929 feet (TF–375).	14	44	921 – 935
6. Dolomite—microgranular, pinkish beige, apparently a thin lens pinching out about 40 feet west of the line of section. Weathers uneven, smooth, medium gray to light pinkish gray. Contains scattered small nodules of subchalcedonic to chalcedonic, light gray to grayish white, white-weathering chert.	0.5	44.5	920.5– 921
7. Limestone, apparently quite pure except for presence of chert—predominantly sublithographic, in part of a granular appearance due to a micro-oölitic or pelleted structure and in part an intraformational granule- to pebble-breccia or conglomerate. Predominantly pearl gray grading to very light brownish gray or woodash gray, in minor part with pinkish streaks and tinges and in part with irregular dusty green argillaceous films. Beds from less than 1 inch to 30 inches thick for the most part fairly	25	69.5	895.5– 920.5

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
thickly bedded. Weathers to fairly regular, generally uneven, smooth to in part solution-pitted ledges. Chert is fairly common in the lower 10 feet of the interval, occurring as shattered lenses and irregular inclusions resembling breccia fragments. It is mostly chalcedonic to subchalcedonic, bluish gray with bluish white and brownish gray streaks, and weathers mostly white and shiny; but at 901 feet is a subgranular, brownish gray, dull-weathering chert that is crowded with oöidlike and irregular pelletlike bodies. From 905 to 915 feet are occasional small angular inclusions of chert similar to that in the lower 10 feet. Above 915 feet chert is abundant as nodules, irregular inclusions, plates, and lenticles that are chalcedonic to subchalcedonic and bluish white to bluish gray. A gastropod resembling *Ozarkospira* was collected from limestone at 908 feet, *Paraplethopeltis* at 911 feet, and a poorly preserved low-spired gastropod at 915 feet. All of these were lumped as collection TF–374.			
8. Limestone, apparently quite pure except for the presence of chert—predominantly sublithographic, in part pelletted or finely oölitic, in minor part an intraformational granule- to pebble-breccia. Predominantly pearl gray, grading in part to light brownish gray and woodash gray, in minor part with pinkish markings. Beds from a fraction of an inch to 30 inches thick, mostly rather thickly bedded. Weathers to generally thick, fairly regular, smooth to uneven, solution-pitted, medium to light bluish gray ledges. The top of interval 8 is marked by a conspicuous chert lens that is 2 feet thick in the line of section and can be traced 50 to 60 feet laterally both east and west. Except for the lower 6 feet of this interval, chert similar to that in the capping lens is abundant as angular blocks in the float and as irregular inclusions, cobble-sized nodules, and lenses in place. This chert is chalcedonic to subchalcedonic, in minor part with quartzose inclusions, in minor part micro-oölitic or with scattered small oöids, in minor part with scattered small dolomolds or included small dolomite rhombs; predominantly bluish gray to bluish white, grading in minor part to brownish gray, and mostly streaked, banded or mottled; weathering mostly shiny white.	27.5	97	868 – 895.5
9. Limestone; in part slightly dolomitic or with irregular inclusions of dolomite, grading to dolomitic limestone in lower 4 feet and to dolomitic limestone and calcitic dolomite from 847 to 853 feet—the rock is sublithographic where pure limestone, grading to medium or even coarse grained where dolomitic; pearl gray to woodash gray, with minor pinkish tinges; beds less than 1 inch to 28 inches thick. Weathers rough, reticulate, the limestone being medium to light bluish gray with the dolomitic portions in positive relief as darker, duller gray reticulations. Minor chert occurs at 837 and 841 feet as scattered nodules and lenticles that are subchalcedonic to semichalcedonic and in part quartzose, pink, pinkish orange, and pinkish gray, and weather dull white. A single specimen of *Paraplethopeltis*, and a single poorly preserved brevicone cephalopod were noted at 863 feet, and one poorly preserved specimen of a *Sinuopea*-like gastropod was seen at 867 feet. All were calcite preservations in limestone and none was collected.	32	129	836 –868
A conspicuous break in a slope (elevation approximately 1465 feet) occurs near the base of interval 9, coming at about 846 feet stratigraphically above the base of the section. Below this			

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
point the section follows a steep hillslope, but in the part stratigraphically above the break in slope, altitude is gradually lost to the top of the section.			
10. Dolomitic limestone and calcitic dolomite—the limestone is sublithographic, grading to medium grained where dolomitic, and the dolomite is mostly medium grained and vuggy. Very light pink to woodash gray, being mostly mottled in shades of light pink, pinkish lavender, and woodash gray to white. Beds 4 to 18 inches thick. Weathers rough, pitted to reticulate, medium brownish to bluish gray, in general not well exposed. Chert occurs in the upper 2 feet as minor irregular inclusions that are subchalcedonic and white to pinkish orange.	10	139	826 – 836
11. Dolomite in the line of section, grading laterally to limestone—the dolomite is medium to coarse grained, conspicuously vuggy; woodash gray to pearl gray, in part with lavender to pinkish tinges; beds 6 to 24 inches thick. Weathers rough, conspicuously pitted, medium gray, in part with a brownish tone.	7	146	819 – 826
12. Limestone, conspicuously interlaced with dolomite and grading laterally to dolomite—the limestone is sublithographic and light pearl gray, in part with a delicate pinkish tinge; the irregular dolomitic inclusions are mostly medium grained and medium rose pink. Bedding indistinct, the interval being divisible into one to three or more beds. Weathers rough, reticulate, the limestone weathering medium bluish gray as contrasted to the dolomite which shows as darker reticulations.	5	151	814 – 819
Base of calcitic facies of Staendebach member of Tanyard formation at base of interval 12 (altitude approximately 1425 feet). Total thickness of facies 121 feet.			
Dolomitic facies: 232 feet thick			
13. Dolomite, in part slightly calcitic and in minor part grading laterally to limestone in upper 7 feet—medium to fine grained, grading to very fine grained in lower 3 feet and in minor part above; in part vuggy especially in the upper 26 feet. Light gray to light pinkish gray, in minor part grading to light brownish or yellowish gray to dull rose, and in minor part with mottles and streaks of pink, lavender, or faint dusty green. Beds mostly fairly thick and regular, ranging from less than an inch to about 40 inches thick. Weathers to fairly regular, thick, smooth, to rough medium gray to iron gray ledges which are in part pitted, especially in the upper 26 feet. Chert is fairly common at various places in the interval, occurring as nodules, lenticles, lenses, plates, small to large angular fractured inclusions, excrescences, and surficial coatings. It was specifically noted as follows: at 737.5 feet, minor quartz druse and chalcedonic chert; at 738 feet, subporcelaneous nodules of chert that are concentrically banded and pinkish white to bluish gray, salmon pink, and rose, weathering white to rose pink; from 749 to 752 feet, scattered nodules and lenticles of semichalcedonic to porcelaneous chert that is china white with minor specks of light bluish gray; from 753 to 760 feet, a conspicuously cherty zone in which subgranular to subporcelaneous, in large part conspicuously drusy, sporadically to abundantly dolomoldic, brownish gray to dirty white, rough weathering excrescences and coatings occur in place and on all surfaces of blocks in the float; from 762 to 768 feet, scattered angular inclusions and larger irregular masses of semichalcedonic to subporcelaneous chert that is white	77	228	737 – 814

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
with light brownish streaks and weathers white; from 775 to 778 feet, scattered to moderately abundant nodules and lenticles of chalcedonic to semichalcedonic chert that is banded in white, bluish gray, and brownish gray, or irregularly marked with the same colors, and weathers white; from 778 to 780 feet, massive inclusions of white-weathering, subchalcedonic, mostly white chert; at 786 feet, thin plates and lenticles of chalcedonic to subporcelaneous, in part very finely oölitic chert that is mostly white with light bluish gray streaks and weathers white; from 791.5 to 794 feet, conspicuously dolomoldic and in part drusy chert excrescences and irregular chert inclusions; from 794 to 798 feet, angular inclusions to fairly large irregularly shattered blocks of subporcelaneous to subgranular and semichalcedonic, in part sporadically dolomoldic, white-weathering chert; at 802 feet, a few nodules of subchalcedonic, crypto-oölitic, brownish gray to white, white-weathering chert; at 805 feet, conspicuously oölitic fractured lenses composed of siliceous dirty white to brown oöids having thin white shells surrounding darker interiors or else darker shells surrounding powdery yellowish weathered or hollow interiors; at 813 feet, nodules of subchalcedonic, bluish gray, white-weathering chert. Chalk white interstitial chert is common in various beds of the interval and abundant in some.			
14. Dolomite—fine to medium grained, in general coarser grained than that in the interval below, in minor part slightly vuggy; light gray to light pinkish gray, grading to faintly yellowish or brownish gray to light rose; bedding indistinct, beds apparently not exceeding about 24 inches thick. Weathers to uneven, medium gray ledges. Interstitial chert is fairly common in the dolomite of this interval. Chert is also abundantly present as excrescences and surficial coatings that are dolomoldic and in part drusy; as well as angular inclusions and plates that are semiporcelaneous to porcelaneous, with scattered to fairly abundant dolomolds, in part quartzose to drusy, in part with small cloudy irregular markings, china white to dirty white, and weather mostly shiny white with yellowish to brownish stains. Nodules and angular inclusions of chalcedonic, bluish gray chert with white streaks were noted at 722 feet. Chert is uncommon as float, probably due to the steepness of the hillslope up which this part of the section was measured.	21	249	716 – 737
X bed at 716 feet. Offset to a point 670 feet airline north-northeast if going up in the section and south-southwest if going down. The actual route of shift follows the trace of a bed that makes a semicircle around the east slope of a hill from an altitude of about 1520 feet near the top of a hill at its southwest end to about 1380 feet near the head of a draw at its northeast end. The bed followed is a fine grained dolomite containing scattered inclusions and nodules of white-weathering subchalcedonic to subporcelaneous chert and overlain by a bed of medium grained pink dolomite with interstitial chert that comes about 5 feet below a dolomite bed conspicuously encrusted with quartzose, dolomoldic chert.			
15. Dolomite—fine to medium grained, in part grading to very fine grained and in general seeming to average somewhat finer grained that the dolomite of interval 14, in minor part vuggy; light pinkish gray to light gray, in part with a faint yellowish to brownish tone and in minor part	32	281	684 – 716

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
grading to a medium brownish gray. Beds irregular, ranging from less than an inch to 22 inches thick. Weathers to uneven medium to rather dark gray ledges. Chert is fairly common throughout interval 15, though not abundant. It occurs both as float and in place. That in place consists of excrescences and coatings of medium grained quartz druse, drusy and dolomoldic chert, thin plates and lenses of chalcedonic white-weathering chert, and interstitial chert. The chert which occurs as float is in part chalcedonic, locally oölitic, bluish gray to bluish white, and weathers shiny white; in part porcelaneous, with scattered to fairly abundant dolomolds, and china white in color; and in part highly dolomoldic to cellular and commonly interlaced with quartz druse. *Helicotoma* cf. *H. uniangulata* (Hall) was collected in drusy dolomoldic float at 710 feet (TF–373).			
16. Dolomite—fine to medium grained, for the most part verging on the boundary between grain sizes and only locally being very fine grained; in minor part with scattered small vugs; in part an intraformational breccia from 657 to 670 feet (pebble-sized phenoclasts). Light gray to light pinkish gray or grayish pink, grading in minor part to light olive gray or brownish gray. Bedding irregular, with beds seeming to range in thickness from about 4 to 24 inches. Weathers to uneven, medium to rather dark gray ledges, in part grading to lighter gray with a faint brownish or yellowish tone. Chert is fairly common, though not abundant, throughout interval 16; occurring both in place and as float, as irregular inclusions, as excrescences, and in part as fairly extensive lenses. The lower 17 feet of the interval is marked by the occurrence of subround to angular, pebble- to cobble-sized inclusions of conspicuously dolomoldic chert and partially chertified dolomite having the general aspect of breccia fragments. A large amount of the chert float is chalcedonic to semichalcedonic, in part crypto-oölitic to oölitic or with indistinct subrounded cloudy markings, bluish gray to bluish white, and weathers mostly shiny white with various shades of discoloration. This type of chert was seen in place as a wide lens 4 inches thick at 679.5 feet. Another type of chert that is common in the float is conspicuously dolomoldic, cellular to porcelaneous, and in part conspicuously interlaced with fine to coarse grained quartz druse. Concentrically banded nodules of chert were also seen, and interstitial chert is fairly common in some of the dolomite beds. *Sinuopea* and *"Pelagiella"* were collected from drusy dolomoldic chert float at 670 feet (TF–372).	41	322	643 – 684
17. Covered in the line of section, but float indicates the interval to be underlain by dolomite. The dolomite seen in the float is medium to fine grained, in part with small vugs, and light gray. Chert is abundant as float in the lower 7 feet of the interval; being subgranular, conspicuously oölitic, and laminar, or semiporcelaneous, oölitic to crypto-oölitic, and light bluish gray to dull grayish white. Chalcedonic, light to medium bluish gray to bluish white chert occurs as scattered float blocks throughout the interval. Most of the chert weathers shiny white with yellowish tinges, grading to yellowish white with russet streaks where oölitic and laminar.	17	339	626 – 643

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
18. Dolomite—fine grained to very fine grained, in part approaching microgranular, in very minor part with scattered small vugs; medium brownish gray to olive gray or rose gray, grading to darker or lighter tones and in part to a delicate rose color, in part with lavender to darker purple mottles and tinges. In general the dolomite in interval 18 is much finer grained and darker colored than the dolomite of interval 17. Beds poorly exposed, bedding indistinct. Weathers to poorly exposed, irregular, medium gray ledges not exceeding 2 feet thick. Chert is fairly common throughout the interval, both in place and as float. It occurs as irregular inclusions, rough excrescences, and thin plates that are in part chalcedonic, crypto-oölitic or with small cloudy inclusions, and bluish to brownish gray and in part porcelaneous, with scattered to abundant dolomolds and occasional quartzose patches, and china white. Both types weather shiny white. Drusy, quartzose chert is common in place, as well as in the float; and conspicuously oölitic, in part laminar chert occurs in the float, having perhaps come from above. Thin plates of white, porcelaneous chert occur within 2 feet of the base of interval 18, in the line of section and to the very base when traced laterally; and white-weathering, porcelaneous and chalcedonic chert becomes abundant in the float above the base of this interval. Scattered specks of green interstitial material at 613 feet may be glauconite. No fossils were noted in interval 18 in the line of section, although brevicone cephalopods and gastropods have been seen in chert weathering from beds equivalent to those in this interval at other localities.	44	383	582 – 626
Base of dolomitic facies of Staendebach member of Tanyard formation at base of interval 18. Total thickness of facies 232 feet, and of member 353 feet. Offset on the Threadgill-Staendebach contact about 830 feet airline east-southeast if going up in the section and west-northwest if going down. This offset follows the member contact across the head of a steep and brushy draw from an altitude of about 1525 feet at its west end to about 1440 feet at its east end and crosses a minor fault at midlength. Yellow paint spots mark a more open but longer route of offset along a sparsely wooded ridge.			
Threadgill member: 250 feet thick *Upper dolomitic facies: 96 feet thick*			
19. Dolomite—mostly medium grained, in part grading to fine grained, locally vuggy; woodash gray to pearl gray, grading to light pinkish or light brownish gray with pinkish and purplish tinges and streaks. Beds generally not well exposed and bedding indistinct, but no bed appears to exceed 24 inches in thickness. Weathers to irregular, generally poorly exposed, knobby, in part pitted, medium to rather dark gray ledges. Siliceous elements in the lower 7 feet consist of fairly abundant irregular excrescences of fine to medium grained quartz druse and scattered angular inclusions of semichalcedonic, light bluish white, white-weathering chert with scattered to fairly abundant small dolomolds. Interstitial chert is fairly abundant in some beds. Chert is also very abundant as float over the surface of interval 19 and the upper 15 feet of interval 20. Some of this float is probably derived by weathering from interval 19, but the probability is that much of it has floated down from beds of	32	415	550 – 582

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
the Staendebach member above. This chert float shows considerable variation; ranging from orange stained, conspicuously cellular, dolomoldic chert through a siliceous rock that consists of irregularly interlaced quartz druse and white, smooth-fracturing, dolomoldic chert to a white subporcelaneous to porcelaneous, in part, quartzose chert, with scattered but fairly abundant dolomolds or even to a subgranular, bluish white chert or a dolomoldic chert that is chalk white and almost chalk textured. Fossils were collected from chert float through interval 19 and about the upper 10 feet of interval 20. They are probably derived in part from interval 19 and in part from the beds of the Staendebach member above. Fossils collected were species of *Ophileta, Ozarkina, "Ozarkispira," "Pelagiella," Schizopea, Sinuopea, Gasconadia, Ectenoceras* and other cephalopods, chiton plates, and cystid plates (TF-371).			
20. Dolomite, in very minor part slightly calcitic—mostly medium grained, grading to coarse and fine grained, in part vuggy and especially so in the upper 15 feet; woodash gray to pearl gray, brownish gray, light pinkish to purplish tinges and with yellow to buff coatings in the vuggy parts. Bedding indistinct, generally massive, with no recognizable bedding surfaces in intervals up to 5 and 6 feet thick. Weathers to irregular, somewhat hummocky, generally massive, in part pitted, rather dark gray to iron gray ledges. Chert was noted as scattered, irregular inclusions and excrescences at 488, 503, and 512 to 515 feet; but it is generally scarce in place in interval 20. It is subgranular to semichalcedonic, in part with scattered dolomolds or dolomite rhombs, medium bluish to brownish gray to dull white, and weathers dull to moderately shiny white to dull brown. Siliceous residues show minor finely disseminated silica in the interval, and although it all seems to be crystalline there is a possibility that some is very fine silt. *Gasconadia* and *Ectenoceras* were seen in chert float in the upper third of interval 20, but they were probably derived from interval 19 or even higher beds.	64	479	486 – 550
Base of upper dolomitic facies of Threadgill member of Tanyard formation at base of interval 20 (altitude approximately 1470 feet). Thickness of upper dolomitic facies 96 feet.			
Calcitic facies: 76 feet thick			
21. Limestone, grading laterally to dolomite in the bottom and top few feet and with minor irregular inclusions and occasional pockets of calcitic dolomite and dolomitic limestone throughout—predominantly sublithographic, grading in part to a fine to coarse pellet limestone, medium to coarse grained in the dolomitic portions. Woodash gray to pearl gray, with pinkish and greenish tinges and occasional irregular, greenish, argillaceous films. Beds from fraction of an inch to 36 inches thick, generally fairly massive and indistinctly bedded. Weathers to massive, irregular, somewhat hummocky ledges alternating with benches that are strewn with subrounded to subangular cobble-sized rubble; the weathered color being medium to light bluish gray, with local patches that are almost white, and with darker brownish gray irregularly raised streaks and patches where dolomitic. Minor chert occurs at 428 and 467 feet as irregular excrescences that are partly semichalcedonic, with a fracture resembling that of freshly broken paraffin, in part subgranular, locally crypto-oölitic or containing cloudy pelletlike	76	555	410 – 486

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
bodies, with local quartzose patches, rather dark to purplish gray, and weather dull brown. Except as they are affected by the chert noted, siliceous residues are virtually nonexistent from interval 21, but minor waxy-lustered greenish argillaceous flakes do occur. Unidentifiable cross sections of gastropods were seen from 458 to 464 feet, among which a few impressions are of a robust few-whorled gastropod suggesting *Sinuopea*. A chertified object which suggests *Ozarkina* but is probably inorganic was collected at 482 feet (TF–370).			
Base of calcitic facies of Threadgill member of Tanyard formation at base of interval 21 (altitude approximately 1430 feet). Thickness of calcitic facies 76 feet.			
Lower dolomitic facies: 78 feet thick			
22. Dolomite, slightly calcitic in upper few feet—coarse to medium grained, vuggy; woodash gray to almost white, in part with pinkish and yellowish tinges and scattered purplish specks; bedding indistinct. Weathers to rough, generally pitted, hummocky, generally medium gray surfaces. The weathered expression suggests a massive, nonbedded rock and recognizable bedding surfaces are scarce if not entirely absent. Siliceous residues from this interval are extremely minor in quantity and consist primarily of individual or clustered very small siliceous grains of a crystalline appearance and minor waxy-looking greenish argillaceous flakes.	78	633	332 – 410
Base of lower dolomitic facies of Threadgill member of Tanyard formation and Cambrian-Ordovician boundary at base of interval 22 (altitude approximately 1385 feet). Thickness of lower dolomitic facies 78 feet, of member 250 feet, and of formation 603 feet.			
Upper Cambrian: 332 feet described			
Wilberns formation: 332 feet described			
Pedernales dolomite member: 73 feet thick			
23. Dolomite, calcitic in the lower 3 feet and slightly calcitic in a few other beds—mostly very fine grained to microgranular. Yellowish to brownish gray, olive gray, or rose gray, grading to dull rose or lavender, with pinkish and rose tones being most common in the lower 5 feet; in part irregularly mottled and streaked with tones of pinkish and brownish gray. A 2-inch band of very finely color-laminated dolomite was noted at about 329 feet, a little east of the line of section. Bedding generally indistinct; measuring 3 to 14 inches thick where observed, but with more massive-looking, indistinctly bedded ledges commonly extending to a vertical thickness equivalent to 3 or 4 feet of section without clear indications of bedding surfaces. Weathers to uneven, hackly, indistinctly bedded, medium gray to brownish gray surfaces. Chert is fairly common in place and as float from 298 to 315 feet. That in place occurs as excrescences and plates that are subporcelaneous to subgranular or chalk textured, in part very finely dolomoldic, in part finely drusy, bone-white, to yellowish, and weather rough and dirty white. The chert float occurs as large blocks that are more generally chalk textured, very finely dolomoldic, and in part drusy. Scattered interstitial and possibly globular glauconite was seen at 263 and 322 feet. Interstitial glauconite was also seen about 800 feet west of the line of section, on the next spur west and immediately below the Cambrian-Ordovician boundary.	73	706	259 – 332

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Finkelnburgia sp. was collected from dolomite at 263 feet (TF–367), "*Hyolithes*" sp. at 265 feet (TF–368), and the free cheek of a large trilobite at 292 feet (TF–369). No other fossils were seen in interval 23, although search was made for them in the cherty zone.			
Base of Pedernales dolomite member of Wilberns formation at base of interval 23 (altitude approximately 1335 feet). Thickness of member 73 feet.			
San Saba limestone member: 144 feet thick			
24. Limestone and dolomitic limestone, with dolomitic limestone predominating in the lower and upper 4 feet—fine grained to microgranular, in part sublithographic where the limestone is purest; conspicuously oölitic from 250.5 to 251 feet. Light brownish gray to deep pinkish purple, with irregular streaks and mottles of rose to salmon pink, greenish gray, and yellow to buff; the more vivid colors predominate in the upper 6 feet, beginning with a 4-inch band of dark pinkish purple, slightly glauconitic limestone. Beds from a fraction of an inch to 12 inches thick. Weathers rough to smooth, medium bluish gray, with dirty brown to brownish buff elevated streaks and mottles where dolomitic. Globular glauconite was noted at 251, 253.5, and 255 feet, and occasionally throughout the upper 6 feet. Other macroscopically detectable resistant elements consist only of minor irregular argillaceous films in the purer parts of the limestone. Siliceous residues show significant amounts of fine silt, containing scattered flakes of clear mica. Except for stromatolites of the cryptozoon type from 238 to 240 feet and occasional girvanellas no "structures" of organic origin were seen.	23	729	236 – 259
25. Limestone; in part with minor irregular inclusions of dolomitic limestone, especially above 127 feet; grading to slightly dolomitic limestone at top—sublithographic to medium grained, being visibly granular principally in the dolomitic portions but with some beds of granular fragmental limestone; conspicuously oölitic in the lower 8 inches and in a 1-inch band at 117.5 feet. Light brownish to greenish gray, grading to pearl gray or silver, with mottles and streaks of buff to yellow or pinkish bronze where dolomitic and in part with irregular greenish films of argillaceous material. Beds from a fraction of an inch to 42 inches thick, generally thinner bedded in lower 12 and upper 21 feet, with intervening beds averaging 18 to 24 inches thick. Weathers to uneven, fairly regular, medium bluish to in part brownish gray ledges with irregularly raised buff mottles and streaks where dolomitic. Chert was seen at 128 feet as minor excrescences which are semiporcelaneous to chalk textured and dull brownish white. Siliceous residues from the lower 15 and upper 35 feet of interval 25 show relatively small amounts of fine silt, containing scattered flakes of clear mica. The residues from the intervening rocks are even smaller in quantity, showing very minor silt and small amounts of finely crystalline silica and pale argillaceous flakes. On the basis of siliceous residues alone, this interval, and interval 24 above it, could easily be miscorrelated with the basal 130 feet of the Tanyard formation in the Pete Hollow section on Llano River in Mason County. Although rare specks of glauconite were seen the interval seems to be essentially nonglauconitic. Although fragments of fossils are common in the intermittently occurring fragmental limestone beds, identifiable	121	850	115 – 236

Description	*Thickness in feet Interval*	*Cumulative*	*Feet above base*
macrofossils are generally uncommon. A single calcitic trilobite was collected from float probably derived from 185 feet (TF–365), and silicified *Billingsella* were collected from 194 to 196 feet (TF–366). Girvanellas occur intermittently throughout the interval but are generally not conspicuous on weathered surfaces. Hexactinellid sponge spicules are fairly common in some of the limestone from 125 to 130 feet.			
Base of the San Saba limestone member of Wilberns formation at base of interval 25. Thickness of member 144 feet.			
Point Peak shale member: 115 feet measured, and all assigned to upper biohermal zone			
26. Limestone, probably with interbedded shale and shale partings represented by covered parts—the exposed limestone is microgranular to fine grained, with minor sublithographic inclusions, largely fragmental and in part crowded with unrecognizable cross sections of fossils. Greenish to brownish gray, in part with dusty green argillaceous films and small green specks of glauconite. Beds a fraction of an inch to 4 inches thick. Mostly covered in the lower half, thinly bedded and poorly exposed in the upper half. The upper limestones weather to thin, medium bluish gray plates or banded blocks, but in the covered basal portion are crinkly-surfaced green plates of fine grained micaceous limestone such as commonly characterize the Point Peak shale member. Small globules of glauconite and greenish argillaceous films occur in some beds. Minor amounts of fine silt with scattered flakes of clear mica appear in the siliceous residues. Fossils consist of a few unidentified gastropods, cross sections of uncertain nature, and a few small pelmatozoan columnals with a very small lumen probably representing cystoids. Monaxon and hexaxon sponge spicules were noted in the upper part of the interval. A few girvanellas were also seen. The weathered expression of interval 26 suggests a zone of interbedded limestone and shale such as is normal to the Point Peak shale member, and probably fresh exposures would reveal shale in the covered portions of interval 26. *Plectotrophia*, which here probably occurs 5 to 10 feet below the base of interval 26, occurs about 30 feet below the base of the San Saba limestone member and within the normal facies of the Point Peak shale member in the north limb of the Honey Creek basin where stromatolitic bioherms are small and insignificant. On the basis of the apparent position of *Plectotrophia* and the known associations of the stromatolitic bioherms in which it here occurs, it would be logical to draw the member boundary at the top of interval 26 even if there were no shale in it.	14.5	864.5	100.5– 115
27. Limestone: a biostrome, or a zone of coalesced stromatolitic bioherms that are locally slightly dolomitic—sublithographic, grading to fine grained where dolomitic; with pockets of fine to coarse grained, glauconitic, clastic limestone. Greenish to brownish or olive gray, with mottles and streaks of buff where dolomitic and duller dusty green where argillaceous films are present; the color distribution is uneven and clouding and mottling is the rule. Bedding indistinct, generally massive, with individual ledges up to 4 feet thick. Weathers to uneven, hummocky surfaces or fairly even massive ledges that are medium to dark bluish to brownish gray and locally streaked and mottled with buff or brown. Largely covered from 42 to 47, 52 to 62, and 80 to 88 feet, and possibly with minor shale in these intervals. This interval of irregularly massive, predominantly sublithographic, biohermal limestone, with its local pockets of	81	945.5	19.5– 100.5

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
granular and glauconitic limesands, persists in the same expression laterally through the Moore Hollow area and westward beyond it to the next major fault. Its stromatolitic nature is betrayed by the local occurrence of recognizable cryptozoon heads, and by the massive, sublithographic, sparingly glauconitic lithology so characteristic of the stromatolitic limestones of the Wilberns formation throughout the Llano region. Globular glauconite is abundant in some of the clastic pockets and scattered grains occur locally in the sublithographic portions. It is most abundant in the lower 40 feet of the interval. Besides glauconite the minor siliceous residues contain small amounts of fine silt, a little finely crystalline silica, and occasional flakes of argillaceous material. The dorsal valve of a straight-hinged, alate, syntrophoid brachiopod probably assignable to *Plectotrophia, Scaevogyra* cf. *S. elevata* Whitfield, and several specimens of a trilobite resembling *Platycolpus,* except that the glabella does not reach the rim, were collected from limestone between 90 and 95 feet (TF–207). Sections of trilobites were also noticed at 78 and 100 feet.			
Although it was known since April, 1944, that the thick zone of stromatolitic limestones so well displayed by interval 27 and extending to the base of interval 30 held a stratigraphic position normally occupied by interbedded shales and limestones of the Point Peak shale member, the boundary between the Point Peak shale and San Saba limestone members is wrongly drawn at the base of the conspicuous biostrome or zone of biohermal limestones (base of interval 30) on the map of the Moore Hollow area. The map of this area was already in the hands of the engraver when additional work by the authors in other areas made it apparent that the inconsistency perpetrated by including the biohermal zone in the San Saba limestone member was greater than the inconsistency of including 115 feet of mostly limestone (and probably minor shale) in the Point Peak shale member.			
28. Limestone—fine grained, green, with buff and light gray mottles and specks; a 6-inch bed. Weathers to a single rather dark brownish gray ledge. Glauconite is very abundant, being mostly globular but in part interstitial.	0.5	946	19 – 19.5
29. Covered. Probably an interval of interbedded shale and limestone.	9	955	10 – 19
30. Limestone, in part with minor irregular inclusions and scattered grains of dolomite—sublithographic, grading to fine grained where dolomitic. Greenish gray, with mottles and streaks of buff where dolomitic and olive or dusty green along irregular argillaceous films; in part with brownish tinges. Beds irregularly massive, 4 to 34 inches thick, and probably stromatolitic. Weathers uneven, hummocky, medium bluish gray, in part with brownish and yellowish streaks and mottles.	10	965	0 – 10
Base of biohermal limestone zone of Point Peak shale member of Wilberns formation at base of interval 30. Total thickness of zone 115 feet. Total thickness of Wilberns formation here described 332 feet.			
Base of Moore Hollow section, a segment of the composite Riley Mountain section at base of interval 30. Altitude approximately 1245 feet. About 800 feet up Moore Hollow from the Riley Mountain fault. Total thickness of section 965 feet, of which 332 feet belongs to the Wilberns formation of Upper Cambrian age, and 603 feet to the Tanyard formation and 30 feet to the Gorman formation of Lower Ordovician age.			

East Canyon Section (Supplementary)

The base of the supplementary East Canyon section is at the nonconformable contact of the Hickory sandstone member of the Riley formation with the pre-Cambrian Packsaddle schist. It is at an elevation of approximately 1125 feet in the draw known as East Canyon, about 1 mile airline north-northeast from the juncture of the Llano-Click road with the road to Click Gap and 0.45 mile airline west of the Llano-Click road (Pl. 10).

The top of this section is at the contact of the Point Peak shale and San Saba limestone members of the Wilberns formation. It is at an elevation of approximately 1380 feet on a north-south fence line, about 0.55 mile by trail up Moore Hollow from the Riley Mountain fault and 0.65 mile north-northwest from the base of the section.

Because of relatively steep dips and generally favorable topography it was possible in the Moore Hollow area to locate a computable section of the rocks older than those directly involved in the Ellenburger problem without much additional work. The East Canyon section was chosen because it offered the most brush-free direct traverse of the beds involved in a direction nearly normal to the strike. Better exposures of the Hickory sandstone member of the Riley formation are encountered in a traverse going directly north from Burnt Hill, but the exposures above the Hickory are as good in the East Canyon section as they are anywhere in the Moore Hollow area.

Computed thicknesses are based on measurements taken from large scale (approximately 8 inches to 1 mile) aerial photographs and a series of vertical traverses made with a Paulin precision altimeter to determine elevations based on numbers of readings averaged to the nearest 5 feet for each point of determined elevation. The computed thicknesses were supplemented by and adjusted to direct measurement from the base of the Lion Mountain sandstone member of the Riley formation to the *Eoorthis* zone of the Morgan Creek limestone member of the Wilberns formation.

In summary, the East Canyon section includes stratigraphic units as follows: 335 feet of the Hickory sandstone member, 421 feet of the Cap Mountain limestone member and 24 feet of the Lion Mountain sandstone member of the Riley formation; and of the Wilberns formation, 17 feet of the Welge sandstone member, 110 feet of the Morgan Creek limestone member, and 101 feet of the Point Peak shale member to the base of the zone of stromatolitic bioherms. *Eoorthis texana* Walcott, and *Elvinia roemeri* (Shumard) were obtained 65 feet above the base of the Wilberns formation (TF–297). The general stratigraphic characters of the units above the base of the Wilberns formation are graphically shown on Plate 14.

Although this section is rather fossiliferous at a number of places above the Hickory sandstone member, no effort was made to collect or even to record the fossils seen in the Riley formation (except *Aphelaspis* at the top), and numbers of additional fossils could be obtained from the highly fossiliferous Morgan Creek limestone and Point Peak shale members of the Wilberns formation.

BACKBONE MOUNTAIN AREA, BURNET COUNTY

INTRODUCTORY STATEMENT

Reconnaissance indicated a possibility of obtaining a section extending from the Marble Falls limestone to about midway in the Pedernales dolomite member of the Wilberns formation in a section crossing the highway between Marble Falls and Sudduth. Detailed work revealed faults, collapse structures, and poor outcrops, which precluded accurate measurements and description of the rocks. The only other place in this part of the uplift where a reasonably complete section could be measured was along the western side of Backbone Ridge 10 miles west of Sudduth.

The Backbone Ridge section is a composite section, built up over a distance of 3 miles with numerous lateral shifts, some of which are across faults. This section does not reach the Carboniferous,

and the full thickness of the Ellenburger in Backbone Ridge is thus not known. For convenience in reference to location the composite section has been divided into four sections as follows: (1) Hoover Point section (not described), including rocks from near the top of the Hickory sandstone member of the Riley formation to the *Plectotrophia* bed in the Point Peak shale member of the Wilberns formation; (2) Backbone Mountain section, including rocks from the *Plectotrophia* bed to the fault between the Tanyard and the Gorman formations; (3) Mill Creek section, including rocks from the base of the Gorman formation to 60 feet up in the Honeycut formation; and (4) Roaring Spring section, including rocks from 60 feet up in the Honeycut formation to the highest exposure of the Honeycut formation.

Even with detailed mapping at least one fault was crossed in the Tanyard portion of the section. About 100 feet of beds are cut out and if the one fault found is responsible for their absence, the missing beds belong to the upper part of the Staendebach member of the Tanyard formation. As measurements of the Threadgill member of the Tanyard indicated it to be about 100 feet thinner than elsewhere noted in the Llano uplift, it was at first expected that a fault would be found to cut out Threadgill beds. No such faulting was detected, however, and check measurements of the Threadgill in the "wedge" section (fig. 8) to the north, and in another section measured along the south side of the Backbone Ridge, indicate that it actually is about 100 feet thinner than in other parts of the Llano uplift.

The "wedge" section is located along the western edge of Backbone Ridge, west of Longhorn Cavern and south of Inks Dam and is a wedge-shaped fault block along the Roaring Spring fault zone. The block is sharply tilted to the northeast and exposed in it are all the units of the Upper Cambrian and the Lower Ordovician up to and including most of the calcitic facies of the Gorman formation. For anyone wishing to obtain a quick view of these units, this is probably the most favorably situated section in the uplift. This section is not suited, however, for detailed measurement and description since numerous small faults are present and exposures in places are poor.

A profile, line A-B, on the map of the wedge block (fig. 8) projected to a plane in the direction of dip was made in order to check the thickness of the Tanyard formation. The profile was constructed by hand leveling and pacing along a crooked line of section. The section was made along a cut-out fire-break through otherwise almost impenetrable cedar. Using the thicknesses of the beds between the alate-*Billingsella* bed and the top of the Cambrian, and the thickness of the Gorman formation up to the *Archaeoscyphia* bed as determined in the Mill Creek section, the average dips of these zones for the "wedge" section were obtained. The dip of the upper half of the Wilberns formation averages about 26° and the dip of the lower part of the Gorman formation averages about 24.5°. With these bounding dips the thickness estimated for the Tanyard formation is 525 feet, a figure which is low when compared with 658 feet to the north in the Tanyard-Spicewood Creek sections, 650

Explanation of figure 8, illustration on opposite page.—An area of travertine is indicated by the symbol Qt. All formations, members, and facies of the Ellenburger group of Ordovician age are present and are indicated by symbol as follows: Oh, Honeycut formation; Og(ca), calcitic facies (including *Archaeoscyphia* zone, Oga) and Og(mg), dolomitic facies of the Gorman formation; Ots(ca), calcitic facies and Ots(mg), dolomitic facies of the Staendebach member of the Tanyard formation; Ott(mg), dolomitic facies and Ott(ca), calcitic facies of the Threadgill member of the Tanyard formation. The Cambrian is represented by two formations comprised of 8 members. In the Wilberns formation the members are indicated by symbol as follows: ewp, Pedernales dolomite; ews, San Saba limestone; ewpp, Point Peak shale; ewm, Morgan Creek limestone; and eww, Welge sandstone. In the Riley formation the members are indicated by these symbols: erl, Lion Mountain sandstone; erc, Cap Mountain limestone; and erh, Hickory sandstone. The pre-Cambrian is represented by coarse grained granite, cgr. Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940. Geology by Virgil E. Barnes and Lincoln E. Warren, 1945.

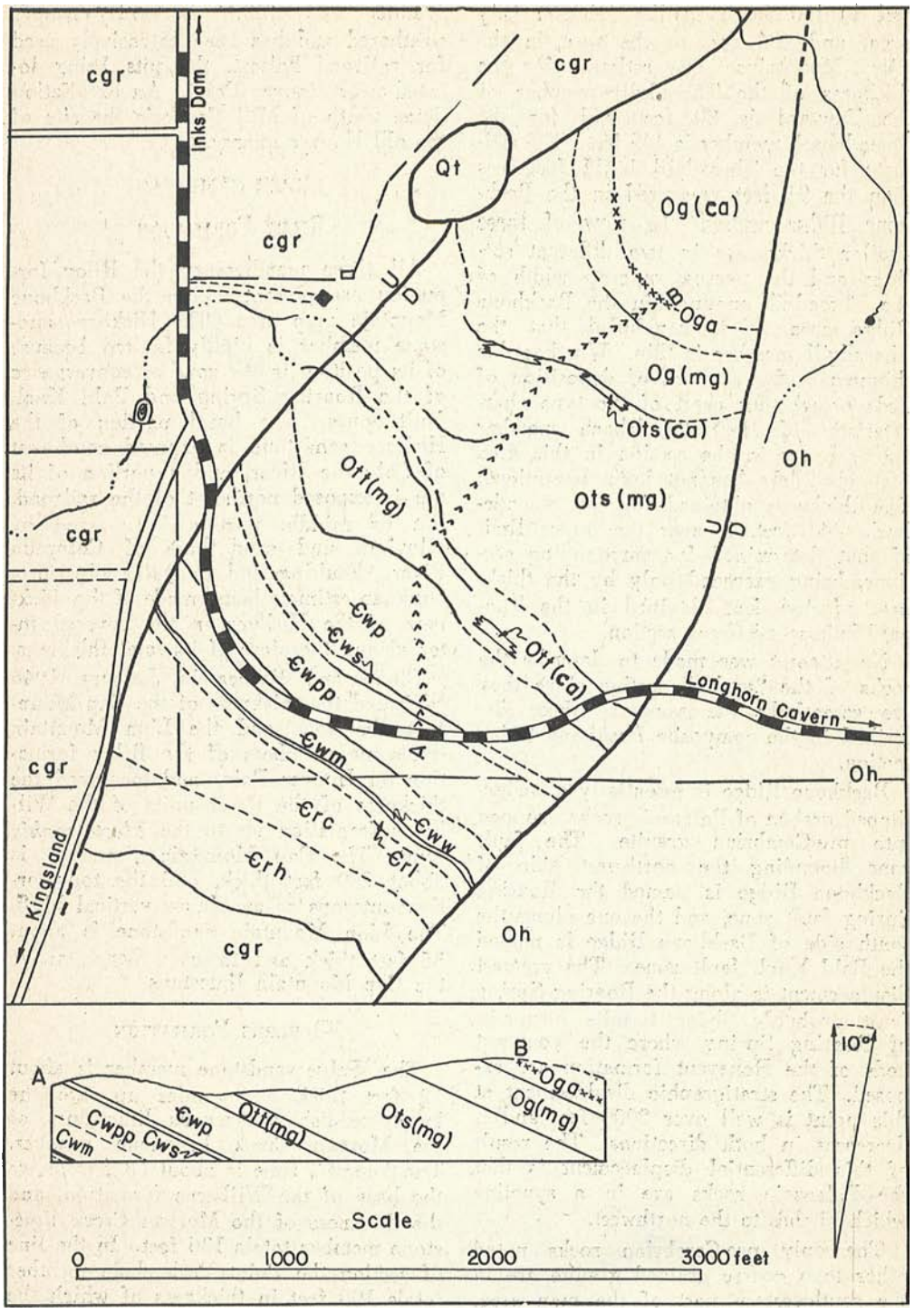

Fig. 8. Geologic map of a fault-wedge 2 miles west of Longhorn Cavern, Burnet County, Texas.

feet to the south in the Johnson City area, and 603 feet to the west in the Riley Mountains. The estimate for the thickness of the Threadgill member of the Tanyard is 80 feet and for the Staendebach member is 445 feet. The estimate for the Threadgill is 11 feet less than the 91 feet measured in the Backbone Ridge section. In view of these similar thicknesses in two different sections and the narrow outcrop width of the Threadgill mapped in the Backbone Ridge area, it is concluded that the Threadgill member is thin. Whether this thinness is due to lack of deposition of beds or whether chert of the type characteristic of the Staendebach member comes lower in the section in this area than elsewhere has not been determined. The thickness obtained for the Staendebach, 445 feet, is near the upper limit of that determined for surrounding sections, being exceeded only by the thickness of 456 feet obtained in the Tanyard-Spicewood Creek section.

No attempt was made to describe the rocks of the "wedge" section since they are essentially the same as those described in the composite Backbone Ridge section.

Backbone Ridge is essentially a wedge-shaped graben of Paleozoic rocks dropped into pre-Cambrian granite. The fault zone bounding the northwest side of Backbone Ridge is named the Roaring Spring fault zone, and the one along the south side of Backbone Ridge is named the Bald Knob fault zone. The greatest displacement is along the Roaring Spring fault probably about 1 mile northeast of Roaring Spring where the youngest beds of the Honeycut formation are exposed. The stratigraphic displacement at this point is well over 2000 feet and it decreases in both directions. The result of this differential displacement is that the Paleozoic rocks are in a syncline which pitches to the northwest.

The only pre-Cambrian rocks noted other than coarse grained granite are in the southwestern part of the map area. They are two small outcrops of Packsaddle schist included in the coarse grained granite and one small outcrop of aplo-granite. The granite is mostly deeply weathered and has been extensively used for railroad ballast, the pits being located near Hoover Point. An exfoliation dome north of Mill Creek is the site of the old Hoover quarry.

UPPER CAMBRIAN

Riley Formation

All three members of the Riley formation are present within the Backbone Mountain map area. The Hickory sandstone member is highly faulted because of its position in the zone of convergence of the Roaring Spring and Bald Knob fault zones. The basal portion of the Hickory sandstone is exposed southwest of Colorado River, and a portion of its top is exposed northeast of the railroad, but its middle portion is covered by alluvium and sand bars of Colorado River. Faulting and irregular dips preclude an estimate being made of the thickness of the Hickory in the covered interval and therefore of its total thickness.

Cloud and Barnes in January 1946 estimated the thickness of the Cap Mountain limestone and the Lion Mountain sandstone members of the Riley formation on Hoover Point and measured the thickness of the lower units of the Wilberns formation up to the *Plectotrophia* zone. The Cap Mountain limestone is about 200 feet thick, and the top portion outcrops as an almost vertical bluff. The Lion Mountain sandstone is about 36 feet thick and forms a bench above the Cap Mountain limestone.

Wilberns Formation

The Welge sandstone member is about 12 feet thick and grades up into the basal reddish arenaceous limestones of the Morgan Creek limestone member. The *Eoorthis* zone is about 68 feet above the base of the Wilberns formation, and the thickness of the Morgan Creek limestone member totals 136 feet. In the line of section the Point Peak shale member totals 190 feet in thickness of which the bottom 89 feet is predominantly shale, the next 85 feet is a stromatolitic bioherm, and the top 16 feet is limestone

and shale. The zone of *Plectotrophia* and alate-*Billingsella* is 3 feet beneath the top of the Point Peak shale member and marks the top of the Hoover Point section. The stromatolitic bioherms in the Point Peak shale are erratically distributed in the upper portion, extending mostly to within 10 or 15 feet of the *Plectotrophia* zone. The inter-bioherm beds are in part limestone where the stromatolites are closely spaced, but are shale elsewhere. Stromatolitic limestone is absent in the Point Peak shale member beneath the Backbone Mountain section.

The San Saba limestone member does not form a continuous outcrop in the Backbone Ridge area, as in several places the Pedernales dolomite member extends down to the top of the Point Peak shale member. In the line of section the San Saba limestone is 48 feet thick with an estimated 20 feet of fluctuation above this, making a total of about 70 feet of limestone and dolomite intergradation in this area. The Pedernales dolomite in the line of section is 224 feet thick. The bottom portion is very fine grained to microgranular, and the upper portion is mostly fine grained with a few beds that are medium grained. In color the Pedernales dolomite is mostly somber, with shades of browns and greenish grays predominating. Chert in the upper part is mostly quartzose to semiporcelaneous and dolomoldic. Collecting is poor in the Pedernales of this area and fossils found in the top interval, as determined on the basis of lithology, could just as well be Ordovician in age.

LOWER ORDOVICIAN

Ellenburger Group

Tanyard formation, Threadgill member.—The Threadgill member of the Tanyard formation is coarse grained, white to light gray dolomite and contrasts strongly with the somber colored Pedernales dolomite beneath. Limestone grades in and out in the outcrop area, but the line of section is entirely in dolomite. A small amount of minutely quartzose to semiporcelaneous, compact, smoky chert is present in the upper portion. The Threadgill is 91 feet thick, which is much thinner than measured in other sections in the Llano uplift.

Tanyard formation, Staendebach member.—The Staendebach member of the Tanyard formation is predominantly dolomite, is medium grained ranging toward fine grained in the lower part, and is medium to coarse grained in the upper portion. About the upper hundred feet of the Staendebach in the Backbone Mountain section is cut out by faulting. The portion missing by faulting could have been measured somewhere between Mill Creek and Bald Knob, but since no marker bed is present on which to shift, no additional information would be obtained about the amount of section cut out by the fault. Small outcrops of limestone in the Staendebach are situated just beneath its top boundary and these grade laterally to dolomite.

Chert is abundant in the Staendebach and is mostly porcelaneous to semiporcelaneous and dolomoldic, with considerable chert that is chalcedonic to subchalcedonic, and a small amount that is granular. The Staendebach, even in the upper usually fossiliferous portion, seems to be almost devoid of fossils in the Backbone Mountain area.

Gorman formation.—The contact between the Gorman formation and the Tanyard formation appears to be sharp, with microgranular dolomite containing fine sand resting either on limestone or the laterally equivalent coarse grained dolomite of the Tanyard. The dolomitic facies of the Gorman is 220 feet thick and is composed mostly of microgranular dolomite with a small amount of fine to medium grained dolomite and a small amount of limestone. A 1-foot bed of limestone is present 7 feet above the base in the line of section, and other small outcrops of limestone have been seen elsewhere in the basal portion of the Gorman formation of Backbone Ridge.

The *Archaeoscyphia* zone of the Gorman formation is 263 feet above the base of the formation and while not well displayed in the line of section is well displayed a short distance on either side. The calcitic facies of the Gorman formation is 263 feet thick and comprises an

upper and lower portion composed predominantly of limestone and a middle portion composed predominantly of microgranular dolomite. On Plate 14 this tripartite division of the calcitic facies is seen to persist throughout the sections of the eastern part of the uplift. In the Cherokee section and westward while some dolomite is still present in the middle of the calcitic facies, it is predominantly limestone. The upper limestone of the Gorman is a very massive pure limestone in this area, as it is in all of the other sections examined at the surface except in the Johnson City area where considerable network dolomite is present.

Longhorn Cavern, a short distance to the northeast of the Backbone Mountain area, is in the upper massive limestone of the Gorman formation. A large cave reported within a few hundred yards southeast of the top of the Mill Creek section is probably in the upper limestone of the Gorman. The cedar in this vicinity is very thick, and the writers did not take time to find and map the cave.

The Gorman formation is not very fossiliferous in this area and only *Rhombella* and *Lecanospira* were noted. *Diaphelasma* was not found.

Honeycut formation.—The contact between the Honeycut formation and the underlying Gorman formation is not as sharp as could be desired. Several feet of limestone-dolomite intergradation appears in the vicinity of the contact, and its mapped position might vary through as much as 15 feet of section. *Xenelasma* normally limits the upward placement of the boundary.

The lower 60 feet of the Honeycut formation is measured in the Mill Creek section and the rest is measured in the Roaring Spring section. Lower beds than are included in the section are present up the drain to the southeast of the bottom of the Roaring Spring section, but erosion has not quite reached the Gorman-Honeycut contact. The Honeycut in the Roaring Spring section is an alternation of limestone and dolomite with dolomite predominating and being mostly microgranular.

The Honeycut formation of the Roaring Spring section is rather fossiliferous even in the dolomitic facies, which normally is almost unfossiliferous. The usual Honeycut fossils are common at many places, and the sponge *Calathium*, unknown to the writers from other localities in central Texas, occurs in interval 29 of the Roaring Spring section.

The top of the Roaring Spring section is 402 feet above the base of the Honeycut formation and includes the highest known beds of Honeycut age in the vicinity. The thickness of the Honeycut strata removed by erosion between the Carboniferous and the present surface is unknown but probably is not far from 100 feet.

DESCRIPTION OF THE BACKBONE RIDGE SECTIONS

The composite Backbone Ridge section is made up of the following four sections: (1) the Roaring Spring section which includes most of the Honeycut formation; (2) the Mill Creek section which includes all of the Gorman formation and the bottom portion of the Honeycut formation; (3) the Backbone Mountain section which includes all of the Tanyard formation not cut out by faulting, and the upper part of the Wilberns formation down to the *Plectotrophia* zone; and (4) the Hoover Point section which includes the part of the Wilberns formation below the *Plectotrophia* zone and nearly all of the Riley formation above the Hickory sandstone member. This last section is not described in detail but is discussed in a very general manner above.

Yellow spots are painted every 5 feet throughout the section and each fifth interval is numbered, that is, number 1 is 25 feet from the base of the section, number 2 is 50 feet from the base of the section, etc. The description and measurements of the section are carried in sequence from the top of the *Plectotrophia* bed of the Wilberns to the top of the Honeycut formation. The thinness of the Tanyard formation in the measured section suggested faulting, and restudy established a fault between the Tanyard formation and the Gorman formation. On

the correlation chart for the Llano uplift (Pl. 14), 100 feet has been allowed for the displacement of the fault but this has not been carried into the figures for the section. Consequently to correspond to the correlation chart, 100 feet should be added to all figures from the base of the Gorman formation to the top of the section.

The section was measured and described by Barnes and L. E. Warren in January 1945, and it was sampled by Leo Hendricks and L. E. Warren in August 1945.

Roaring Spring Section

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Lower Ordovician			
Ellenburger group: 1357 feet measured			
Honeycut formation: 402 feet present			
The top of the Roaring Spring section is located about 3500 feet northeast of B.M. 919 and about 2000 feet east of the Burnet-Kingsland road. For its exact location see Plate 11.			
1. Dolomite—microgranular, beige, beds 3 inches to 1 foot thick.	3	3	1629 –1632
2. Dolomite—microgranular, beige, one bed.	2	5	1627 –1629
Chert subchalcedonic and medium gray, occurring as finger-sized to 1½-inch nodules.			
Shift across fault westward about 300 feet to top of hill and continue down in section in a direction about S. 38° W.			
3. Limestone—sublithographic, ivory, composed of a layer of stromatolites 6 inches to 1 foot in size with dolomite in layers 1 grain thick helping to outline the stromatolitic structure. Laterally a mottled dolomite containing brachiopods occupies some of the space between the stromatolites.	1	6	1626 –1627
Chert cannonballs, highly fossiliferous, are sporadically distributed.			
Silicified fossils collected from this bed east of the fault are *Bathyurellus* sp., *Finkelnburgia* cf. *F. cullisoni*, and a cephalopod siphuncle (27T–9–44B). Another collection from float below interval 5 is probably from this interval. The fossils are *Bolbocephalus* sp. and cf. *Orospira* (27T–9–44C). The fossils collected from the dolomite are not silicified and are *Tarphyceras* and *Finkelnburgia* cf. *F. cullisoni* (27T–9–44F).			
4. Dolomite—microgranular, mottled, nutria and dark gray, essentially one bed.	3	9	1623 –1626
Chert subchalcedonic, medium gray, occurring as 1-inch nodules.			
5. Limestone—sublithographic, beige, two beds.	4	13	1619 –1623
Chert semiporcelaneous, beige, somewhat fossiliferous, occurring as skeletal cannonballs.			
Silicified fossils are *Ceratopea* sp. 5?, *Hormotoma*, and *Ophileta* sp. (27T–9–44A).			
6. Dolomite—microgranular, beige, in beds 1 to 2 feet thick.	6	19	1613 –1619
7. Limestone—sublithographic, old ivory in part mottled dark gray, one bed.	1	20	1612 –1613
8. Dolomite—microgranular, dark beige, porous, bedding joints indistinct, essentially one bed.	7	27	1605 –1612
Chert cannonballs at 1607 feet fairly common.			
9. Dolomite—microgranular, dark gray to nutria, beds about 3 feet thick exposed in a vertical face.	8	35	1597 –1605
Chert porous, dark, dirty brown cannonballs at 1600 and 1605 feet.			
10. Dolomite network with some centers of limestone—mottled medium to dark gray, essentially one bed.	3	38	1594 –1597
Chert semiporcelaneous, medium gray, skeletal cannonballs. Silicified fossils noted are gastropods.			

Description	Thickness in feet: Interval	Cumulative	Feet above base
11. Dolomite—microgranular, beige, bedding joints poorly developed 1 to 3 feet apart, closely spaced (varvelike) bedding visible on weathered surface. A few ½-inch limestone stringers are present at 1563 to 1565 feet. Chert semichalcedonic, medium gray, occurring as flattened nodules at 1563 feet. Chalky textured, dirty white chert nodules from ½ to 1 inch in size at 1584 to 1586 feet.	31	69	1563 –1594
12. Dolomite—mostly covered but where seen similar to the dolomite above and below.	6	75	1557 –1563
13. Dolomite—microgranular, beige, bedding joints poorly developed, closely spaced (varvelike) bedding visible on weathered surfaces. Chert present but very scarce.	11	86	1546 –1557
14. Dolomite and limestone—rounded masses of sublithographic, old ivory limestone, surrounded by microgranular, beige dolomite, essentially one bed.	3	89	1543 –1546
15. Dolomite—microgranular, beige to medium gray, bedding indistinct. Chert subchalcedonic to subporcelaneous, white to medium gray or bluish gray.	7	96	1536 –1543
16. Limestone with abundant network dolomite—beige, one bed. Chert chalky textured, dirty white, abundant as finger-sized pieces.	2	98	1534 –1536
17. Dolomite—microgranular, beige, bedding joints indistinct. Chert subchalcedonic to semiporcelaneous, medium gray to beige, occurring as a few flattened nodules.	6	104	1528 –1534
18. Limestone—sublithographic, old ivory to beige, one bed. Silicified fossils are poorly preserved ceratopeas seen 50 feet to the east. A collection obtained about 1000 feet to the east is about from this horizon and contains trilobite gen.?, *Jeffersonia* spp., *Bolbocephalus* sp., *Ceratopea* sp., *Archaeoscyphia* sp., cf. *Orospira*, and *Finkelnburgia* cf. *F. cullisoni* (27T–9–44D).	2	106	1526 –1528
19. Dolomite—microgranular, mottled beige and dark gray, essentially one bed.	3	109	1523 –1526
20. Limestone with abundant network dolomite—one bed. Chert grayish brown, compact cannonballs with fossil impressions on their exteriors. Calcite fossils are common in the limestone. A *Tarphyceras* collected about 700 feet to the southeast is probably from near this horizon (27T–9–45C).	2	111	1521 –1523
21. Dolomite—microgranular, light gray to beige, bedding joints very indistinct, closely spaced (varvelike) bedding visible. Chert subchalcedonic to semiporcelaneous, white to light gray, occurring as a few flat nodules.	10	121	1511 –1521
22. Limestone—sublithographic, old ivory to beige, poorly developed bedding joints, essentially one bed. Chert semiporcelaneous, beige to medium gray to brown, occurring as a myriad of small finger-sized nodules and a few 1- to 2-inch thick plates.	4	125	1507 –1511
23. Dolomite—microgranular, beige to dark gray, beds 1 to 2 feet thick. Chert chalcedonic, light gray to brownish gray, occurring as flattened nodules or thick plates up to 3 inches thick and a foot or more long.	10	135	1497 –1507
24. Limestone—sublithographic, old ivory, essentially one bed with bedding joints poorly developed. Chert semiporcelaneous, brown, compact, fossiliferous. Silicified fossils are poorly preserved ceratopeas in the limestone.	2	137	1495 –1497

Description	Thickness in feet: Interval	Cumulative	Feet above base
25. Dolomite—microgranular, mottled medium gray and brownish gray. Bedding joints are short and at different levels, being absent in some exposures. Bedding is indicated by raised ridges ¼ inch and more apart. This interval becomes somewhat calcareous toward top. Chert chalky textured, white to brown, occurring as a few ½- to 1-inch nodules in lower part. Fossils are cross sections of low-spired gastropods on bedding surfaces.	5	142	1490 –1495
26. Limestone—sublithographic, old ivory, one bed. *Hormotoma* is abundant in calcite preservation on parts of the top surface. Silicified fossils obtained from near this interval are *Ceratopea* sp. 5, *Mcqueenoceras* siphuncle, *Ophileta?*, *Jeffersonia* sp., *Orospira* sp., and *Hormotoma* sp. (27T–9–45B) and *Ceratopea* sp. 5 (27T–9–45D).	2	144	1488 –1490
Shift across fault through ravine and along west side of hill south-southwest for a distance of about 2200 feet. This shift was made chiefly on an oölitic chert in combination with a laminated zone of limestone. This shift is unsatisfactory in that the oölite is discontinuous and the beds change back and forth from limestone to dolomite. In addition the laminated limestone decreases in thickness from north to south and it is difficult to know whether this takes place at the top or bottom or possibly both. Oölitic chert of this type has not been seen either above or below the zone traced and it may well hold one narrow horizon.			
27. Limestone—sublithographic, dark gray, very thinly laminated, poorly exposed in upper part, forms a bench. Chert subchalcedonic to chalcedonic, medium to dark gray, highly oölitic with oöids weathering in relief. The chert bed is about 3 inches thick and is fairly persistent laterally.	4	148	1484 –1488
28. Dolomite—microgranular, brownish gray to medium gray and nutria, in beds 2 inches to 1 foot thick. Quartz nodules in lower 3 feet, fairly common.	12	160	1472 –1484
29. Limestone—sublithographic, medium gray, one bed. Chert subchalcedonic and medium gray, in large cannonballs which range from skeletal to compact. Silicified fossils are *Ceratopea* sp. and *Orospira* sp. noted and *Calathium* sp. and *Jeffersonia* sp. collected from this bed ¼ mile to the northeast (27T–9–45K).	4	164	1468 –1472
30. Dolomite—microgranular, nutria, one bed. Chert subchalcedonic, medium gray, as elongated nodules up to 2 or 3 inches thick.	1	165	1467 –1468
31. Dolomite—microgranular, nutria, mottled, beds 6 inches to 2 feet thick.	4	169	1463 –1467
32. Dolomite—microgranular, brownish gray to medium gray, beds 6 inches to 1 foot thick	3	172	1460 –1463
33. Dolomite—microgranular, nutria, mottled, beds 6 inches to 2 feet thick. Quartz nodules fairly common.	5	177	1455 –1460
34. Limestone—sublithographic, dark gray, mottled with network of dolomite. Quartz has replaced a portion of the dolomite network producing branching and anastomosing structures wherein the branches are about ¼ inch in diameter. Fossils are silicified cephalopod siphuncles, and many calcite fossils on bedding surfaces.	2	179	1453 –1455
35. Dolomite—microgranular to fine grained, mottled, lower part nutria and dark gray and upper part medium and dark gray, beds 1 to 2 feet thick. A network present on weathered surfaces has the appearance of burrows.	8	187	1445 –1453

	Description	Thickness in feet: Interval	Cumulative	Feet above base	
36.	Dolomite—microgranular, brownish gray to medium gray, beds 6 inches to 2 feet thick. Quartz nodules in bottom half fairly common.	3	190	1442	–1445
37.	Limestone—sublithographic, dark gray, one bed. Chert subchalcedonic to semiporcelaneous, medium gray, as somewhat porous or vuggy cannonballs.	1	191	1441	–1442
38.	Dolomite—microgranular, brownish gray to medium gray, beds 6 inches to 2 feet thick.	6	197	1435	–1441
39.	Dolomite—microgranular, nutria, mottled, beds about 2 feet thick. Quartz nodules are abundant.	7	204	1428	–1435
40.	Limestone—sublithographic, dark gray, one bed. Chert chalcedonic, medium gray, occurring as nodules and plates. Silicified fossils are cephalopod siphuncles, *Ceratopea* sp. 4, *Ceratopea robusta* Oder (young ones look like *C. capuliformis*), *Raphistomina* or *Ophileta,* and *Archaeoscyphia annulata* Cullison (27T–9–45E).	3	207	1425	–1428
Offset 130 feet southeast along bed, 50 feet N. 60° W. along fault, and 100 feet east along same bed and continue section down hill to the south.					
41.	Dolomite—microgranular, nutria, with top 5 feet medium gray with a pinkish tone, beds 4 inches to 1 foot thick, in part weathers with a slightly pitted surface. Chert chalcedonic, dark gray, as elongated nodules is scattered throughout interval. Some brown, flattened cannonballs are located at 1417 feet.	11	218	1414	–1425
42.	Limestone—sublithographic, dark gray, with considerable network dolomite and isolated dolomite rhombs. Chert cannonballs and quartz nodules are common. Silicified fossils are cephalopod siphuncles.	1	219	1413	–1414
43.	Dolomite—microgranular, nutria, beds 1 to 12 inches thick. Chert chalcedonic, medium gray, as a few scattered nodules.	7	226	1406	–1413
44.	Limestone—sublithographic, dark gray, one bed which grades laterally in both directions to dolomite. Chert chalcedonic and in part quartzose. Silicified fossils are cephalopod siphuncles.	1	227	1405	–1406
45.	Dolomite—microgranular, nutria, beds about 1 foot thick. Chert light brown, compact, elliptical cannonballs and chalcedonic, medium to dark gray plates and nodules are common. In top 2 feet of interval elongated nodules of quartz ¼ to ½ inch in diameter are abundant.	6	233	1399	–1405
46.	Limestone—dark gray, granular from presence of dolomite rhombs and some network dolomite, one bed. Fossils are calcitic gastropods on bedding surfaces.	2	235	1397	–1399
47.	Dolomite—microgranular to fine grained, mottled dark gray and nutria, beds about 1 foot thick.	5	240	1392	–1397
48.	Dolomite—microgranular, nutria, beds 4 inches to 1 foot thick. Chert chalcedonic to subchalcedonic, medium gray to brownish and reddish, as nodules and plates in lower part and as a layer at 1391 feet. Small quartz nodules are common from 1390 to 1391 feet.	7	247	1385	–1392
49.	Limestone—sublithographic, dark gray, one bed.	1	248	1384	–1385
50.	Dolomite—microgranular, nutria, not well exposed.	2	250	1382	–1384
51.	Limestone—sublithographic, medium gray, beds 1 to 2 feet thick. Chert cannonballs in top portion are semiporcelaneous, medium gray and up to 6 inches in diameter. Chert layer 1381 feet chalcedonic, medium gray, up to 2 inches thick.	8	258	1374	–1382

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
	Silicified cephalopod siphuncles are common in the lower part of interval. *Ceratopea* cf. *C. capuliformis* Oder and *Hormotoma* sp. at 1381 feet (27T–9–45J). A collection from the hill to the south containing *Hormotoma* sp., undetermined gastropod, *Ceratopea* cf. *C. capuliformis* Oder, *Jeffersonia* sp., and a siphuncle cf. *Mcqueenoceras* may be from this bed (27T–9–45G).			
52.	Dolomite—microgranular, brownish gray in beds 4 to 8 inches thick.	2	260	1372 –1374
	Chert chalky textured, white, occurs as small flat nodules.			
53.	Limestone—sublithographic, dark gray with strong network of dolomite.	6	266	1366 –1372
	Chert at 1366 to 1369 feet semiporcelaneous, medium gray, occurs as skeletal cannonballs to long skeletal layers along bedding. Quartz nodules ½ inch in diameter are in top portion of interval.			
	Silicified *Archaeoscyphia* and calcitic gastropods common.			
54.	Dolomite—fine grained to microgranular, mottled dark gray and nutria.	1	267	1365 –1366
	Chert chalcedonic to semiporcelaneous, medium gray to brown occurring as nodules and plates 2 inches thick.			
55.	Dolomite—of network type with small amount of limestone, nutria, beds approximately 1 foot thick.	3	270	1362 –1365
	Quartz as nodules and elongated pieces ½ inch in diameter is common.			
56.	Limestone—sublithographic, dark gray, with heavy network of dolomite, essentially one bed.	5	275	1357 –1362
57.	Dolomite—top 2 feet medium grained, dark gray, one bed. Bottom foot microgranular, brownish gray, one bed. The dolomite grades laterally to limestone.	3	278	1354 –1357
	Chert semiporcelaneous to subchalcedonic, medium gray, occurs on top surface as skeletal cannonballs.			
	Fossils are *Ceratopea* cf. *C. capuliformis* Oder, *Hormotoma* sp., and *Jeffersonia* sp. in both chert and limestone (27T–9–45I). Collection 27T–9–45H from same bed on hill to south contains *Archaeoscyphia* sp., *Hormotoma* spp., *Jeffersonia producta* Cullison, "*Ophileta*," *Ceratopea capuliformis* Oder, *Xenelasma syntrophioides* Ulrich & Cooper, and siphuncle of *Mcqueenoceras*.			
58.	Limestone—sublithographic, medium gray, one bed.	2	280	1352 –1354
	Chert chalcedonic to subchalcedonic, medium gray, occurring as ¼-inch pellets and in larger irregular, ramifying, skeletal groups.			
59.	Limestone—sublithographic, light to medium gray, bedding joints 1 to 2 inches apart, bedding laminae closely spaced.	7	287	1345 –1352
60.	Limestone—sublithographic, light to medium gray, beds 6 inches to 3 feet thick.	10	297	1335 –1345
	Chert chalcedonic to subchalcedonic, medium gray to brown, common as nodules and plates about 2 inches thick.			
61.	Dolomite—microgranular to very fine grained, dark gray, beds 6 inches to 2 feet thick, in part weathers saccharoidal.	6	303	1329 –1335
	Chert chalcedonic to subchalcedonic, medium gray to brown, common as nodules and plates about 2 inches thick.			
62.	Limestone—sublithographic, light to medium gray, bedding indistinct and appears to be massively bedded.	10	313	1319 –1329
	Chert extremely abundant as porous, medium gray masses several feet in size and containing molds of fossils and pebbles. In part layered horizontally, in part dipping steeply, and in part vertically, suggesting conformation to stromatolites. The chert is very irregularly distributed			

	Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
	throughout interval. Some chalcedonic to semiporcelaneous light to medium gray chert ellipsoids and plates are at 1323 feet. Fossils are mostly small and poorly preserved. A collection from this interval 250 feet to the west contains gastropod fragments (27T–9–45A).			
63.	Dolomite—microgranular, light brown to nutria, beds about 6 inches thick. Chert chalcedonic, white to medium gray, somewhat banded, occurs as almost continuous layer at the bottom of the interval. Quartz nodules are sparsely distributed in the bottom 2 feet.	4	317	1315 –1319
64.	Limestone—sublithographic, medium gray, one bed.	1	318	1314 –1315
65.	Dolomite—microgranular, light brown to nutria.	1	319	1313 –1314
66.	Limestone—sublithographic, old ivory, with one bedding joint in middle, and bedding laminations spaced 10 or more to the inch. Chert chalcedonic, white to medium gray, somewhat banded, occurring as a 1- to 2-inch almost continuous layer in middle of interval.	2	321	1311 –1313
67.	Dolomite—microgranular, light brown to nutria, beds about 6 inches thick.	8	329	1303 –1311
68.	Limestone—sublithographic, brownish gray, with 1- to 6-inch spacing between bedding joints, minutely laminated so that it splits into paper thin sheets upon being struck.	5	334	1298 –1303
69.	Dolomite—microgranular, yellowish brown, essentially one bed.	2	336	1296 –1298
70.	Limestone—sublithographic, old ivory, one bed. Chert semiporcelaneous to subchalcedonic, medium gray, fossiliferous, occurring as rounded cannonballs to irregular masses. Fossils preserved as calcite abundant.	1	337	1295 –1296
71.	Limestone and dolomite—sublithographic, light gray limestone minutely interbedded with dark gray dolomite.	1	338	1294 –1295
72.	Limestone—sublithographic, light gray, heavily reticulated with nutria dolomite, bedding joints about 6 inches apart. Chert semiporcelaneous, medium gray, fossiliferous, occurring as skeletal cannonballs in top bed.	2	340	1292 –1294
73.	Dolomite—microgranular, brownish gray to nutria, bedding joints about 6 inches apart. Chert semiporcelaneous, light brown occurring as semi-cannonballs containing some small gastropods and located at about 1290 feet. The next bed beneath contains quartz nodules.	3.5	343.5	1288.5–1292
	Go south-southwest about 4800 feet to top of hill at fence and resume section at top of quartz-nodule bed and continue section along fence to the south-southwest.			
	MILL CREEK SECTION			
74.	Dolomite—microgranular, dark gray to light brown and somewhat streaked or mottled, bedding joints about 6 inches or less apart. Quartz in round to flattened nodules abundant. This bed is the key to the shift mentioned above.	1.5	345	1287 –1288.5
75.	Dolomite—fine to medium grained, mottled medium gray and nutria, one bed. Across fence to east the bed changes to limestone. Chert subchalcedonic, clouded, medium gray, occurring as crooked, occasionally branching masses, 2 feet or more long, mostly about 2 inches in diameter. *Xenelasma* (?) noted about 200 feet to the east.	2	347	1285 –1287

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
76. Dolomite—microgranular, somewhat mottled or streaked dark gray to light brown, bedding joints about 6 inches apart.	4	351	1281 –1285
77. Limestone—sublithographic, old ivory, bedding planes 6 inches to 2 feet apart. Chert semiporcelaneous with quartzose areas, composing skeletal cannonballs up to 8 inches in diameter is common. Some chalcedonic chert nodules in this zone to the east have *Archaeoscyphia* structure.	9	360	1272 –1281
78. Dolomite—microgranular, dark gray to light brown and somewhat mottled and streaked, bedding joints 6 inches or less apart. Quartz nodules irregular in shape are located at 1264 and 1272 feet.	13	373	1259 –1272
79. Limestone—sublithographic, ivory, one bed. Chert semiporcelaneous with quartzose areas, light grayish brown occurring as skeletal cannonballs.	4	377	1255 –1259
80. Dolomite—fine grained, bedding closely spaced, rock splits into 1-inch slabs. Chert chalcedonic, medium gray to light brown, mostly as elliptical nodules up to 2 inches thick.	1	378	1254 –1255
81. Dolomite—microgranular, beige, with bedding joints about 2 to 6 inches apart.	7	385	1247 –1254
82. Limestone—sublithographic, ivory, one bed. A few hundred feet to the west this bed grades to dolomite. Chert semiporcelaneous, light grayish brown, cannonballs with vuggy quartz interiors. Some disseminated silica is also present. Fossils are *Xenelasma syntrophioides* and *Hormotoma* in cannonballs and in top surface of limestone (27T–9–46C).	2	387	1254 –1247
83. Limestone and dolomite—the limestone has a strong dolomite network which appears to be burrows. The top 6 inches is mottled medium gray and nutria dolomite. Sand is in the top 6 inches of the interval. Cross sections of a widely phaneromphalus gastropod suggesting *Euconia* (strict sense) and *Rhombella* were seen.	2	389	1243 –1245
84. Dolomite—microgranular to fine grained, nutria, bedding joints 6 to 12 inches apart. Sand is abundant in bottom 6 inches of interval.	4	393	1239 –1243
85. Limestone and dolomite—a network transition from limestone to dolomite.	2	395	1237 –1239
86. Limestone—sublithographic, ivory, thickly bedded.	5	400	1232 –1237
87. Dolomite—fine to medium grained, medium gray, one bed. Sand in bottom 2 inches of interval.	2	402	1230 –1232
Gorman formation: 483 feet thick			
Calcitic facies: 263 feet thick			
88. Limestone—sublithographic, ivory, bed 3 to 4 feet thick. The top foot changes to dolomite laterally. Chert chalcedonic to subchalcedonic in part oölitic, medium gray to light brown, occurring as 2- to 3-inch plates along bedding from 1216 to 1221 feet. Sand disseminated in top foot.	21	423	1209 –1230
89. Limestone and dolomite—this zone is mostly covered, but along the strike it appears to alternate between limestone and dolomite with bedding joints 2 to 3 inches apart. The dolomite is fine grained and weathers brown and saccharoidal.	2	425	1207 –1209
Shift on chert in top of interval described below about 300 feet northwest and continue section down hill to the southwest.			
90. Limestone—sublithographic, ivory, with cream colored shallow stylolite markings, beds up to 3 or 4 feet thick alternating with zones composed of beds 1 to 2 inches thick.	29	454	1178 –1207

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base	
	Chert chalcedonic, forms a layer at 1184 feet. Beekite nodules ¼ inch in size are common from 1190 feet to the top of the interval. A chert up to 3 inches thick located at the top of the interval is subchalcedonic to semiporcelaneous, dirty white to brown and fossiliferous. Silicified fossils not well preserved are *Rhombella* and *Lecanospira* in top chert. Calcitic fossils were seen on bedding planes throughout interval.				
91.	Dolomite—microgranular, with a small amount verging on fine grained, predominantly light pinks and beige with some that is brownish gray. The color intensity varies giving a mottled or variegated appearance. Bedding joints 2 to 18 inches apart. Chert at 1143 to 1160 feet subchalcedonic to semiporcelaneous, mostly light to medium gray, occurring mostly as 1- to 2-inch irregular to elongate nodules, common. Some of the chert contains subangular fragments which may in part be oöids.	35	489	1143	–1178
92.	Limestone—sublithographic, old ivory with purple marks, beds 1½ feet thick, some network dolomite present. Fossils are calcite preservation and are present in bedding surfaces.	3	492	1140	–1143
93.	Dolomite—microgranular, nutria and in part with purplish mottlings in bottom portion, and light brown with mottlings in upper part. Chert small amount at top of interval.	15	507	1125	–1140
94.	Limestone—sublithographic, ivory, beds 3 to 12 inches thick. In both directions the limestone grades to dolomite. Chert chalcedonic, grayish to brownish and reddish, in masses up to 3 inches thick and several feet long.	4	511	1121	–1125
95.	Dolomite—microgranular, pinkish, beds indistinct but 1 foot or more thick.	6	517	1115	–1121
96.	Limestone—sublithographic, old ivory and some light pink, beds 6 to 12 inches thick. Bottom 2 feet has a network of beige dolomite in it. Chert at 1112 feet chalcedonic, varying from medium gray to a clear brownish red, occurring as masses up to a foot in size. The same kind of chert in smaller masses and layers extends from 1112 to 1115 feet,	11	528	1104	–1115
97.	Dolomite—microgranular, medium gray to nutria with some brown mottles and a few beds which are pinkish gray, beds range from 2 inches to 2 feet thick. Chert common throughout interval with that in the bottom 10 feet mostly subchalcedonic, medium gray in part red streaked or mottled, occurring as elongated nodules. The chert in the upper portion is more nearly porcelaneous, in large part dolomoldic, weathers chalky and white and occurs as irregular layers and masses some of which are fragmented. The top 6 feet of beds are nearly chert free.	40	568	1064	–1104
98.	Dolomite—medium grained, light gray, beds average about 6 inches thick. Chert subchalcedonic to semiporcelaneous, brown to dirty white, occurring as poorly defined nodules and layers.	4	572	1060	–1064
99.	Limestone—sublithographic, ivory with shallow yellow stylolites, thickly bedded. Chert in bottom foot chalcedonic to semiporcelaneous, white to medium gray, layered, occurring as long irregular nodular masses up to 3 inches thick.	6	578	1054	–1060
100.	Limestone—sublithographic, ivory with shallow yellow stylolites, beds essentially 2 to 5 feet thick with a 4-foot bed and a 3-foot bed at top separated by a thin zone of 1-inch bedded limestone. Chert very rare.	20	598	1034	–1054

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
101.	Limestone—sublithographic, ivory, bedding marks numerous (several to the inch), bedding joints ranging from a fraction of an inch to 6 inches apart. Chert porcelaneous, old ivory, occurs as ½-inch nodules and plates. Similar chert interspersed with limestone extends a few inches into the overlying interval.	4	602	1030 –1034
102.	Limestone—sublithographic, ivory with shallow yellow stylolites, thickly bedded. Chert microgranular, old ivory to brownish (resembling closely some of the microgranular dolomites), weathers chalky and white, occurs as a fairly continuous 2- to 3-inch layer at 1015 feet.	18	620	1012 –1030
103.	Limestone—sublithographic, beige to ivory, one bed. Chert chalcedonic occurring as nodules, especially well developed 50 feet west of line of section and containing in part *Archaeoscyphia* structure. In top of interval is a layer of flattened ellipsoids of chalcedonic chert showing some concentric structure. Fossils are *Archaeoscyphia* the structure of which can be seen on broken surfaces of the chert nodules. This is the zone of the Gorman *Archaeoscyphia* which is shown on the map (Pl. 11).	3	623	1009 –1012
104.	Limestone—sublithographic, beige to ivory, beds 3 to 18 inches thick.	4	627	1005 –1009
105.	Limestone—sublithographic, beige to ivory. Chert chalcedonic, mottled dirty gray, and composed of subangular to rounded fragments with small vugs lined by quartz films, occurring as masses 1 foot in diameter. This chert has much the appearance of cannonball chert but is not quite typical of it.	3	630	1002 –1005
106.	Limestone—sublithographic, stained yellows and browns from weathering, beds ⅛ to ¼ inch thick, cusped as if ripple marked.	1	631	1001 –1002
107.	Limestone—sublithographic, beige to ivory and in part pinkish, with shallow stylolites predominantly yellow with some that are brown and red, beds 6 inches to 5 feet thick.	27	658	974 –1001
108.	Limestone—sublithographic, pinkish gray. Chert chalcedonic, layered, white to medium gray, occurs as an almost continuous layer. Sand in bottom of interval is in part in chert.	1	659	973 – 974
109.	Limestone—not exposed in section but where seen elsewhere is in thin 1- to 2-inch beds.	2	661	971 – 973
110.	Limestone and dolomite—sublithographic, ivory limestone with a network of beige dolomite which weathers a light red, beds 2 feet or more thick. *Dolomitic facies: 220 feet thick*	4	665	967 – 971
111.	Dolomite—microgranular, with a wide range of colors and mottlings from light to dark gray and beige to pink with mottles and streaks of reds and purples, one bed 5 feet thick and rest about 6 inches thick. Chert in bottom foot chalcedonic, red to light gray.	8	673	959 – 967
112.	Dolomite—coarse grained, medium gray, weathers in one long slope as if it is one bed.	7	680	952 – 959
113.	Dolomite—microgranular, with a wide range of colors and mottlings as in interval 111, beds 4 to 18 inches thick. From 945 to 948 feet covered but probably microgranular dolomite.	10	690	942 – 952
114.	Limestone—sublithographic, dark ivory, beds 1 foot or more thick.	3	693	939 – 942
115.	Limestone with dolomite rhombs—light ivory to pinkish, very thinly bedded.	1	694	938 – 939

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
	Chert chalcedonic, light to dark gray, in part oölitic, in part containing small pebbles, and in part layered, occurring as a bed 2 inches thick at the base of the interval.			
116.	Limestone—sublithographic, light ivory with red streaks, one bed.	1	695	937 – 938
117.	Dolomite—microgranular, with a wide range of colors and mottlings as in interval 111. Chert in bottom 2 feet interstitial to dolomite rhombs. Some thin excrescences of quartzose material are also present.	19	714	918 – 937
118.	Dolomite—fine to medium grained, pinkish gray, beds 1 foot thick. Sand is disseminated in bottom of interval.	2	716	916 – 918
119.	Dolomite—microgranular, with a wide range of colors and mottlings as in interval 111. Chert at 890 to 894 feet chalcedonic to subchalcedonic, reddish brown to medium gray, concentrically banded, common as nodules and thin plates. Chert at 912 to 916 feet similar in character and abundant as elongated nodules.	33	749	883 – 916
120.	Dolomite—microgranular, beige to deep pink, thickly bedded.	5	754	878 – 883
121.	Dolomite—microgranular, with a wide range of colors and mottlings as in interval 111. Chert semiporcelaneous to subchalcedonic, dolomoldic, medium gray with red streaks, rare.	17	771	861 – 878
122.	Dolomite—medium grained, light to medium brown, in part suffused with pink, essentially one bed. Chert at base forms a fairly continuous zone and is semiporcelaneous to subchalcedonic, dolomoldic, medium gray with red streaks, occurs as disseminated ½-inch pieces and larger fractured masses.	1	772	860 – 861
123.	Dolomite—microgranular with some fine grained; wide range of colors and mottlings from light to dark gray and biege, to pink with mottles and streaks of reds and purples; beds 6 inches to 2 feet thick. Chert in bottom 2 feet semiporcelaneous, mostly with concentric banding, medium gray with some red, weathers to a white chalky texture at surface, occurs as nodules and plates and is less common in rest of interval. Sand as a few grains along a bedding plane seen on Mill Creek at 847 feet, and between Mill Creek and section, but not in section.	19	791	841 – 860
	Shift east-southeast 1800 feet across a fault to Mill Creek using a combination of sands and cherts to establish the shift and continue section downstream along western bank.			
124.	Dolomite—microgranular with some fine grained at top, pinkish, gray mottled purple and red, beds 6 to 12 inches thick, with a 10-inch zone near middle with beds 1 to 2 inches thick. Chert at bottom quartzose to semiporcelaneous, dirty white, weathering rough and chalky textured, occurring as fragmented masses up to 1 foot thick and 4 feet long. Sand at top occurs in a 3-inch zone.	6	797	835 – 841
125.	Dolomite—microgranular, beige to chalky white, one 5-foot bed at bottom of interval and beds 18 inches or more thick in rest of interval. Chert top 3 feet chalky textured probably from weathering, occurring as thin plates.	12	809	823 – 835
126.	Dolomite—microgranular, flesh to a darker pink, two beds. Chert chalky textured probably from weathering, occurs as long ¼-inch thick plates in lower part of interval and as long ½-inch thick plates in upper part of interval.	5	814	818 – 823

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
127.	Dolomite—microgranular, much of it a uniform light beige, and some is pink with purplish and reddish mottles, bedding joints very poorly developed. Chert at 811 feet subchalcedonic to chalcedonic, weathers chalky, pinkish gray, occurs as a layer of plates.	8	822	810 – 818
128.	Dolomite—microgranular, pinkish and mottled purplish and reddish, beds up to several feet thick, sphenoidally jointed. Chert subchalcedonic to chalcedonic, weathers to a chalky texture, pinkish gray, scarce. Sand at top disseminated in a 2-inch band with some sand grains as much as 1 foot below.	10	832	800 – 810
129.	Dolomite—medium grained, light gray, beds 6 to 12 inches thick.	4	836	796 – 800
130.	Dolomite—microgranular, pink and in part mottled purplish and reddish, beds up to 3 feet thick. Chert subchalcedonic to chalcedonic, weathers chalky, pinkish, gray, concentrically banded, occurs as nodules and plates 1 inch thick. Sand at 791 and 792 feet occurs in beds ranging from 1 to 3 inches thick.	12	848	784 – 796
131.	Dolomite—medium grained, pinkish gray, one bed.	2	850	782 – 784
132.	Dolomite—fine grained, purple and red mottled. Chert at top semiporcelaneous, flesh colored weathering to limonite brown, occurring as nodules up to 1 inch in size. Sand is disseminated in the bottom inch.	1	851	781 – 782
133.	Dolomite—microgranular to fine grained, pinkish gray and in part purplish mottled, beds about 2 feet thick.	11	862	770 – 781
134.	Dolomite—medium grained, light purplish gray to beige, beds 6 to 12 inches thick. Chert near top chalcedonic to semiporcelaneous, in part micro-oölitic, dirty white to pinkish, weathers to limonite brown and dull jasper red, occurs as fairly continuous irregular layer up to 6 inches thick.	7	869	763 – 770
135.	Dolomite—microgranular to fine grained, pinkish gray mottled by purples and reds.	8	877	755 – 763
136.	Limestone—sublithographic, ivory with red streaks and network, a single bed. Chert chalcedonic to subchalcedonic, weathers chalky, dull red to medium gray, occurs as nodules and ropy nodular groups.	1	878	754 – 755
137.	Dolomite—fine to medium grained, pinkish gray with purple lines and splotches, beds approximately 6 inches thick. Chert chalcedonic to subchalcedonic, weathers chalky, dull red to medium gray, occurs as nodules and ropy nodular groups.	6.5	884.5	747.5– 754
138.	Dolomite—microgranular, pinkish gray with purple lines. Sand grains of small size are scattered throughout. This is the basal bed of the Gorman formation. It rests at this point on limestone at the top of the Staendebach member of the Tanyard formation which a few hundred feet laterally grades to coarse grained dolomite.	0.5	885	747 – 747.5

Shift about 2200 feet to the west-southwest to a point south of the crest of a hill where the Gorman formation and the Tanyard formation are probably in fault contact. Continue section down the hill to the southwest. At the time the section was measured the fault was not recognized, so the measurement for the Tanyard is short probably about 100 feet.

Backbone Mountain Section

Tanyard formation: 472 feet measured below fault
Staendebach member: 381 feet measured below fault and all in dolomite facies

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
139.	Dolomite—coarse grained pinkish gray to purplish red, massively bedded with 1 foot or more between bedding joints. In part weathers with cavernous surface and is vuggy within. Chert chalcedonic to subchalcedonic, in part highly oölitic, weathers red, occurs as nodules and masses of various shapes, very abundant.	25	910	722 – 747
140.	Dolomite—coarse grained, and the same as in interval 139.	19	929	703 – 722
141.	Dolomite—coarse grained, and the same as in interval 139. Chert semiporcelaneous, oölitic, common as nodular plates.	3	932	700 – 703
142.	Dolomite—coarse grained, and the same as in interval 139.	17	949	683 – 700
143.	Dolomite—coarse grained as in interval 139, with some medium grained. Chert quartzose and in part porcelaneous, large dolomolds are present, in part oölitic, common in masses of angular fractured fragments occupying areas 6 inches by several feet in size. Silicified fossils from float are probably from this interval and are brevicone cephalopods (27T–9–46E).	28	977	655 – 683
144.	Dolomite—medium grained, medium gray to pinkish gray, beds 6 to 18 inches thick. Chert porcelaneous, nodules up to 3 inches in size, widely scattered throughout interval.	30	1007	625 – 655
145.	Dolomite—medium grained, brownish gray. Chert subchalcedonic, somewhat oölitic, occurring as irregular clusters of small pieces.	1	1008	624 – 625
146.	Dolomite—medium grained, medium gray with a pinkish tint, beds poorly defined 6 to 18 inches thick. Chert porcelaneous and very rare.	32	1040	592 – 624
147.	Dolomite—medium grained, medium gray to beige, two beds. Chert porcelaneous and quartzose in fragmented masses.	2	1042	590 – 592
148.	Dolomite—medium grained, brownish gray.	7	1049	583 – 590
149.	Dolomite—medium grained, beige to medium gray with some brownish gray. Chert porcelaneous to subchalcedonic, occurring as nodules up to 2 inches in size.	15	1064	568 – 583
150.	Dolomite—medium grained, beige to medium gray, beds 2 feet or more thick. Chert porcelaneous, dolomoldic with wide variation from almost interstitial to nearly compact, occurs as masses up to 2 feet thick.	9	1073	559 – 568
151.	Dolomite—medium grained, medium gray to beige with bedding faintly visible between bedding joints. Chert porcelaneous to subchalcedonic; a small amount which is quartzose occurs as thin plates along the bedding.	17	1090	542 – 559
152.	Dolomite—medium grained with some approaching coarse grained, medium gray, in part brownish and pinkish tinted, bedding joints not well developed but appear to range from about 6 inches to 2 feet apart.	21	1111	521 – 542
153.	Dolomite—medium grained, medium gray, in part brownish and pinkish tinted, beds not well developed, but probably ranging from about 6 inches to 2 feet thick. Chert porcelaneous with very small amount subchalcedonic, structureless except for a few dolomolds, occurs abundantly as irregular to rounded masses up to 6 inches in size, and as ½-inch thick brecciated appearing stringers.	21	1132	500 – 521
154.	Dolomite—predominantly medium grained, with some fine grained beds which appear in large part to grade laterally into medium grained, medium gray in part brownish and pinkish tinted, beds not well developed but appear to range between about 6 inches and 2 feet in thickness.	51	1183	449 – 500

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Chert porcelaneous and in minor part subchalcedonic and dolomoldic. It is abundant as irregular to rounded masses not over 6 inches in diameter, and as irregularly fractured layers about one-half inch thick.			
155. Dolomite—medium to fine grained, medium gray with a pinkish tone, bedding not well exposed.	27	1210	422 – 449
Chert porcelaneous, white and highly dolomoldic, very abundant as lacy clusters and as bedding plane layers. In addition and also very abundant is a porcelaneous, in part concretionary chert, occurring in masses up to 1 foot thick.			
Cross fence at 445 feet in section.			
156. Dolomite—medium grained, medium gray with a pinkish tone.	22	1232	400 – 422
Chert porcelaneous, white and highly dolomoldic, very abundant as lacy clusters and bedding plane layers.			
157. Dolomite—medium grained with some coarse grained near top.	8	1240	392 – 400
158. Dolomite—medium grained with small amount of fine grained, medium gray with a pinkish tone, not well exposed, beds appear to range between 6 and 18 inches in thickness.	19	1259	373 – 392
Chert porcelaneous, white and highly dolomoldic, very abundant as lacy clusters up to several feet thick throughout interval. A few masses of stromatolitic (?) chert occur near the top of the interval and some hand-sized pieces of porcelaneous, oölitic chert are present.			
159. Dolomite—medium grained, medium brownish gray to medium and light gray, beds about 1 foot thick.	7	1266	366 – 373
Chert porcelaneous, micro-oölitic, abundant as masses 4 to 5 inches in size, and in bottom foot of interval jointed.			
Threadgill member: 91 feet thick and all in dolomitic facies			
160. Dolomite—coarse grained, almost white to light gray, with some beds a medium gray with a brownish tint. The beds very indistinct with bedding joints widely spaced and irregular.	36	1302	330 – 366
Cross fence at 350 feet in section.			
161. Dolomite—coarse grained, and same as in interval 160.	5	1307	325 – 330
Chert minutely quartzose to semiporcelaneous, compact, smoky on fresh surfaces, weathers white, occurs mostly as ½-inch isolated angular fragments.			
162. Dolomite—coarse grained, and the same as in interval 160.	4	1311	321 – 325
163. Dolomite—coarse grained, and the same as in interval 160.	2	1313	319 – 321
Chert minutely quartzose to semiporcelaneous, compact, smoky on fresh fractures, weathers white, occurs as a network in relief on the dolomite.			
Fossils probably from this interval collected 2100 feet to the southeast are *Sinuopea* sp., *Ozarkina* sp., *Ophileta* sp., and brevicone cephalopods (27T–9–46A).			
164. Dolomite—coarse grained, and the same as in interval 160. An unctuous green material is sparingly present between dolomite rhombs.	44	1357	275 – 319
Shift along Tanyard-Pedernales contact south-southwest 1300 feet to fence and continue section down hill to the west.			
Upper Cambrian:			
Wilberns formation: 275 feet measured			
Pedernales dolomite member: 224 feet thick			
165. Dolomite—fine grained, beige to deep rose, well bedded, beds from 3 to 12 inches thick. A coarse grained bed at 268 to 270 feet in section pinches out laterally.	18	1375	257 – 275

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	Chert at the top along the strike is mostly finely granular to quartzose, dark olive brown to black, weathers to a jasper red, occurs as fist-sized to 2-foot masses. In the bottom 2 feet the dolomite contains some quartzose films. Silicified fossils collected from white chert at the top of the interval 500 feet east of the fence are *Schizopea* sp. and a high spired gastropod of uncertain relationships (27T-9-56A). (These could be Ordovician in age.)			
166.	Dolomite—fine grained with some approaching medium grained, color varies from bed to bed in shades of brown and greenish grays, mostly mottled with some beds of fairly even tone. Bedding indistinct with an indication that beds may be 2 feet or more thick. Chert quartzose to semiporcelaneous, dolomoldic, with dolomolds being perfect in more solid fragments and poorly defined in lacy portions, occurs as a lacy network which weathers in relief. Silicified fossils at bottom of this interval collected 100 feet east of the fence are small high spired gastropod and *Finkelnburgia* sp. (27T-9-56B).	16	1391	241 – 257
167.	Dolomite—fine grained, colored as in interval 166, beds 6 to 12 inches thick. Chert present but very scarce.	10	1401	231 – 241
168.	Dolomite—fine grained, colored as in interval 166, beds 1 foot thick. Chert quartzose to semiporcelaneous, dolomoldic, with dolomolds being perfect in more solid fragments and poorly defined in lacy portions, occurs as a network in top and bottom foot of interval.	4	1405	227 – 231
169.	Dolomite—fine grained, colored as in interval 166, beds 1 to 1.5 feet thick.	16	1421	211 – 227
170.	Dolomite—fine grained with a few medium grained beds, colors as in interval 166, beds 3 to 9 inches thick.	29	1450	182 – 211
171.	Dolomite—medium grained, nutria and medium greenish gray, bedding joints indistinct but appear to be 1 foot or more apart, weathers with a cavernous irregular surface.	5	1455	177 – 182
172.	Dolomite—fine grained with a few beds in the upper part approaching medium grained, colored as in interval 166, beds mostly 6 to 12 inches in thickness, weathers smooth.	39	1494	138 – 177
173.	Dolomite—fine grained, colored as in interval 166, some beds contain stylolites with bright yellow material along them.	29	1523	109 – 138
	Section crosses drain at 138 feet in section.			
174.	Dolomite—very fine grained, brownish gray with an olive cast and only slightly mottled. Partially silicified girvanellas are present.	1	1524	108 – 109
	Shift south about 250 feet along bed containing partially silicified girvanellas, continue section down hill to the west.			
175.	Dolomite—very fine grained, brownish gray with an olive cast and only slightly mottled, bedding joints fairly distinct 6 inches to 3 feet apart, some breccia present. Calcite girvanellas (?) seen on fresh breaks.	21	1545	87 – 108
176.	Dolomite—very fine grained to microgranular, mottled, beige and dark greenish gray, bedding joints fairly distinct and 6 inches to 2 feet apart. Calcite girvanellas (?) seen on fresh breaks.	7	1552	80 – 87
177.	Dolomite—very fine grained to microgranular, mottled brownish gray and dark greenish gray, very massive with indistinct bedding joints 2 to 6 feet apart.	20	1572	60 – 80
178.	Dolomite—very fine grained to microgranular, mottled nutria to cinnamon brown or darker with dark greenish gray splotches, essentially one massive bed.	6	1578	54 – 60

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
179. Dolomite and limestone intergradation—essentially one bed, with the dolomite very fine grained, mottled cinnamon to nutria with dark greenish gray splotches.	3	1581	51 – 54
Shift around hill south-southeast about 400 feet on bed containing small silicified brachiopods, continue section down hill to the southwest. (Note that the bottom of the dolomite fluctuated vertically through an interval of about 20 feet.)			
San Saba limestone member: 48 feet thick			
180. Limestone—sublithographic, brownish gray, with network of lighter brownish gray fine grained dolomite which weathers to a dirty brown on a background of medium gray. Beds 1.5 to 2 feet thick with one 4-inch oölite bed at 48 feet in section.	6.5	1587.5	44.5– 51
Silicified brachiopods located on top surface of interval are poorly preserved *Finkelnburgia* sp. (27T–9–56C).			
181. Limestone—granular, glauconitic, brownish gray, one bed, contains partially silicified girvanellas.	1.5	1589	43 – 44.5
Calcitic fossils present are trilobites.			
The lower portion of the San Saba limestone member in this section is an alternation of limestone beds and thinly bedded zones of argillaceous limestone and has characteristics which run throughout the portion measured. The thin bedded intervals are poorly exposed in the line of section, but in the drain to the east of the section they are mostly exposed and are irregularly bedded, giving a nodular appearance. All of the intervals described are slightly glauconitic and the limestone ranges in texture from perhaps sublithographic or microgranular to coarse grained. The coarse grained portions form a network when present. The colors are chiefly beige to greenish gray for the very thin bedded rocks ranging to brownish gray for the thicker bedded ones. The descriptions of the following intervals are abbreviated, stating only the variations from the normal characteristics.			
182. Limestone—thinly bedded, some dolomite rhombs present.	5	1594	38 – 43
183. Limestone—fine grained, beige to medium gray, beds 1 to 6 inches thick.	1.5	1595.5	36.5– 38
184. Limestone—thinly bedded.	2	1597.5	34.5– 36.5
185. Limestone—oölitic, medium brownish gray, one bed.	0.5	1598	34 – 34.5
186. Limestone—thinly bedded.	6	1604	28 – 34
187. Limestone—beds 1 to 4 inches thick, some sponge spicules present on weathered surfaces.	5	1609	23 – 28
188. Limestone—thinly bedded.	8.5	1617.5	14.5– 23
189. Limestone—one bed.	0.5	1618	14 – 14.5
190. Limestone—thinly bedded.	2	1620	12 – 14
191. Limestone—two beds.	1	1621	11 – 12
192. Limestone—thinly bedded with a few 3- to 4-inch limestone beds containing dark cinnamon brown network of coarse grained calcite.	5	1626	6 – 11
193. Limestone—irregular beds 1 to 8 inches thick.	3	1629	3 – 6
Point Peak shale member: 3 feet measured			
194. Shale—not exposed in line of section.	3	1632	0 – 3
The bottom of the section is at the top of a 6-inch, granular, brownish gray limestone bed, which contains numerous rounded pebbles, trilobite fragments, glauconite, and a silicified species of alate *Billingsella* on the top surface. *Plectotriophia* was not found in the line of section but to the southeast one-half mile they are abundant in this bed (27T–9–56D). The bottom of the described section is about 4900 feet east-southeast of the intersection of the Burnet road with the Kingsland-Marble Falls road and about 1700 feet east-northeast of the railroad crossing on the Kingsland-Marble Falls road near Hoover Point. The Hoover Point section is not described; thicknesses of the various units are given above, page 290.			

Supplementary Information, Backbone Ridge Section

In the list below are given the intervals in which sand was noted by Cloud, in an examination of the insoluble residues of the Backbone Ridge section; as is also the sand noted by Barnes and Warren in their field description of the section.

Cloud (from residues)		Barnes and Warren (from field description)
1395–1400	S*	----------
----------		1240–45
1235–40	A	*1235–40*
----------		1230–35
1225–30	R	*1225–30*
1165–70	R	----------
1155–60	S	----------
1125–30	R	----------
1090–95	VA	----------
1080–85	C	----------
1075–80	A	----------
1060–65	VA	----------
1025–30	A	----------
980–85	R	----------
----------		970–75
945–50	S	----------
----------		915–20
885–90	S	----------
880–85	S	----------
850–55	S	----------
----------		845–50
840–45	VA	*840–45*
810–15	A	----------
----------		805–10
790–95	VA	*790–95*
----------		780–85
----------		745–50

*VA = very abundant.
A = abundant.
C = common.
S = scattered.
R = rare.

Of the 27 recordings of the presence of sand, only 4 (italicized) were seen by both parties. It is somewhat surprising that only 4 out of the 12 sands noted in the field were sampled. As should be expected more sand was seen in the residues (19), than in the field (12). Cloud noted silt in the residues of the following intervals, whereas, Barnes and Warren record none:

1460–65	S	325–30	S
855–60	S	200–05	C
850–55	S	105–175	C
845–50	R	55–105	R

JOHNSON CITY AREA, BLANCO COUNTY

INTRODUCTORY STATEMENT

The Johnson City area is in central Blanco County and includes the southeasternmost Paleozoic outcrops of the Llano uplift. A detailed planimetric geologic map (Pl. 3) of an area about 6.5 by 13 miles in size, elongated in an east-west direction, includes Johnson City near the southwestern corner. Pedernales River, swinging through the area in broad meanders, has stripped away the Cretaceous rocks exposing the Paleozoic rocks. Except in the northwestern part, the map has a border of Cretaceous rocks, and a narrow band of Cretaceous rocks trending in a northwest-southeast direction north of Johnson City isolates the Paleozoic rocks of the eastern area from those of the west.

To obtain a complete section in the Johnson City area, extensive and painstaking mapping was necessary. Faulting precludes a continuous section, but several other factors make the area an especially important one toward an understanding of the Ellenburger group and the closely related underlying Cambrian rocks. The Pedernales dolomite member of the Wilberns formation was named from past work in this area. The thickest section of the uppermost formation of the Ellenburger group is in Honeycut Bend, and the thickest undisturbed sequence of Devonian rocks yet known in the Llano uplift tops the Ellenburger in Honeycut Bend.

Mapping in the Johnson City area, in addition to that necessary to establish sections, demonstrates the practicability of mapping the various formations and members defined, where complicated by faulting and the close proximity of Cretaceous conglomerates which shed chertified Ordovician fossils indiscriminately. This is one of the first areas in which the various units as defined in the Cherokee area were mapped. Because of facies changes which were brought to light upon completion of the mapping of other areas, some inconsistencies in interpretation may be found on the geologic map of the area (Pl. 3). The

Honeycut-Gorman boundary drawn during the mapping is about 34 feet too high, at least in the Honeycut Bend area. Contacts between the Gorman and Honeycut formations as shown on this portion of the map are all a little too far southeast. Difficulty was also experienced in separating the calcitic facies of the Gorman formation from the dolomitic facies, so the two facies of the Gorman of the Johnson City area have not been mapped except in the areas shown on Plates 12 and 13. The calcitic facies of the Gorman formation in the Johnson City area, as has been pointed out for other sections of the eastern part of the uplift, has a dolomitic portion in its central part. Where this dolomite is in isolated fault blocks it is difficult to distinguish from the lower dolomitic facies of the Gorman. Also adding to the confusion in identifying the two facies of the Gorman is lateral gradation between limestone and dolomite which is more prevalent than was thought at the time the area was mapped. The Rowntree No. 1 Kott well in Gillespie County reveals that nearly all of the limestone seen in the Gorman formation at the surface has graded to dolomite, and it is possible that the Honeycut Bend area is in the region where this change to dolomite has started. With experience later gained in other areas, the boundary between the calcitic and dolomitic facies could have been mapped in the Johnson City area, but it was felt that the advantages that might be so gained did not warrant delay in publication of the present report.

Rocks mapped in addition to the divisions of the Lower Ordovician include: Upper Cambrian—the Hickory sandstone, Cap Mountain limestone and Lion Mountain sandstone members of the Riley formation; the Welge sandstone, Morgan Creek limestone, and Pedernales dolomite members of the Wilberns formation; Devonian—the Pillar Bluff (?) formation and the Stribling formation; Mississippian—the Ives breccia, Chappel limestone, and Barnett formation; Pennsylvanian—(1) a lower biohermal limestone, (2) a middle spiculite member, and (3) an upper limestone member, of the Marble Falls limestone unrestricted; Lower Cretaceous—the Sycamore sand, Cow Creek limestone, and Hensell sand members of the Travis Peak formation; and the Glen Rose limestone.

Fossils were collected from 96 Ordovician and uppermost Cambrian localities in the Johnson City area. Of these, 5 are from the Pedernales dolomite member of the Wilberns formation; 4 from the Threadgill member and 26 from the Staendebach member of the Tanyard formation; 24 from the Gorman formation; and 37 from the Honeycut formation. Some fossil beds were mapped but not in their entirety.

UPPER CAMBRIAN

Riley Formation

Hickory sandstone member.—The lowest member of the Riley formation, the Hickory sandstone, outcrops in the extreme northwestern corner of the Johnson City area (Pl. 3). Only the upper portion of the Hickory sandstone member is present; it is noncalcareous, shows various shades of brown, and in the upper portion forms a sandy flat vegetated by widely spaced clumps of oak. The flat is very narrow in the map area but is much wider in most other areas noted in the Llano uplift. The Hickory sandstone beneath the upper thinly vegetated portion seems to be less friable and is possibly cemented with a siliceous cement. This portion of the Hickory sandstone supports a much more abundant growth of oak, yet still forms a rather open woodland. In contrast the Cap Mountain limestone member of the Riley is well vegetated. It is also extremely sandy in the lower part, but the presence of calcareous cement and impure limestone beds makes it resistant to weathering, thus forming steep slopes which contrast strongly with the flat at the top of the Hickory sandstone member beneath. This contrast is especially well shown on aerial photographs.

The contact of the Hickory sandstone and the Cap Mountain limestone members is gradational, being at different stratigraphic levels in different areas.

Cap Mountain limestone member.—In Blanco County the Cap Mountain lime-

stone member is estimated to be 455 feet thick, whereas in the northwestern part of the Llano uplift, in the Brady City water well No. 3, it is only about 135 feet thick. The Cap Mountain limestone member of the Johnson City area consists of a lower portion made up of alternating impure dark brown limestone and calcareous sandstone, becoming more calcareous upward, and an upper portion of mostly brownish gray, thickly bedded to massive limestone. The lower boundary, based on lithic features, rises westward, crossing faunal zones. The top boundary, likewise, is gradational but much more nearly at the same time horizon. The outcrop width of the Cap Mountain within the map area is about 1.5 miles.

Lion Mountain sandstone member.—The Lion Mountain sandstone member is a highly glauconitic sandstone, in the lower part of which are numerous lenses or tangential beds of a coquina-like limestone made up chiefly of trilobites. The Lion Mountain sandstone member forms a bench with clumps of scattered vegetation distinct from the uniform vegetation cover of the members above and below. On aerial photographs the Lion Mountain sandstone member has a characteristic appearance that can be confused only with the bench previously mentioned as occurring at the top of the Hickory. The Lion Mountain sandstone probably averages about 20 feet thick, which is about half as thick as it is 40 miles to the west in Gillespie County. Its outcrop averages a little over 100 yards in width.

Wilberns Formation

Welge sandstone member.—The bottom member of the Wilberns formation, the Welge sandstone, is a brown, sparsely glauconitic, in part reconstituted, fine grained sandstone which is sharply distinct from the Lion Mountain sandstone of the Riley formation beneath. In many places in the Llano uplift the base of the Welge is slightly coarser than the rest of it, occasionally small pebbles up to a quarter of an inch in size being present. The Welge forms an abrupt scarp adjacent to the upper edge of the Lion Mountain bench and is very heavily vegetated, producing on aerial photographs a very narrow dark line of vegetation. In Blanco County the Welge sandstone member is about 10 feet thick, only one-third as thick as in Gillespie County 40 miles to the west. Its outcrop width is very narrow, being exaggerated on the map.

Morgan Creek limestone member.—The Morgan Creek limestone member, which grades up from the Welge sandstone member, is 140 feet thick in the Johnson City area and consists mostly of alternations of fine to medium grained, glauconitic, greenish to twine gray limestone and very fine grained to sublithographic, light greenish gray, stromatolitic limestones. A small amount of shale, some oölitic limestone in the bottom one-third, a thin shingle conglomerate, and a bottom 11-foot interval of dark reddish brown arenaceous limestone complete the member. On aerial photographs the Morgan Creek is seen to be a distinctly bedded member with many individual beds traceable for long distances. Its normal outcrop width is a little more than half a mile, and the outcrop is separated into three areas by overlapping Cretaceous rocks.

Point Peak shale member.—An 11- to 14-foot interval of thinly bedded, argillaceous, dolomitic and glauconitic limestone above the Morgan Creek limestone member should probably be considered as belonging to the Point Peak shale member, but except for its thinness of bedding and calcareous composition is similar to the overlying Pedernales dolomite member and has been mapped with it. An 11-foot limestone, beneath the thinly bedded interval in the Scott Klett ranch section is included with the Point Peak shale instead of the Morgan Creek limestone. A glance at the correlation chart for the Llano uplift (Pl. 14) shows that the stromatolitic limestones are predominantly associated with the Point Peak shale, and the convention has been adopted of including stromatolitic limestone with the Point Peak shale wherever it is in contact with the Point Peak shale. As interpreted on the correlation chart,

25 feet of Point Peak (?) shale member is present in the Johnson City area. This thickness is sufficient to map and if the mapping were to be revised, this interval should probably be mapped as Point Peak shale.

Pedernales dolomite member.—No rocks assignable to the San Saba limestone member of the Wilberns formation are present in the Johnson City area, the stratigraphic interval occupied by the San Saba at other localities being here represented by the Pedernales dolomite member. As explained elsewhere, the San Saba limestone and the Pedernales dolomite members are essentially facies, with limestone predominating to the west and dolomite to the east. The type section of the Pedernales dolomite member of the Wilberns formation was chosen in the Johnson City area on the assumption that because the dolomite extended farther down in the section here than anywhere else noted, more of it is present. This is not true, for only about 195 feet of the Pedernales dolomite member is present in the Johnson City area, whereas 224 feet is present in the Backbone Mountain section and 277 feet in the Tanyard section. The total thickness of the Wilberns formation in the Johnson City area is 370 feet, which is much thinner than the 615 feet measured on Threadgill Creek 40 miles to the west. The thinning appears to be above the *Plectotrophia* zone, which, however, was not found in the Pedernales River section. One specimen of a syntrophid brachiopod resembling *Plectotrophia* cf. *P. bridgei* was found at locality 16T–2–56A in the Johnson City area in coarse grained dolomite and associated with a chert similar to that seen 37 feet below the top of the Pedernales in the Pedernales River section. If this is the position of the *Plectotrophia* zone in the Johnson City area, its position above the base of the Wilberns formation compares closely to that in the Moore Hollow and Hoover Point sections. It is likely that the Pedernales dolomite member was eroded at the top prior to the deposition of Tanyard sediments. The exposures of this contact in the Johnson City area are limited, and local evidences of erosion could easily be missed. In the Cherokee area there is definite evidence of an unconformity, whereas on Threadgill Creek, deposition seems to have been essentially continuous across the systemic boundary.

The bottom 86 feet of the Pedernales dolomite member of the Wilberns formation is fine grained and evenly bedded, contrasting sharply with the overlying massive portion. The coarse grained dolomites are predominantly light gray and silvery gray with occasional intervals that are yellowish gray or nutria. The fine grained dolomite is predominantly yellowish gray to beige with some nutria in the upper part. The entire dolomite section of the Johnson City area is speckled to mottled with dull, dark reddish purple in varying degrees. Glauconite, common elsewhere in the upper Wilberns, was not noted except in the basal few feet of beds of the Pedernales dolomite member in the Johnson City area.

The type section of the Pedernales dolomite member of the Wilberns formation contains some chert, mostly near the top of the lower fine grained portion. It is mostly fine grained, minutely to coarsely quartzose, compact to very porous, and medium brown to various shades of dirty gray and white. The chert is irregularly porous. It does not display distinct molds of either dolomite rhombs or oöids. Four miles to the northeast of the type section, chert of similar appearance is much more abundant in the Pedernales.

Fossils are rare in the cherts, only five collections having been obtained in the area.

The Pedernales bears a thick growth of cedar except where a cedar eradication program has been in effect. The soil developed on the Pedernales is scanty, and a characteristic surface is made up of projecting boulders on a flat or gentle slope, mostly poorly drained and in wet weather noticeably wetter and more swampy than any other stratigraphic unit in the Llano uplift.

LOWER ORDOVICIAN

ELLENBURGER GROUP

Tanyard formation, Threadgill member.—In the Johnson City area the Threadgill member of the Tanyard formation, 242 feet thick, is predominantly coarse grained, light gray dolomite, except in the vicinity of the Towhead Creek where a section of approximately 182 feet of white to light gray sublithographic limestone was measured. A remarkable feature of the Threadgill rocks is the abruptness with which limestone and dolomite replace each other laterally. The limestone mass cut by Towhead Creek ends so abruptly eastward that a fault would be suspected. Enough interfingering and gradational meshwork-type dolomite in the limestone is present, however, to disprove a fault. Westward the gradation is not as sharp, and there is more interfingering. The Threadgill rests upon the microgranular Pedernales dolomite member of the Wilberns formation along about half of its 3 miles of normal contact (Pl. 12) and in the western half rests directly upon coarse grained dolomite of the Pedernales. The coarse grained dolomites of these two units are so similar that the contact could not be followed, and the boundary was placed by the aid of aerial photographs and an attempt to walk out beds. Both dolomites are so massive that it is almost impossible to recognize and follow any one bed.

In the Johnson City area chert is scarce in the Threadgill member of the Tanyard and consists mostly of small nodules or thin sheets along the bedding surfaces. It is mostly of a dark smoky or dirty gray color, opaque, lusterless except for a slight sparkle of minute quartz crystals and is mostly compact but in part honeycombed. Few fossils were found in the chert, but enough were obtained to identify the rocks as Tanyard. Sections of fossils are somewhat more common on limestone surfaces, but *Lytospira*, so common in the Threadgill member in Gillespie County, was not found. The Threadgill member of the Tanyard has no characteristics of outcrop, topography, or vegetation in its limited area of occurrence in the vicinity of Johnson City to distinguish it on aerial photographs from the Pedernales dolomite member of the Wilberns.

Tanyard formation, Staendebach member.—The boundary between the Threadgill and Staendebach members of the Tanyard formation is not as well displayed in the Johnson City area as could be desired. There is only slightly more than a mile of normal contact, and the boundary drawn in the western part includes the lowest fairly persistent porcelaneous cherts and was placed at the top of a thin, fine grained, discontinuous dolomite. On the basis of grain size change in the dolomites, the boundary would be placed 33 feet higher.

The Staendebach member of the Tanyard formation is predominantly dolomite, with small areas of limestone near its base in the vicinity of Towhead Creek (Pl. 12), and thin discontinuous limestone beds at its top north of Pedernales River and in the Honeycut Bend area (Pls. 3 and 13). The basal 33 feet is coarse grained, light gray dolomite, followed by about 130 feet of fine grained dolomite that is predominantly nutria to yellowish gray with some other colors such as beige, old ivory, and flesh. The grain size increases upward, and the top 150 feet is mostly medium to slightly coarser grained dolomite, mostly of light gray to yellowish gray color. In the lower part of the Honeycut Bend section, about 30 feet of massive light to medium gray limestone tops the Staendebach member. The limestones in the lower Staendebach of the vicinity of Towhead Creek grade abruptly to dolomite, are thinly to thickly bedded, have much the same mottled appearance as does the limestone of the Threadgill member on Threadgill Creek, and even display sections of *Lytospira* on some of the bedding surfaces.

Chert is abundant, occurring as large masses, small masses, nodules, excrescences, and interstitial material between dolomite rhombs. It ranges from compact to dolomoldic and is predominantly porcelaneous and white. The chert is so abundant in the upper part that it influ-

ences the topography and vegetation. The chert accumulated on the surface masks outcrops and supports oaks, especially around chert knobs. These features have photographic characteristics that are easily recognized on the aerial photographs. Cedar, as elsewhere in this area, takes over where the chert is less plentiful.

Fossils are common, especially near the top of the member, but these are discussed elsewhere.

Gorman formation.—The Gorman formation is 490 feet thick in the line of section. The boundary between the Gorman and Tanyard formations is sharp. The basal Gorman is microgranular dolomite, which rests either on limestone or medium to coarse grained dolomite of the Tanyard. Locally there is evidence to suggest a stratigraphic discordance at this contact, but this is not sufficiently conclusive to warrant an unqualified statement.

The division of the Gorman formation into a lower dolomitic facies and an upper calcitic facies has been attempted only locally in the Johnson City area. The two facies were mapped in the vicinity of Honeycut Bend (Pl. 13), with the *Archaeoscyphia* bed serving as the approximate boundary. In this section 29 feet of limestone and 228 feet of dolomite was measured below *Archaeoscyphia*. The *Archaeoscyphia* bed has been mapped at some other places, but in general to find and trace this bed in the various fault blocks requires more time than the results warrant.

The calcitic facies of the Gorman formation in the Honeycut Bend area, as it is in other sections in the eastern part of the Llano uplift, is separable into an upper and a lower limestone and a middle dolomite. The upper limestone is different from that in any other section measured in that it contains abundant network dolomite and is scarcely recognizable as the persistent pure massive limestone that is present in this position in the rest of the outcrop area of the Gorman in the Llano uplift.

An abundance of microgranular dolomite characterizes the Gorman and Honeycut formations. In the lower dolomitic facies of the Gorman, 175 feet of microgranular dolomite and 53 feet of mostly fine grained dolomite was measured. In the upper calcitic facies, 90 feet of microgranular and 38 feet of fine grained and some medium grained dolomite was measured. Many of the limestones and dolomites, especially the fine to medium grained ones, grade laterally from one to the other and to limestone, and no two sections would show the same proportions. It is thought, however, that the microgranular dolomite shows less tendency to be displaced laterally by limestone.

The microgranular dolomites are mostly mottled and streaked in combinations of many colors such as old ivory, yellowish gray, beige, buff, and cinnamon, with occasional nutria and other tones of brown being present. The fine and medium grained dolomites are mostly pearl gray, yellowish gray, and nutria, with colors such as light to medium gray, cement gray, and buff being common. The limestones are predominantly light to medium gray and yellowish gray.

In the Johnson City area a significant feature of the Gorman formation is the large number of thin sandy beds. The lower part of the Gorman formation has much the same photographic expression as the Tanyard formation beneath, whereas the upper part, consisting of alternating beds, has a pattern like that of the Honeycut formation above. Much of the microgranular dolomite weathers to produce sphenoidally jointed blocks. Cedar is the dominant type of tree that grows in the sparse soils on the Gorman formation.

The top boundary of the Gorman in the Johnson City area has probably been mapped correctly in some fault blocks, but in the line of section it is known to have been mapped 34 feet too high. At the time of the mapping in this area, the boundary was drawn on the basis of the lowest occurrence of *Xenelasma* in combination with the lowest cannonball cherts of the Honeycut formation. The lowest occurrence of these is now known to fluctuate. With the upper massive limestone as dolomitic as it is and with lateral gradation to dolomite locally present, the boundary between massive limestone and

alternating beds of limestone and dolomite cannot be used as readily as it has been used in other areas to map the boundary between the Gorman and the Honeycut formations. However, the well developed sandy bed taken to be the base of the Honeycut formation is persistent throughout the area and is easy to follow. Other sandy beds in this portion of the section could easily be confused with it, but they too are rather persistent, and usually from the spacing of these beds the correct one can be identified.

Chert is more conspicuous in the upper calcitic portion of the Gorman than it is in the lower dolomitic portion. The chert varies through chalcedonic to subchalcedonic, porcelaneous to semiporcelaneous, and chalk textured. It ranges from white to light gray to shades of brown such as nutria. Some of the chert is crypto-oölitic, some is dolomoldic, and a small amount is oölitic. A few quartzose excrescences are present.

Honeycut formation.—The type locality of the Honeycut formation, named from the Honeycut survey from which the local names of Honeycut Bend, Honeycut Hollow, and Honeycut Spring have stemmed, is about 5 miles east of Johnson City. The measured section, mostly along Pedernales River in Honeycut Bend, had to be offset to Rough Hollow in order to complete the measurement of the bottom portion of the Honeycut formation. Additional beds at the top of the section make the Honeycut formation thicker in this area, 679 feet, than elsewhere in the Llano uplift.

The Honeycut formation is composed of three distinct units (Pl. 14) which, however, have not been separately mapped. The lower unit, composed of alternating dolomites and limestones, in the measured section consists of limestone—88 feet; fine to medium grained dolomite—55 feet; and microgranular dolomite—16 feet. The middle dolomite unit consists of limestone—26 feet; fine to medium grained dolomite—69 feet; and microgranular dolomite—206 feet. The upper limestone unit consists of limestone—160 feet; fine to medium grained dolomite—14 feet; and microgranular dolomite—45 feet.

The lower unit of the Honeycut formation is about equally dolomite and limestone, the middle unit preponderantly dolomite, and the upper unit mostly limestone. The high proportion of microgranular to very fine grained dolomite in the middle unit is an outstanding feature of the Honeycut rocks in their type section, as well as in other sections in the eastern part of the Llano uplift.

The limestone of the lower unit is nutria, yellowish gray, and light to medium gray in color; the small amount in the middle unit is light gray; and the upper unit has a wider range in color—light gray, old ivory, yellowish gray, and near the base a reddish zone.

The fine and medium grained dolomites in the lower unit are nutria, woodash gray, pearl gray, light gray, and old ivory; in the middle unit—pearl gray, yellowish gray, and light gray; and in the upper unit—pearl gray, old ivory, and mouse gray.

The microgranular dolomites are darker, except in the upper unit, than are the microgranular dolomites of the Gorman formation. The predominant colors are browns and some lighter colors such as old ivory, beige, yellow beige, flesh, pearl gray, and cinnamon. The microgranular dolomites of the upper unit are mostly ivory, beige, and related colors, with some mouse gray, yellowish gray, and nutria.

The chert of the Honeycut formation is about the same in all units except that it is in part darker in the lower unit, where also some radial quartz nodules are found. The chert is in part chalcedonic to subchalcedonic, in part porcelaneous to semiporcelaneous, in part chalk textured, and occurs in part as cannonballs. It is white to various shades of grays and browns, including nutria in the lower half, and a thin zone of maroon chert is associated with the reddish limestone of the upper unit.

The upper part of the Honeycut formation (Pl. 13) is sharply truncated, being overlapped by Devonian and Carboniferous rocks. A *Ceratopea "keithi"* bed 100 feet below the top in the type section is cut out by overlap one-half mile to the northeast. Farther to the

northeast some of the beds again come out from under the overlap, but there is no evidence that any Ordovician beds younger than those in the type section are exposed.

The vegetation on the Honeycut formation is mostly cedar, arranged in bands of varying density along the bedding similar to that of the upper part of the Gorman formation. The paleontology of the Honeycut formation is discussed elsewhere.

DEVONIAN

The rocks of Devonian age are described by Barnes, Cloud, and Warren (1945, 1947). The Stribling formation tops the Honeycut formation at the type section and is present at a few other places to the northeast (Pl. 3). A pocket of Pillar Bluff (?) limestone is present in the top of the Ellenburger strata near the type section of the Stribling (Pl. 13).

CARBONIFEROUS

In the work that preceded the preliminary publications on the Ellenburger and the Devonian of central Texas (Cloud, Barnes, and Bridge, 1945; Barnes and Cloud, 1945; and Barnes, Cloud, and Warren, 1945) the Carboniferous of the Johnson City area was not examined critically, leading to an error in identification of one unit. The portion of the section referred to as the "Chappel formation" is not Chappel limestone but is of Morrow age and probably belongs to F. B. Plummer's Sloan member of the Marble Falls limestone (Plummer, 1945, pp. 66–67).

Mississippian

Mississippian rocks so far recognized in the Johnson City area are the Ives breccia, the Chappel limestone, and the Barnett formation. The Ives breccia outcrops throughout an estimated one-half of the length of outcrop possible. It is more nearly continuous in the southwestern part of the Carboniferous outcrop area. The Ives breccia at Elm Pool is 21 inches thick, about a maximum thickness except at a few places which appear to be small collapses. The average thickness is probably about 10 or 12 inches. The Ives is composed predominantly of angular chert fragments, and in some localities a small amount of limestone matrix surrounds the fragments.

The Ives breccia appears not to have been subjected to any extensive movement. The rounded pieces of chert in the Ives appear to be unbroken chert nodules rather than water-worn cherts, and the predominance of angular pieces may be due to the disintegration of the chert along incipient fractures. The Ives breccia above the Stribling formation appears to have more rounded cherts in it than does the Ives above the Honeycut formation, which is probably a natural reflection of the difference in the cherts of the two underlying formations. It seems likely that the Ives is an accumulation, essentially in place, of the insoluble constituents of the formations upon which it rests as the limestone is removed by solution. A detailed systematic examination of the Ives breccia from the standpoint of comparing it with the insoluble constituents of the immediately underlying formations has not been attempted, but such an investigation might yield interesting results.

Barnes, Cloud, and Warren (1945, p. 176) mention that a limestone at locality 16T–2–27A_1 on the Cage ranch (Pl. 3) is closely related to if not laterally equivalent to the Ives breccia, and that it contains a lower Mississippian (possibly Glen Park) macrofauna. The same macrofauna has since been found 30 feet to the west of the original locality at a place where the relationship of the lower Mississippian (possibly Glen Park) limestone to the Ives breccia is apparent. A section at this place, in descending order, is as follows:

	Thickness Inches
(1) Ives breccia	8–14
(2) Unevenly granular (medium grained to microgranular) limestone that is reddish brown to olive gray, olive, and pinkish gray, and contains scattered fragments of chert and "fish" bone. It also displays some fragments of limestone resembling the Stribling formation, as well as scattered sand grains. It contains lower Mississippian brachiopods, among which *Sedenticellula* aff. *S. hamburgensis* (Weller) suggests a Glen Park age, although the genus is known to range higher (16T–2–27A_{1c})	8
In the upper surface of the limestone a local channel or pocket about 3 inches deep is filled with a coarse grained, pinkish gray, crinoidal, and slightly glauconitic limestone that resembles the Chappel limestone. The conodont assemblage from this pocket, as reported on by Dr. W. H. Hass (memorandum of May 13, 1946), includes "species" of four "genera" generally regarded as Devonian, as well as a few specimens of two Carboniferous "genera." Dr. Hass ventured no opinion on the age of this assemblage, but he considers the conodonts from 16T–2–27A_2 to be "of lower Mississippian age," whereas those from the Ives breccia (interval 1 above) "with the exception of *Solenodella* . . . suggest a Devonian age."	
(3) Pink, glauconitic, granular, crinoidal limestone containing quartz grains and crystals and Mississippian trilobites (16T–2–27A_{1b})	1.5
(4) Nodular, in part calcareous, chert of the Devonian Stribling formation	12
(5) Limestone and chert of the Stribling formation, thickness not measured.	

From this section, measured by the writers in December 1945, it seems clear that lower Mississippian limestone of possible Glen Park age underlies the Ives breccia, and that the Ives is thus also Mississippian. The evidence of the conodonts, however, is equivocal.

Conodont- and bone-bearing phosphatic or phosphatic and calcareous beds similar to those discussed above have been noted and collected at several localities, including 16T–2–33D, 16T–2–25B, 16T–1–32C, and 16T–2–421. However, the limestone at locality 16T–2–27A_1 seems to be beneath the Ives breccia, whereas the others seem to be either on top of the Ives breccia or to occur where the Ives is missing. Apparently either the Ives goes laterally to limestone or several similar limestones occur at different stratigraphic levels.

At Elm Pool (16T–2–32C) a phosphatic bed with general resemblance to the occurrences of conodont- and bone-bearing beds noted is located 22 inches above the top of the Ives breccia. The following section, in descending sequence, was excavated, measured, and sampled by the writers at this locality on December 4, 1945:

	Thickness Inches
(1) Chappel limestone estimated to be about 5 feet thick and overlain by shales of the Barnett formation.	
(2) Calichified material which possibly is derived from a shale	8
(3) Red siliceous limestone and calcareous chert	2
(4) Dark brown phosphatic bed containing pieces of "fish" bone	5
(5) Brown to yellow calcareous shale which breaks into little rectangular blocks, and the bottom few inches of which appear to be a yellow clay	22
(6) Ives breccia	21
(7) Red siliceous and calcareous detrital rock with scattered angular chert fragments	8
(8) Limestone of the Honeycut formation, having at one place an irregular pocket 12 inches deep that is filled with detritus.	

Macrofossils were not obtained from the section above, but conodonts were obtained from 14 samples collected by the writers, L. E. Warren, and W. H. Hass. With reference to numbers in the sections above, data furnished by Dr. W. H. Hass (memorandum of May 13, 1946) on the conodonts are as follows:

(1) Two samples from the Barnett formation contain typical Barnett conodonts, and three samples from the Chappel limestone contain typical Chappel conodonts. (2) The assemblage from this interval "is a thoroughly mixed one in which Mississippian types predominate over the Devonian kinds." (3) "*Siphonodella* and *Palmatolepis* are present. No comment as to age." (4) "Only one identifiable conodont was found; it is a fragment of *Palmatolepis*." (5) Two samples contain "an Upper Devonian fauna. . . . Some of the conodonts in this zone are like those that have been described from the Grassy Creek shale." (6) Two samples from the Ives breccia yielded a few fragmentary conodonts "identified as *Polygnathus* cf. *P. linguiformis*. . . . *Palmatolepis* and *Ancyrognathus*." (7) A sample from interval 7 contains "distinctive species of *Ancyrognathus, Ancyrodella,* and *Palmatolepis* . . . probably from the Upper Devonian." (8) A sample from the irregular detritus-filled pocket in the top of the Honeycut formation "contains fragmented conodonts."

The evidence of the conodonts, as interpreted by Hass, thus indicates that the rocks above interval 3 are Mississippian, and those below interval 4 are Devonian. If generally cited ranges of conodont "genera" were strictly followed the Devonian-Mississippian boundary would fall between intervals 4 and 3. However, it was shown on page 316 that the relationships of the Ives breccia at locality 16T–2–27A require it to be of Mississippian age at that place. Moreover, evidence from mapping and regional studies (p. 417) now indicates the Ives to be essentially an isochronous basal Mississippian breccia. The writers, therefore, are inclined to the view that the apparent testimony of the conodonts is deficient, whether because of the insufficiently understood ranges in the standard sections or because of their peculiarly sensitive reaction to potentially contaminating mechanisms (currents, reworking, infiltration, etc.). In other words, the writers consider the shale and phosphatic limestone between the Ives breccia and the Chappel limestone to be of lower Mississippian age. Coming, as it does, between the Chappel limestone of Chouteau age (p. 50) and the Ives breccia of probable Grassy Creek-Glen Park age (p. 48), it may represent the Hannibal shale.* At present it seems better that these rocks remain unnamed.

Exposures of the Chappel limestone are very much more restricted than are those of the underlying Ives breccia, but it persists as isolated outcrops, one of which is almost 2000 feet long, throughout the possible outcrop area. The Chappel limestone and the overlying biohermal member of the Marble Falls limestone were confused at the time the preliminary report on the Ellenburger was written. Chappel limestone, however, could easily have been included in the stratigraphic section at Honeycut Bend since it outcrops within a short distance of the top of the Honeycut portion of the section, as well as between this point and where the Carboniferous portion of the section was measured. The Chappel limestone is brownish gray and crinoidal, the crinoid columnals being mostly smaller and less distinct than in the overlying rocks. The correlation of the Chappel limestone and its paleontology are discussed on pages 49–52.

Shale of the Barnett formation outcrops at Elm Pool, and forms a bench for a total distance of little over a quarter of a mile in both directions from Elm Pool. About 10 feet of the Barnett formation is exposed, and an undetermined but probably small amount is present in the bench above the exposed portion and beneath the spiculite member of the Marble Falls limestone. The lower few inches are quite glauconitic, and yield a typical Barnett assemblage of conodonts. The Barnett in the rest of the exposure is shale that weathers to a brownish color. In Honeycut Bend, across Pedernales River from the outcrops of the Stribling formation, a bench between the Chappel limestone and the Marble Falls limestone is probably occupied by shale. If it is shale it is probably the shale seen in the

*W. H. Hass (Bull. Geol. Soc. Amer., vol. 58, p. 1190, 1947) has recently indicated that the conodonts confirm this supposition. Fig. 2 (p. 44) is the then-unpublished chart to which he makes reference, as filed with the Committee on Geologic Names of the U. S. Geological Survey 6/18/48 shortly after this paragraph was written.

section in the basal portion of the biohermal member of the Marble Falls limestone, but it could be shale of the Barnett formation.

Pennsylvanian

The Marble Falls limestone (unrestricted) is composed of three members, two of which are in the line of section. The bottom member is a zone of massively lenticular and possibly biohermal limestone interspersed with well-bedded limestone and black shale, with a 21-inch black shale at the base which has considerable lateral persistence. Fossils collected from this member during the summer of 1945 and during February, 1946, by Dr. G. A. Cooper and the writers are regarded by Dr. Cooper (oral communication) as of Morrow age, and it is probably equivalent to the Sloan member of the Marble Falls limestone as defined by Plummer (1945). It outcrops continuously except where covered by more recent materials for a distance of more than 1½ miles to the northeast of the top of the Honeycut Bend section. Another poorly exposed outcrop is situated on the north bank of Pedernales River (locality 16T–2–33F), and in this direction no other outcrop was seen until Cypress Mill is reached, which is beyond the map area. At locality 16T–2–33F the top foot only of this member is exposed in a recess beneath the spiculite; it is glauconitic, friable, calcareous, and granular without recognizable macrofossils. A sample was submitted to Dr. W. H. Hass who reports as follows: "The collection contains many specimens of *Idiognathodus* and *Streptognathodus*. These two genera have not been reported from rocks older than the Pennsylvanian." To the southeast of Honeycut Bend the basal member of the Marble Falls limestone outcrops in Honeycut Hollow, where fossils in the top part are in chert.

The middle member of the Marble Falls limestone is continuous throughout the map area except where covered by more recent formations, and it is mapped separately from the rest of the Marble Falls limestone because it is lithically so different. It is a dark gray, calcareous spiculiferous rock, which in thin section is seen to be a mat of sponge spicules in a calcareous groundmass. When leached of calcite it ranges in color on fresh breaks from white to an ivory or even apricot or darker color, depending on the amount of iron present. The weathered rock ranges from a friable tripoli to a minutely porous to compact blocky light colored rock which under the microscope is seen to be composed of cryptocrystalline silica. So far only a lithic basis exists for mapping the spiculite member separately. Neither it nor the overlying limestones has been searched for fossils. The spiculite in places rests directly on the Honeycut formation, and this is the highest member of the Marble Falls limestone (unrestricted) that rests on the Ellenburger rocks in this area.

The upper limestone member of the Marble Falls limestone (unrestricted) has not been examined in detail, being seen only while mapping the Cretaceous rocks around it on one side and the spiculite member on the other. The dark gray to grayish black limestones of the upper member are in part cherty and in part non-cherty, and some shale is present in the lower portion. Not enough is known about the spiculite member and the upper limestone member of the Marble Falls limestone in this area to correlate them with the members proposed by Plummer (1945).

Lower Cretaceous

Rocks of Lower Cretaceous age outcropping in the Johnson City area are given conventionally as follows: (1) Travis Peak formation—Sycamore sand (bottom), Cow Creek limestone, and Hensell (top) sand member; and (2) Glen Rose limestone. Mapping in the Johnson City area and to the west shows that the so-called Hensell sand member of the Travis Peak formation is really a shoreward facies of the Glen Rose limestone, but the present report does not disturb the conventional terminology.

The Sycamore sand member, the lowest unit of the Travis Peak formation, outcrops in the Johnson City area (Pl. 3) along the lower portion of Miller Creek and downstream from Miller Creek along Pedernales River. It is highly conglomeratic especially in the vicinity of Pedernales Falls, and downstream from Pedernales Falls the bed of the river is conglom-

erate for a considerable distance. The top of the Sycamore sand rises somewhat stratigraphically toward the uplift at the expense of the Cow Creek member, and in some places the Cow Creek member is entirely absent. Within the map area the Sycamore sand overlaps mostly rocks of Carboniferous age.

The Cow Creek limestone member of the Travis Peak formation outcrops almost continuously from Honeycut Hollow to the eastern boundary of the map and overlaps the top portion of the Honeycut formation and all of the Carboniferous within the map area. It is a fossil coquina in which the fossils are mostly poorly preserved and are bonded into a massive limestone bed which forms the most weather-resisting unit of the Trinity group. Along Pedernales River below Pedernales Falls to Colorado River and along Colorado River within its outcrop area, the Cow Creek limestone forms the lip of gorges and cliffs, and the overlying Hensell sand occupies a broad zone forming a wide bench.

The so-called Hensell sand member of the Travis Peak formation is really a basal facies of the Glen Rose limestone. It outcrops almost continuously throughout the map area except where high hills of Paleozoic rock extend upward into the normal or upper limestone facies of the Glen Rose limestone. The Hensell sand overlaps Paleozoic rocks within the map area from the top of the Cap Mountain limestone member of the Riley formation to the Carboniferous, and to the west of the map area it overlaps the rest of the Cambrian and some of the pre-Cambrian rocks. The Hensell sand is mostly poorly assorted clastic materials ranging from conglomerates at the base through silty and shaly sands to the overlying sandy, silty, and shaly Glen Rose limestone. The basal portion of the Hensell is reddish, the color rising stratigraphically as the ancient shore is approached. The top portion of the Hensell is gray and the boundary between the two color phases is an indistinct lateral as well as vertical transition.

The Glen Rose limestone of conventional usage occupies the higher ground of the map area, mostly around the edges. It is in contact with the Paleozoic rocks only in areas where pre-Cretaceous hills of Paleozoic rocks were unusually high. The Glen Rose limestone is an alternating series of hard but mostly impure limestone beds, with softer marly, shaly or sandy beds, which causes a characteristic stair-step topography. For ease in tracing the lower boundary of the Glen Rose limestone, the lip of the bottom stair-step, the tread of which is limestone, is included with the Glen Rose and the slope beneath is included with the Hensell sand. Occasionally the bottom stair-step is caused by a well cemented sand bed; and it is possible that in places the facies boundary has been drawn beneath one of these, inasmuch as this boundary has not been walked but has been drawn with the aid of a stereoscope between points checked at intervals of a mile or so in the field.

DESCRIPTION OF THE JOHNSON CITY COMPOSITE SECTION

Because of faulting, the section has been pieced, as shown on the correlation chart for the Llano uplift (Pl. 14). The lateral shifts and jumps over faults are explained in the description of the section, and the line of section is shown by chevrons pointing up in the section in Plates 12 and 13. The sections can hardly be mistaken on the ground if the maps and descriptions are used in following them. In most cases station numbers have been painted on rock surfaces, but these eventually fade. Cairns were used to mark stations on the Towhead Creek section. These have disappeared but the stations could easily be relocated from directions given.

Each section is credited to the persons involved. These include Bruce Harlton, of the Amerada Petroleum Company, and Leo Hendricks, Louis Dixon, L. E. Warren, and V. E. Barnes, of the Bureau of Economic Geology.

The section was started 25 feet above the Ellenburger strata, in order to include representative rocks of the Devonian, Mississippian, and Pennsylvanian, so that the user of this section will know what to expect above the Ellenburger in contiguous areas of the subsurface.

The Johnson City sections are all given in sequence from top to bottom, and the descriptive matter has been systematized but will probably not be in the order of importance for every user.

The location of the Scott Klett ranch section is not shown, except on the correlation chart (fig. 14). It is located along a drain which passes through the Scott Klett barnyard. The bottom of the section is near Pedernales River and extends to the overlying Cretaceous near the barnyard.

Downstream Honeycut Bend Section

Section 8-F, Honeycut Bend section (downstream segment), Blanco County, Texas; measured, described, and sampled by V. E. Barnes and L. E. Warren, July, 1944.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Pennsylvanian			
Marble Falls limestone (unrestricted)			
(Spiculite member—75 ± feet present, lower 5 feet only sampled.)			
1. Spiculite—microgranular (from spicule content), dark gray, breaks splintery, has a harsh feel and is fissile. Weathers to a lighter gray on bluff exposures and to an ivory, apricot, or even darker shade on gentle slopes. A thin section of this rock is crowded with sponge spicules, some of which are replaced by calcite, in a microgranular groundmass of calcite.	5	5	1315 –1320
(Lower biohermal limestone member—8.5 feet thick.)			
2. Limestone and shale—the limestone has an uneven rough fracture, is brownish gray near nutria, somewhat crinoidal, and is in a series of bioherms flanked by steeply dipping beds of similar limestone separated by beds of black shale. One lenticular bed of light gray crinoidal limestone truncates the steeply dipping beds at the top of the interval. Black shale, in addition to being interbedded with the bedded limestone between the bioherms, forms a continuous bed at the bottom of the interval and ranges between about 1 and 2 feet in thickness. Calcitic fossils are brachiopods and gastropods indicating a Morrow age. (Collections made by Dr. G. A. Cooper and the writers are in the U.S. National Museum.)	8.5	13.5	1306.5–1315
Mississippian			
Ives breccia: 1.5 feet thick			
3. Chert with some limestone—the chert is chalcedonic to subchalcedonic, mostly light brownish gray also ranging from light gray to old ivory, smooth fracturing and opaque to translucent, occurring as angular to subrounded pieces up to 6 inches or more in size, with some minor pockets of crinoidal, brownish gray limestone near nutria in color. Fossils are conodonts abundant in the limestone.	1.5	15	1305–1306.5
Devonian			
Stribling formation: 10 feet thick			
4. Limestone—microgranular, medium gray ranging to reddish buff and beige with about 2 inches at the base being old ivory in color, bedding very irregularly lenticular from almost fissile to 6 inches thick. Weathers uneven and to a medium gray. Chert chalcedonic to subchalcedonic and brownish to grayish in lower parts, occurring as irregular lenses and "false" joint fillings. Some lenticles of yellowish siliceous limestone come in about 1 to 2 feet above the base. The bottom foot is noncherty. Sand grains are common in the bottom 2 inches.	10	25	1295 –1305

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Fossils—see "Devonian of central Texas," Univ. Texas Pub. 4301, pp. 173–174.			
Shift southwest along the Devonian-Ordovician contact to a point west of a small fault and south of fossil locality 16T–2–43J.			
Ordovician: Ellenburger group			
Honeycut formation: 679 feet thick			
5. Limestone—sublithographic, light gray, beds range from 6 inches to 2 feet thick. Chert chalcedonic to subchalcedonic, semitranslucent and gray with an olive green cast, occurs as angular fragments except at top of interval where it is fossiliferous and present as large rough surfaces. Silicified fossils present on top ledge are *Hormotoma* sp., *Ceratopea* cf. *C. tennesseensis* Oder, and *Orospira* sp. (16T–2–43L). The top ledge is almost a *Hormotoma* coquina in which only a small portion of the fossils are silicified.	5	30	1290 –1295
6. Limestone—sublithographic, light gray, thickly bedded. Chert at 1280 feet, chalcedonic, crypto-oölitic, light gray to reddish buff, translucent, occurs as a 2-inch bed. Silicified fossils at 1285 feet are *Ceratopea* sp. poorly preserved (16T–2–43K), found to the northeast beneath the Stribling type section.	15	45	1275 –1290
7. Limestone—sublithographic, light gray with some thin seams of pinkish limestone, thickly bedded.	5	50	1270 –1275
8. Limestone—sublithographic, light gray with rust brown areas along small stylolites, thickly bedded. Intervals of "brecciation" are present 1 inch or less thick in which very small limestone fragments are cemented with clear calcite. Chert matrix sand and sand disseminated in limestone at base of interval is about ½ inch thick. Chert subchalcedonic, light gray to brownish gray, translucent; sand grains in chert weather in relief.	5	55	1265 –1270
9. Limestone—sublithographic, light gray, thickly bedded. Chert bed near base, chalcedonic, white to medium bluish gray, translucent, 1 inch thick. Fossils at 1259 feet are poorly preserved *Ceratopea* sp., which are only partly silicified and scarce (16T–2–43J).	13	68	1252 –1265
Station 41 (elevation 981) painted on *Ceratopea* bed.			
10. Limestone with paper-thin shaly partings—sublithographic, light greenish gray to pinkish, paper-thin to 1/16-inch bedding, weathers fissile and recessive.	1.5	69.5	1250.5–1252
11. Dolomite—microgranular, ivory to beige, in part mottled, medium bedded.	10.5	80	1240 –1250.5
12. Dolomite—medium to fine grained, pearl gray, medium bedded.	5	85	1235 –1240
13. Limestone—sublithographic, light gray, one bed.	2	87	1233 –1235
14. Limestone with minor streaks of dolomite—sublithographic, light gray, thickly bedded. Chert semiporcelaneous, white, opaque, smooth fracturing, occurs as nodules and fragments.	6	93	1227 –1233
15. Dolomite—fine grained ranging toward medium grained, mottled, from old ivory to mouse gray, medium bedded. Chert semiporcelaneous, white, opaque, smooth fracturing; occurs as nodules and fragments near the middle of the interval.	5.5	98.5	1221.5–1227
16. Limestone—sublithographic, light gray, medium to thickly bedded. Chert near top, semiporcelaneous, dark gray, fossiliferous, similar in texture to that of cannonball chert; occurs in a 3- or 4-inch layer.	5.5	104	1216 –1221.5

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base	
17. Dolomite—microgranular, beige, indistinctly bedded.	1	105	1215	–1216
18. Limestone—sublithographic, light gray, medium to thickly bedded.	4	109	1211	–1215
19. Dolomite—microgranular, upper part white to mouse brown and lower part yellowish gray to brownish gray, bedding indistinct.	10	119	1201	–1211
20. Limestone—sublithographic, light gray, medium to thickly bedded, becomes somewhat dolomitic laterally. Chert porcelaneous, snow white to brownish gray, smooth fracturing.	6	125	1195	–1201
Station 40 (elevation 982) at 1195 feet in section is painted on top of a *Ceratopea* bed. Shift northeast along *Ceratopea* bed across Pedernales River to Station 39.				
21. Limestone—sublithographic, light gray to brownish gray, thickly bedded, rhombs of dolomite sporadically distributed. Chert semiporcelaneous, white to light gray, opaque, smooth fracturing, cannonball type chert in top 2 feet. Silicified fossils in top portion of bed are numerous *Ceratopea keithi* Ulrich and rarely cephalopod siphuncles (16T–2–43I).	4	129	1191	–1195
Station 39 (elevation 987) is painted on top of the *Ceratopea* bed.				
22. Dolomite—medium grained, pearl gray to mouse gray, thickly but indistinctly bedded. Chert subchalcedonic to porcelaneous, white to beige, in part translucent, occurs as elongated, ellipsoidal, fractured and jointed masses.	2	131	1189	–1191
23. Limestone and dolomite—sublithographic, light gray to yellowish gray, lenticularly bedded limestone grading laterally into medium grained, light gray dolomite. Chert subchalcedonic to porcelaneous, greenish gray to white, in part translucent, occurs as elongated ellipsoidal, fractured and jointed masses.	4.5	135.5	1184.5	–1189
24. Limestone—sublithographic, light gray, fissile.	0.5	136	1184	–1184.5
25. Limestone and dolomite—sublithographic, yellowish gray "stromatolitic" limestone with some network, medium grained, similar colored dolomite. Chert subchalcedonic, white to yellowish gray, somewhat mottled, smooth fracturing, semitranslucent to translucent. Silicified fossils at 143 feet, *Ceratopea keithi* Ulrich (16T–2–43H).	8	144	1176	–1184
Station 38 (elevation 987) painted on top of bed.				
26. Dolomite—microgranular, sugary textured, ivory, thickly bedded, weathers to a superficially appearing chalky texture which, however, on close examination is seen to be granular.	3	147	1173	–1176
27. Limestone and dolomite—sublithographic, light gray, massive "stromatolitic-appearing" limestone with a network of medium grained dolomite in which the rhombs range from light gray to cinnamon. The deeper color where present is in the middle of the rhombs. Silicified fossils are *Ceratopea keithi* Ulrich (16T–2–43G).	8	155	1165	–1173
Station 37 (elevation 987) is painted on *Ceratopea* bed at 1168.5 feet in section.				
28. Dolomite—microgranular, yellowish gray, thickly bedded.	9	164	1156	–1165
29. Limestone and dolomite—sublithographic, light gray with a 3-inch pinkish mottled bed, top 6 inches is interlaced by medium grained dolomite, thinly bedded.	3	167	1153	–1156
30. Dolomite—microgranular, light gray, thickly bedded.	7	174	1146	–1153

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
31. Dolomite—microgranular, nutria to brownish gray, medium bedded with 6 inches at top chalky white and fissile. Chert porcelaneous to subchalcedonic, white to light gray, semitranslucent, occurs as flat and ellipsoidal masses along the bedding.	5	179	1141 –1146
Shift across a small fault having about 10 feet of displacement to same horizon.			
32. Limestone and dolomite—sublithographic, light gray, thickly bedded limestone with much brownish gray fine grained dolomite and some thin seams of pinkish medium grained dolomite. Laterally the bed changes entirely to dolomite. Chert porcelaneous to semichalcedonic, dirty white to medium gray, opaque to semitranslucent, smooth fracturing, occurs as masses along bedding planes and as large cannonballs.	5.5	184.5	1135.5–1141
33. Limestone—sublithographic, light gray, thickly bedded. Chert porcelaneous to semichalcedonic, dirty white to medium gray, opaque to semitranslucent, smooth fracturing, occurs as masses along bedding plane and as large cannonballs.	4.5	189	1131 –1135.5
34. Limestone—sublithographic, old ivory, top half—rounded "stromatolitic" masses, lower half—medium bedded to thickly bedded.	10.5	199.5	1120.5–1131
35. Limestone—sublithographic, mottled in dull orange reds, medium to thickly bedded. Chert porcelaneous, white, smooth fracturing.	4	203.5	1116.5–1120.5
36. Limestone—sublithographic, old ivory, thickly bedded. Top 1.5 feet contains beekite, a quartzose chert replacing fossils. Silicified fossils are *Ceratopea keithi* Ulrich (16T–2–43F; also TF–269).	3.5	207	1113 –1116.5
Station 36 (elevation 988) is painted on upper surface of *Ceratopea* bed at 1116.5 feet in section.			
37. Limestone—sublithographic, dull orange red mottled by pink, medium bedded. Some beds contain scattered dolomite rhombs.	7	214	1106 –1113
38. Limestone—sublithographic, light gray, thickly bedded. Silicified fossils are *Ceratopea keithi* Ulrich (16T–2–43E).	7	221	1099 –1106
Station 35 (elevation 991) is painted on upper surface of *Ceratopea* bed at 1101 feet in section.			
39. Limestone and dolomite—sublithographic, light gray limestone, with much network medium grained orange red dolomite. Grades to dolomite laterally.	2	223	1097 –1099
40. Covered—topographic expression suggests very thin bedded fissile limestone.	2	225	1095 –1097
41. Limestone—sublithographic, light gray, medium bedded.	2	227	1093 –1095
42. Limestone and dolomite—sublithographic, pinkish, thinly bedded, contains disseminated dolomite rhombs of about the same color. Chert subchalcedonic to chalcedonic, opaque to semitranslucent, maroon with minor greenish streaks. Dolomite rhombs occur in thin zones in the chert.	2	229	1091 –1093
43. Limestone—sublithographic, alternating yellowish gray and brown, thinly bedded. Chert oölitic, dirty brown, translucent.	5	234	1086 –1091
44. Limestone—sublithographic, light gray.	1	235	1085 –1086
45. Dolomite—fine to medium grained, mouse gray. Chert at top of interval white, weathered chalky.	1	236	1084 –1085
46. Limestone—sublithographic, mottled light gray with 1-inch reddish bed at top, thinly bedded.	1.5	237.5	1082.5–1084
47. Limestone—sublithographic, light gray, medium bedded.	1.5	239	1081 –1082.5

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
48. Limestone, some dolomite—limestone sublithographic, light gray, thickly bedded, with yellowish, medium grained dolomite network. Silicified fossils are *Ceratopea* or crushed siphuncle (16T–2–43D).	5	244	1076 –1081
Station 34 (elevation 992) painted on *Ceratopea* bed at 1078 feet in section.			
49. Dolomite—medium grained, light gray to yellowish gray, thickly bedded. Laterally it changes to limestone.	5	249	1071 –1076
50. Dolomite—microgranular, yellowish gray, mottled, medium bedded.	10	259	1061 –1071
51. Dolomite—microgranular, brownish gray to old ivory, medium bedded, has a petroliferous odor. Chert in small nodules, white, weathered chalky.	2.5	261.5	1058.5–1061
52. Dolomite—medium grained, light gray, thickly bedded, becomes calcareous laterally.	2.5	264	1056 –1058.5
53. Dolomite—microgranular, light gray becoming darker in lower 5 feet, ranging from yellowish to brownish gray, mottled, medium to thickly bedded. Silicified fossils in chert are abundant at about 1040 feet in section along strike 300 feet to the north. Fossils are *Orospira* sp., *Ceratopea keithi*, *Tarphyceras* cf. *T. chadwickense* Ulrich, Foerste, Miller, and Furnish, and "*Ophileta*" sp. (TF–268).	25	289	1031 –1056
54. Dolomite—microgranular, beige to nutria, mottled, medium bedded. Chert subchalcedonic, translucent to opaque, dirty white or brownish, has minute variation in translucency suggesting pellets. Zones crossing the chert appear to be mylonite in which the chert fragments are varicolored,	3	292	1028 –1031
55. Limestone—sublithographic, light gray, fissile to thinly bedded. Chert in lower 2 feet porcelaneous, white, semitranslucent, smooth fracturing, and in top foot dirty white, weathers chalky.	3	295	1025 –1028
56. Dolomite—microgranular, light gray to beige with some in lower part approaching yellow ochre, mottled, medium bedded. Chert porcelaneous, dirty white to white, weathers chalky, occurs as irregular jointed masses.	8	303	1017 –1025
57. Dolomite—medium to fine grained, pearl gray to yellowish gray, medium bedded.	9.5	213.5	1007.5–1017
58. Limestone—sublithographic, light gray, thickly bedded. Grades to dolomite laterally. Silicified fossils are *Orospira* sp., cephalopod siphuncle, and *Ceratopea* sp. (16T–2–43C).	2.5	315	1005 –1007.5
Station 33 (elevation 995) painted on top of limestone bed. Shift north 600 feet along strike of rather poorly defined beds and continue section in a northwest direction. There is room for error of possibly as much as 5 feet either way in making this shift.			
59. Dolomite—microgranular, nutria with small light gray mottlings, medium bedded.	2	317	1003 –1005
60. Dolomite—microgranular, nutria, medium bedded. Chert subchalcedonic to porcelaneous, white, slightly translucent, occurs as plates.	2.5	319.5	1000.5–1003
61. Dolomite—medium grained, pearl gray, one bed.	1	320.5	999.5–1000.5
62. Dolomite—microgranular to fine grained, nutria to yellowish gray, mottled, medium bedded.	9.5	330	990 – 999.5
63. Dolomite—microgranular to fine grained, nutria, medium bedded. Chert subchalcedonic, dirty white, semitranslucent, occurs as elongated nodules.	5	335	985 – 990

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
64.	Dolomite—microgranular, brownish gray, medium bedded in upper half, lower half not exposed. Chert in place porcelaneous, dirty white. Cannonball chert float abundant throughout interval.	5	340	980 – 985
65.	Dolomite—microgranular, yellowish gray, medium bedded. Chert porcelaneous, white, smooth fracturing.	5	345	975 – 980
66.	Dolomite—microgranular, shades near nutria, medium bedded, lower part has petroliferous odor.	15	360	960 – 975
67.	Dolomite—microgranular, nutria, medium bedded. Chert porcelaneous to subchalcedonic, dirty white to gray, opaque to translucent, occurs as nodules and flat plates.	5	365	955 – 960
68.	Dolomite—microgranular, shades of brownish gray, mottled, medium bedded.	5	370	950 – 955
69.	Dolomite—microgranular, nutria, medium bedded. Chert chalcedonic to semiporcelaneous, dirty white to cinnamon brown, opaque to translucent, contains some sponge spicules.	10	380	940 – 950
70.	Dolomite—microgranular, brownish gray to nutria, mottled, medium bedded. Chert chalcedonic to porcelaneous, dirty white to gray, opaque to translucent, occurs as elongated chalky appearing nodules in upper part and scattered 1- to 1½-inch round white nodules in lower part.	10	390	930 – 940
71.	Dolomite—microgranular, old ivory to dark gray, medium bedded. Chert chalcedonic to porcelaneous, dirty white to light gray and nutria, opaque to translucent, occurs as angular masses having a chalky textured exterior.	5	395	925 – 930
72.	Dolomite—microgranular, old ivory, medium bedded.	5	400	920 – 925
73.	Dolomite—microgranular, old ivory to nutria being darker toward the base, medium bedded. Chert chalcedonic to porcelaneous, dirty white to light gray and nutria, opaque to translucent, some banded chert near the middle, occurs as angular masses having a chalky textured exterior.	15	415	905 – 920
74.	Dolomite—microgranular, brownish gray to yellowish gray, medium bedded.	5	420	900 – 905
75.	Dolomite—microgranular, brownish gray, poorly exposed. Chert not seen in place, but cannonball type float common in interval. (This interval is in a long strike opening in the cedar followed by a cattle trail and open enough for automobile driving.)	5	425	895 – 900
76.	Dolomite—microgranular to fine grained, nutria, in part mottled, medium bedded. Chert chalcedonic, white to light bluish gray, translucent, occurs as small angular fragments.	5	430	890 – 895
77.	Dolomite—fine grained with some fine to medium grained in bottom 5 feet, light gray, medium bedded.	18	448	872 – 890
78.	Dolomite—microgranular, light gray, mottled with cinnamon, medium bedded. Chert chalcedonic, dirty white to bluish gray, opaque to translucent, weathers chalky, occurs as small irregular nodules.	2	450	870 – 872
79.	Dolomite—fine grained, nutria and some yellowish gray, medium bedded. Chert dirty white, weathers chalky.	5	455	865 – 870
80.	Dolomite—fine grained approaching medium grained toward bottom; nutria at top, yellowish gray in middle and pearl gray at the bottom, all mottled; medium bedded.	15	470	850 – 865
81.	Dolomite—microgranular, mottled light gray and cinnamon, medium bedded. Chert white, weathers chalky.	5	475	845 – 850

Description	Thickness in feet. Interval	Cumulative	Feet above base
82. Dolomite—microgranular, brownish gray to yellow beige, medium bedded.	5	480	840 – 845
83. Dolomite—microgranular, brownish gray to nutria, medium bedded. Chert porcelaneous, porous, dirty white to nutria, weathers chalky, occurs as rounded to ellipsoidal cannonballs.	5	485	835 – 840
84. Limestone and dolomite—sublithographic, light gray, thickly bedded limestone in part with network of medium grained dolomite. Laterally the bed changes entirely to dolomite. Silicified fossils are *Ceratopea robusta* Oder and cephalopod siphuncles (16T–2–42D).	5	490	830 – 835
Station 29 (elevation 1002) painted on *Ceratopea* bed at 831 feet in section. The shift to the Rough Hollow section, 6000 feet to the southwest, was made using this bed. Some additional section below this bed is described (using letters for interval designation) as well as some above this bed in the Rough Hollow section.			
A. Limestone—sublithographic, medium gray to nutria, thinly bedded to fissile, contains some coarse grained calcite veinlets. Chert subchalcedonic to semiporcelaneous, white, faintly translucent, contains small pellets, occurs as small white ellipsoidal nodules along one bedding plane.	2.5	492.5	827.5– 830
B. Dolomite—microgranular, in part alternate bands of beige and cinnamon and in part near old ivory, medium bedded.	2.5	495	825 – 827.5
C. Limestone—sublithographic, between medium gray and nutria, very thin to thinly bedded, beds not over 1 inch thick. Chert subchalcedonic, yellowish gray, feebly translucent, contains breccia zones resembling mylonite, occurs as weathered, dirty white, irregular masses along bedding planes.	2	497	823 – 825
D. Dolomite—fine grained, light gray to brownish gray, medium bedded.	3	500	820 – 823
E. Dolomite—medium grained, nutria mottled with light gray, medium bedded.	1	501	819 – 820
F. Limestone and dolomite—sublithographic, yellowish gray, massive, contains network of medium grained dolomite. Chert variable from porous, weathered chalky, dirty white incipient cannonballs to brittle, nonporous, subporcelaneous to subchalcedonic, translucent, light brown, jointed and fractured masses.	2.5	503	816.5– 819
G. Dolomite—microgranular, yellowish gray in upper part to medium gray in lower part, medium to thickly bedded. Chert porcelaneous to subchalcedonic, in part quartzose, weathers chalky, white to gray banded with brown, opaque to translucent, occurs as elongated ellipsoidal masses in upper part, and as angular nodules, fragments, and ropy masses in lower part.	11.5	515	805 – 816.5
Station 28 (elevation 1006) painted on dolomite ledge at 808 feet in section.			
H. Limestone and dolomite—limestone sublithographic, light gray, massively bedded, contains network of medium grained dolomite. Grades laterally into nutria, medium grained dolomite. Chert semichalcedonic, dirty white to yellowish gray, weathers chalky, opaque to feebly translucent, contains sponge spicules. Some skeletal cannonball chert is present. Silicified fossils are *Archaeoscyphia* sp., cephalopod siphuncles, and one *Ceratopea* sp. The *Ceratopea* was lost while trying to collect it. Many *Archaeoscyphia* sp. in this bed are of limestone preservation.	4	519	801 – 805

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
I.	Dolomite—microgranular, brownish gray, medium to thickly bedded. Chert chalcedonic to semiporcelaneous, white and milky white to gray and brownish gray, semitranslucent, smooth fracturing, occurs as large white nodules 4 to 6 inches in diameter.	11	530	790 – 801

Rough Hollow Section

Section 8-E, Rough Hollow section. Measured, described, and sampled by V. E. Barnes and L. E. Warren, August, 1944. The cumulative thickness and feet above base are referenced to the Honeycut Bend section.

J.	Limestone—sublithographic, light gray, thickly bedded. Chert at top, porcelaneous, white, occurs as elongated finger-like nodules and anastomosing patterns. Silicified fossils are *Ceratopea* sp. 5, *Ceratopea* sp. 4, *Archaeoscyphia* sp., *Ophileta* (?) sp., and tarphycerid cephalopod (16T–2–51C). This collection was made 1500 feet along the strike to the northeast.	3.5	424.5	895.5– 899
K.	Covered—probably fine grained dolomite.	1.5	426	894 – 895.5
L.	Dolomite—fine grained, yellowish gray, medium bedded.	1.5	427.5	892.5– 894
M.	Covered—probably dolomite.	12.5	440	880 – 892.5
N.	Dolomite—microgranular, light gray.	1	441	879 – 880
O.	Covered—probably dolomite.	4	445	875 – 879
P.	Limestone and dolomite—sublithographic, light gray limestone, alternating with fine grained beige dolomite which weathers in relief, thinly bedded, approaching fissile.	3	448	872 – 875
Q.	Dolomite—fine to medium grained, mottled light gray and nutria, poorly exposed.	3	451	869 – 872
R.	Dolomite and limestone—fine grained, light gray dolomite, and sublithographic, light gray limestone with network of beige, fine grained dolomite, poorly exposed.	5	456	864 – 869
S.	Dolomite—fine to medium grained, mottled white to light gray and brownish gray.	2±	458	862 – 864
T.	Dolomite—microgranular to fine grained, light gray. Chert subchalcedonic, translucent, white to light gray, smooth fracturing, contains abundant fossil fragments.	3±	461	859 – 862
U.	Limestone—sublithographic, medium gray. Silicified fossils are cephalopod siphuncles.	2	463	857 – 859
V.	Dolomite—medium to fine grained, mottled beige and nutria. Chert semiporcelaneous, oölitic, light gray, smooth fracturing.	1	464	856 – 857
W.	Limestone—sublithographic, medium gray.	1.5	465.5	854.5– 856
X.	Dolomite—predominantly microgranular, light gray to reddish buff, with some fine to medium grained, mottled white to yellowish gray. Chert in top bed, white, weathers chalky, occurs as anastomosing and finger-sized pieces.	6.5	472	848 – 854.5
Y.	Dolomite—fine to medium grained, mottled pearl gray to nutria. Chert semiporcelaneous, dirty white to brownish gray, occurs as flattened cannonballs. Fossil remnants and breccia-like fragments are scattered throughout.	5.5	477.5	842.5– 848
Z.	Limestone and dolomite—sublithographic, medium gray to brownish gray, thickly bedded limestone with some network beige dolomite, grading down into fine grained, mottled, dark gray and old ivory, thickly bedded dolomite. The limestone also changes to dolomite laterally. Chert subchalcedonic to porcelaneous, white to gray to brown, semitranslucent, occurs as fragments and nodules.	5	482.5	837.5– 842.5

Description	Thickness in feet: Interval	Cumulative	Feet above base
84. Limestone—sublithographic, light to medium gray, thickly bedded. Silicified fossils at 831 feet are *Ceratopea robusta* Oder and cephalopod siphuncles (16T–2–51D), collected along strike 900 feet to northeast. This is the tie point with the Honeycut Bend section.	8.5	491	829 – 837.5
85. Dolomite—microgranular, light gray to old ivory. Chert chalky textured, white, occurs as small nodules.	5	496	824 – 829
86. Dolomite—microgranular, light gray.	10	506	814 – 824
87. Limestone and dolomite—limestone sublithographic, light gray grading into fine to medium grained dolomite of a brownish gray. Chert porcelaneous, white to light gray, concentrically banded and in nodules up to 1 foot in diameter.	1.5	507.5	812.5– 814
88. Limestone—sublithographic, light gray.	2.5	510	810 – 812.5
89. Dolomite and limestone—microgranular to very fine grained light gray to beige dolomite which changes laterally into sublithographic limestone. The entire interval is fissile and breaks into concave-upward saucer-like plates similar to areas between mud cracks.	5	515	805 – 810
90. Dolomite and limestone—microgranular, yellowish gray to brownish gray dolomite which upon weathering splits into thin plates. Along the strike the interval contains various amounts of limestone and in places is entirely limestone. A fresh surface shows closely spaced bedding planes. Chert chalk textured, white, occurs as nodules.	6	521	799 – 805
91. Dolomite—microgranular, yellowish gray and thickly bedded. Becomes calcareous and changes into sublithographic light to medium gray limestone along strike. Chert chalcedonic to porcelaneous, light gray to white, subtranslucent, occurs as white weathering nodules.	5	526	794 – 799
Shift 1400 feet northeast along strike along limestone bed containing cannonball chert and *Archaeoscyphia*. Continue section in northwestward direction.			
92. Limestone—sublithographic, brownish gray, thickly bedded, and some of the limestone is made up of limestone fragments in a clear calcite matrix. Chert subchalcedonic, medium gray, weathers white, occurs both as cannonballs and as silicified sponges. The chert contains many spicules. Silicified fossils are *Archaeoscyphia* sp. and cephalopod siphuncles.	3	529	791 – 794
93. Dolomite—fine grained, nutria.	1	530	790 – 791
94. Limestone—sublithographic, light to medium gray, thickly bedded. Chert subchalcedonic to semiporcelaneous, dirty white, occurs as both cannonballs and silicified sponges. Silicified fossils are *Archaeoscyphia* sp.	3	533	787 – 790
95. Dolomite—microgranular, near pearl gray.	7	540	780 – 787
96. Dolomite—microgranular, yellowish gray. Chert chalcedonic light to medium gray, smooth fracturing, jointed, occurs as large nodules and cross cutting masses.	5	545	775 – 780
97. Limestone—sublithographic, nutria, medium to thinly bedded. Chert chalcedonic, brownish gray, occurs as elongated anastomosing masses along one bedding plane.	1	546	774 – 775
98. Limestone—sublithographic, nutria, thickly bedded. Silicified fossils are *Archaeoscyphia* sp.	2.5	548.5	771.5– 774
99. Limestone—sublithographic, nutria, medium to thinly bedded. Chert chalcedonic, brownish gray, occurs as nodules.	1.5	550	770 – 771.5

	Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
100.	Limestone—sublithographic, yellowish gray, thickly bedded. Chert chalcedonic to porcelaneous, white to light gray, smooth fracturing. One layer of chert is oömoldic and some near the top of the interval contains sponge spicules. Silicified fossils are *Ceratopea capuliformis* Oder, *Archaeoscyphia* sp., and cephalopod siphuncles (16T–2–51F), located at 770 feet in section.	5	555	765 – 770
101.	Limestone—sublithographic, brownish gray, thickly bedded. Chert subchalcedonic, mottled, near nutria, occurs as small round nodules.	1	556	764 – 765
102.	Limestone and dolomite—sublithographic, light gray to yellowish gray and brownish gray, thinly to very thickly bedded with some very thin dolomite beds. Chert subchalcedonic to semiporcelaneous, white to brownish gray, subtranslucent, occurs as nodules.	9	565	755 – 764
103.	Dolomite—microgranular to fine grained, light gray to beige fragments in a nutria groundmass, medium bedded.	2	567	753 – 755
104.	Limestone—sublithographic, nutria, thickly bedded, contains a network of fine grained, nutria dolomite. Chert subchalcedonic, nutria, occurs both as rough fracturing cannonballs and smooth fracturing flat masses.	8	575	745 – 753
105.	Limestone—sublithographic, light gray.	3	578	742 – 745
106.	Dolomite—fine to medium grained, light gray to old ivory.	2	580	740 – 742
107.	Limestone—sublithographic, light to medium gray.	2	582	738 – 740
108.	Dolomite—microgranular to fine grained, brownish gray.	3	585	735 – 738
109.	Dolomite—microgranular, brownish gray to tan, medium bedded. Chert subchalcedonic to semiporcelaneous, in part weathers chalky, occurs as nodules.	2	587	733 – 735
110.	Limestone—sublithographic, light gray, thickly bedded. Chert subchalcedonic, light gray, occurs as large cannonballs.	2	589	731 – 733
111.	Limestone and dolomite—limestone sublithographic, nutria or slightly lighter, very thinly bedded, cusped as if wave marked, separated by very thin dolomite beds. Chert chalcedonic, brown to nutria, has smooth conchoidal fracture.	6	595	725 – 731
112.	Limestone—sublithographic, light gray, thickly bedded.	5	600	720 – 725
113.	Limestone—sublithographic, light gray, thickly bedded, stromatolitic. Chert semiporcelaneous to chalcedonic, banded white to bluish white, semitranslucent to opaque.	5	605	715 – 720
114.	Limestone—sublithographic, light to medium gray, thickly bedded.	2	607	713 – 715
115.	Limestone—sublithographic, light to medium gray, very thinly bedded, weathers recessive.	2	609	711 – 713
116.	Limestone—sublithographic, light gray, thickly bedded.	2	611	709 – 711
117.	Dolomite and limestone—sublithographic, light gray limestone transitional to medium grained light gray dolomite.	1	612	708 – 709
118.	Dolomite—medium grained, light gray, medium bedded.	3	615	705 – 708
119.	Dolomite—medium grained, pearl gray, medium bedded. Chert porcelaneous, white, has dolomite rhombs scattered throughout.	5	620	700 – 705
120.	Dolomite—fine grained to very fine grained near bottom, yellowish gray to reddish buff, medium bedded.	10	630	690 – 700
121.	Dolomite—fine grained, nutria. Chert subchalcedonic, brown, smooth fracturing. It is intimately interbedded as thin seams with the dolomite.	0.5	630.5	689.5– 690

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
122.	Limestone—sublithographic, slightly lighter than nutria, thinly to very thinly bedded. One 6-inch bed near the center of the interval is light gray in color.	5.5	636	684 – 689.5
123.	Limestone—sublithographic, between slate gray and nutria, thickly bedded. Silicified fossils are *Ceratopea* sp. 1 (16T–2–51E). This collection was made 2200 feet southwest along the strike and just south of the Johnson City road.	2.5	638.5	681.5– 684
124.	Limestone and dolomite—sublithographic, slate gray to nutria, medium to thinly bedded. has a network of fine grained dolomite. Chert quartzose granular to chalcedonic, white, occurs as rough inch-sized nodules, also cannonball chert subgranular, nutria, opaque. Silicified fossils are *Archaeoscyphia* sp.	1.5	640	680 – 681.5
125.	Dolomite—fine grained, yellowish gray. Chert chalcedonic, light brown to dirty gray, smooth fracturing, occurs as angular fragments. Some quartzose granular white chert nodules are present.	1	641	679 – 680
126.	Dolomite—medium grained, woodash gray.	1	642	678 – 679
127.	Limestone—sublithographic, light gray.	1	643	677 – 678
128.	Dolomite—medium grained, woodash gray.	2	645	675 – 677
129.	Dolomite—fine grained, mottled yellowish gray and nutria.	1	646	674 – 675
130.	Limestone—sublithographic, light gray, thickly bedded.	3	649	671 – 674
131.	Limestone—oölitic, light gray. Chert subchalcedonic, nutria and darker colored, oölitic, occurs as a bed 4 inches thick.	1	650	670 – 671
132.	Limestone and dolomite—sublithographic, medium gray, medium bedded limestone at top becoming more dolomitic and thin bedded toward bottom. The dolomite is fine to medium grained. Chert porcelaneous to chalcedonic to finely quartzose granular, white to brown, smooth fracturing, weathers chalky at surface.	5.5	655.5	664.5– 670
133.	Dolomite—microgranular, brown, medium bedded. Chert quartzose, granular, white, occurs as excrescences in lower 6 inches.	4.5	660	660 – 664.5
134.	Dolomite—microgranular and light gray, to fine grained and brown, thickly bedded. Chert breccia with small fragments of porcelaneous white to light gray chert in a matrix of clear fine grained quartzose chert, occurs as two beds in top 6 inches.	2.5	662.5	657.5– 660
135.	Limestone—sublithographic, light to medium gray, very thinly bedded, has splintery fracture.	0.5	663	657 – 657.5
136.	Limestone—sublithographic, mottled light to medium gray, thickly bedded.	2	665	655 – 657
137.	Dolomite—fine grained, mottled and streaked brown, thickly bedded. Chert semiporcelaneous, white with gray banding, subtranslucent, occurs as nodules.	2.5	667.5	652.5– 655
138.	Limestone—sublithographic, light to medium gray, stromatolitic, thickly bedded. Chert subchalcedonic to semiporcelaneous, brownish gray, nearly opaque, fossiliferous, occurs as large cannonballs. Fossils in chert are trilobites.	2.5	670	650 – 652.5
Sand disseminated in a very thin bed marks the base of the interval. Shift 6800 feet to the northeast across a fault zone and north of the Pedernales River and continue downward in section to the west.				

Upstream Honeycut Bend Section

Section 8-D, Honeycut Bend section (upstream segment), measured, described, and sampled by V. E. Barnes and L. E. Warren, July, 1944.

	Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
139.	Covered—float is fine grained dolomite with chert matrix sand and oölitic chert near the top of the interval. This interval is also covered below the Rough Hollow section and elsewhere in the Honeycut Bend area.	8	678	642 – 650
140.	Dolomite—microgranular, mottled yellowish gray and old ivory. Chert subchalcedonic to semiporcelaneous, banded dirty white to brownish gray, semitranslucent, smooth fracturing, occurs as concretionary masses.	3	681	639 – 642
141.	Limestone—sublithographic, light to medium gray, thinly to medium bedded. Chert subchalcedonic to semiporcelaneous, banded dirty white to brownish gray, semitranslucent, smooth fracturing, occurs as concretionary masses.	2.5	683.5	636.5– 639
142.	Dolomite and sand—fine grained, light gray to brownish gray. Sand is distributed throughout the dolomite.	0.5	684	636 – 636.5
143.	Dolomite and limestone—fine grained mottled yellowish gray and nutria dolomite with a calcareous zone above the middle containing a strong network of dolomite.	11.5	695.5	624.5– 636
144.	Limestone and sand—brownish gray limestone full of sand grains.	0.5	696	624 – 624.5
145.	Limestone—sublithographic, medium gray, thickly bedded.	2	698	622 – 624
146.	Dolomite and limestone—microgranular to very fine grained, mottled between light gray and beige, medium bedded. This interval contains a small amount of medium gray limestone and laterally becomes more calcareous.	5	703	617 – 622
147.	Dolomite and sand—medium gray dolomite full of sand.	1	704	616 – 617
	Station 23 (elevation 1097) painted on upper surface of sand.			
	Gorman formation: 490 feet thick			
	Calcitic facies: 246 feet thick			
148.	Limestone—sublithographic, medium gray, thickly bedded. Chert subchalcedonic to porcelaneous, white to medium gray, occurs as a reticulated pattern as if filling mud cracks or the space around stromatolites.	3	707	613 – 616
149.	Limestone and dolomite—sublithographic, yellowish gray, thickly bedded, contains a network of medium grained dolomite. Sand is located at the top of the interval as a thin network pattern in the limestone.	5	712	608 – 613
150.	Limestone—sublithographic, yellowish gray, thickly bedded. Chert porcelaneous, white, has a hackly fracture, occurs in bottom foot. A 6-inch sand zone is located at the top.	11	723	597 – 608
151.	Dolomite—microgranular to fine grained, between light gray and yellowish gray, thickly bedded.	6	729	591 – 597
152.	Limestone and dolomite—limestone sublithographic, yellowish gray, thickly bedded, contains a strong network of brownish dolomite, and scattered rhombs of dolomite. Grades laterally into dolomite.	8	737	583 – 591
153.	Limestone and dolomite—limestone sublithographic, yellowish gray, thickly to thinly bedded, contains a network of fine grained dolomite. Chert subchalcedonic, white to light gray, contains some sand. Sand in top layer of limestone and in chert. Silicified fossils are numerous *Lecanospira* sp.	5	742	578 – 583

	Description	Thickness in feet Interval	Cumulative	Feet above base
154.	Limestone and dolomite—limestone sublithographic, yellowish gray, thickly to thinly bedded, contains a network of fine grained dolomite and scattered rhombs of dolomite. Chert subchalcedonic, white to dark gray, banded, translucent, occurs as nodules and anastomosing patterns.	5	747	573 – 578
155.	Limestone—sublithographic, yellowish gray, in part mottled, thickly bedded. Chert in bottom 4 feet of interval subchalcedonic, white to dark gray, banded, translucent, occurs as nodules and anastomosing patterns. Chert at 572 feet oölitic, white to beige. Silicified fossils at 568 to 570 feet are *Diaphelasma pennsylvanicum*, *Lecanospira* sp., cephalopod siphuncle, and unidentified ribbed brachiopod (16T–2–42E).	14	761	559 – 573
156.	Covered—probably dolomite.	3	764	556 – 559
157.	Dolomite—microgranular, light gray, fine grained, reddish buff in top 5 feet; microgranular, brownish, gray in rest of interval, thickly bedded.	10.5	774.5	545.5– 556
158.	Limestone—sublithographic, medium gray, medium bedded. Chert porcelaneous to chalcedonic, white to light bluish gray, translucent, concentrically banded, occurs as large white ellipsoidal nodules.	2.5	777	543 – 545.5
159.	Limestone and dolomite—sublithographic, medium gray limestone with strong network of fine grained light gray dolomite at top becoming more dolomitic toward bottom. Bottom 2 feet is a calcareous yellow beige dolomite. The limestone all grades laterally to a mottled dolomite. Top medium to thinly bedded and bottom thinly (1 inch and less) bedded. Chert subchalcedonic, light gray to light brown, translucent, concentrically banded, occurs as small white nodules.	10	787	533 – 543
160.	Limestone—sublithographic, yellowish gray to brownish gray, thickly bedded. Chert semiporcelaneous, dirty white, occurs as excrescences and massive plates containing many fossils. Also porous, weathered chalky, rounded chert nodules are common. Silicified fossils are *Diaphelasma oklahomense* Ulrich and Cooper and *Lecanospira* sp. (16T–2–42C).	6	793	527 – 533
	Station 22 (elevation 1062) is painted on the top of the *Diaphelasma* bed in the road 200 feet north of the section.			
161.	Dolomite—fine grained, nutria to brown, medium bedded. Chert subchalcedonic, white to nutria, translucent, has concentric banding, occurs in lower 2 feet.	6	799	521 – 527
162.	Dolomite—fine grained to microgranular, brownish gray, contains scattered sand grains.	1.5	800.5	519.5– 521
163.	Dolomite—fine grained, nutria, mottled.	1.5	802	518 – 519.5
164.	Dolomite—microgranular, light gray to cinnamon pink at top and brownish gray in bottom half, thickly bedded. Chert weathered chalky, white, present in lower half as thin excrescences.	10	812	508 – 518
165.	Dolomite—fine grained, yellowish gray, medium bedded.	2	814	506 – 508
166.	Limestone—sublithographic, yellowish gray, thickly bedded. Chert chalcedonic to porcelaneous, white to yellowish gray to bluish gray, semitranslucent, occurs as thick plates and nodules.	3	817	503 – 506
167.	Limestone and dolomite—a breccia composed of limestone and fine grained dolomite fragments in a medium grained dolomite matrix. Sand is scattered throughout in small pockets and masses.	1	818	502 – 503

	Description	Thickness in feet Interval	Cumulative	Feet above base
168.	Limestone—sublithographic, light gray, thinly bedded. Chert semiporcelaneous, white to dirty white to light gray, occurs as masses along the bedding. The chert near the top of the interval is brecciated.	4	822	498 – 502
169.	Dolomite—microgranular with a few beds that are fine grained, light gray somewhat mottled with reddish buff, thickly bedded.	15	837	483 – 498
170.	Dolomite—microgranular, yellowish gray, thickly bedded. Chert subchalcedonic, white to dirty white to light gray, occurs as masses along the bedding. Sand is disseminated through the middle foot of the interval.	5	842	478 –483
171.	Limestone and dolomite intergradational—limestone sublithographic, light to medium gray and dolomite microgranular, nutria or darker. The dolomite has a petroliferous odor. Chert chalcedonic to semiporcelaneous, white to light gray, occurs as masses along the bedding.	5	847	473 – 478
172.	Dolomite—microgranular, brownish gray to brown, thickly bedded, upper 2 inches calcareous and reticulated with dolomite. Chert chalcedonic to semiporcelaneous, white to light gray, semitranslucent, occurs as masses along the bedding.	5	852	468 – 473
173.	Limestone—sublithographic, yellowish gray, thickly bedded.	1	853	467 – 468
174.	Dolomite—microgranular, light gray, old ivory, brownish gray and similar colors, mottled, thickly bedded. Chert in top 4 feet porcelaneous to chalky textured, white to dirty white, translucent, has brownish inclusions some of which resemble bubbles and others small mudballs. Some dolomolds are present. Sand is concentrated in the basal 2 inches of the interval.	9.5	862.5	457.5– 467
	Station 21 (elevation 1011) is painted on top of the sand bed. Continue section along edge of flat upstream.			
175.	Limestone—sublithographic, light to medium gray, thickly bedded.	2	864.5	455.5– 457.5
176.	Dolomite—microgranular, mottled light gray to nutria, thickly bedded.	5.5	870	450 – 455.5
177.	Dolomite—medium grained, pearl gray. Chert chalcedonic, white, semitranslucent.	2	872	448 – 450
178.	Dolomite—microgranular, mottled light gray, old ivory, and reddish buff, thickly bedded. Chert chalcedonic, white to light gray, translucent, occurs as flat masses along the bedding. Sand very fine grained is disseminated through the lower 2 inches.	10	882	438 – 448
179.	Limestone—sublithographic, light gray to yellowish gray, medium to thinly bedded, bottom 5 feet mottled. Chert at 423 to 428 feet subchalcedonic, white to dark gray, translucent, has very closely spaced joints. Chert at 428 to 433 feet is the same except that it is oölitic. Sand 4 inches thick at 443 feet passes laterally into a chert matrix sand.	20	902	418 – 438
180.	Limestone—oölitic, light gray, medium bedded. The oölites give the limestone a medium grained appearance. Chert chalcedonic, white to caramel, translucent, layered.	2	904	416 – 418
181.	Limestone—sublithographic, yellowish gray to brownish gray, mottled, thickly bedded.	10	914	406 – 416
182.	Dolomite—microgranular, light gray, very thinly bedded. Chert chalcedonic to porcelaneous, white to light gray, translucent, layered.	1	915	405 – 416

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
183.	Limestone—sublithographic, light gray, thickly to thinly bedded. Chert granular to semiporcelaneous, dirty white to brownish, occurs as nonfossiliferous cannonballs.	7	922	398 – 405
184.	Dolomite—microgranular to fine grained, light gray, thickly bedded. Chert dolomoldic, dirty white, occurs as thin coatings on dolomite surfaces.	2	924	396 – 398
185.	Covered.	1	925	395 – 396
186.	Limestone—sublithographic, light to medium gray, somewhat mottled, thickly bedded.	7	932	388 – 395
187.	Limestone and dolomite—sublithographic light to medium gray, thickly to thinly bedded, grades laterally into fine grained dolomite. Chert porcelaneous to subchalcedonic, white to gray to brown, layered, contains some dolomite rhombs being slightly dolomoldic near weathered surface. Occurs in 2-inch thick masses along bedding planes.	5	937	383 – 388
	Station 20 (elevation 1014) is painted on top of surface of next interval down (*Archaeoscyphia* zone). Shift along *Archaeoscyphia* bed 1500 feet northward to Station 19 (elevation 1097) and continue down in section to the west.			
188.	Limestone—sublithographic, light gray, stylolitic, thickly bedded. Chert fine grained, light gray to nutria, semitranslucent, occurs as cannonballs which are fossiliferous and spiculiferous. Silicified fossils are *Archaeoscyphia* sp.	3	940	380 – 383
189.	Dolomite—fine to medium grained, mottled, medium gray to light gray to reddish buff, medium bedded. Chert chalcedonic, white to smoky gray, translucent, banded.	4	944	376 – 380
190.	Dolomite—microgranular, light gray.	1	945	375 – 376
191.	Limestone—sublithographic, light gray, thickly bedded with some indication of stromatolitic structure. A very few small dolomite rhombs are scattered throughout. Chert occurs as white reticulations and lacy excrescences on the limestone surfaces.	5	950	370 – 375
192.	Dolomite—medium grained, pearl gray, thickly bedded.	3	953	367 – 370
193.	Dolomite—microgranular, mottled light gray to reddish buff, thickly bedded.	2	955	365 – 367
194.	Dolomite—medium grained, pearl gray, thickly bedded.	1	956	364 – 365
195.	Dolomite—microgranular, mottled light gray to beige, thickly bedded.	2	958	362 – 364
196.	Covered—probably dolomite.	2	960	360 – 362
197.	Dolomite—medium grained, yellowish gray, thickly bedded. Chert interstitial to dolomite rhombs, porcelaneous, white.	1	961	359 – 360
198	Limestone—sublithographic, light to medium gray, stylolitic, thickly bedded, has small dolomite rhombs scattered throughout.	6	967	353 – 359
199.	Dolomite—microgranular, mottled light gray to reddish buff, thickly bedded. Chert subchalcedonic, white, translucent to opaque, in part crypto-oölitic, occurs as elongated flat ovals along the bedding. Sand, very fine grained, occurs throughout 3 inches of the interval at 349 feet.	5	972	348 – 353
200.	Dolomite—medium grained, yellowish gray, medium bedded.	5	977	343 – 348
201.	Dolomite—microgranular to very fine grained, mottled light gray to reddish buff, thickly bedded.	2	979	341 – 343
202.	Dolomite—medium grained, pearl gray, thickly bedded.	2	981	339 – 341

	Description	Thickness in feet Interval	Cumulative	Feet above base
203.	Dolomite—microgranular, mottled light gray to old ivory with some reddish buff in top 14 feet and brownish gray in bottom 8 feet, thickly bedded. Chert matrix sand and sandy dolomite in bottom 6 inches.	22	1003	317 – 339
204.	Dolomite—medium grained, near pearl gray.	1	1004	316 – 317
205.	Dolomite—microgranular, mottled light gray to reddish buff, thickly bedded. Chert subchalcedonic, dirty white to nutria, translucent, concentrically banded.	2.5	1006.5	313.5– 316
206.	Limestone and dolomite—sublithographic, medium gray to yellowish gray, thickly bedded, contains some network dolomite. Laterally this interval grades to dolomite.	15.5	1022	298 – 313.5
207.	Covered—probably dolomite.	3	1025	295 – 298
208.	Dolomite—fine to medium grained with some microgranular, light gray to yellowish gray, thickly bedded.	5	1030	290 – 295
	Station 18 (elevation 1037) is painted on top of a sand bed at the top of the next interval below. Shift along sand bed 1500 feet northward and continue down in section to west.			
209.	Dolomite—microgranular, mottled light gray, old ivory, and reddish buff, thickly bedded. Chert 277 to 283 feet subchalcedonic, mottled white to brown, translucent to opaque, occurs as lenses and irregular masses along bedding planes.	31	1061	259 – 290
210.	Dolomite—medium grained, pearl gray, thickly bedded.	8	1069	251 – 259
	Station 13 (elevation 1133) painted on rock surface at top of bluff at 251 feet in section.			
211.	Dolomite—microgranular, mottled light gray to reddish buff.	3	1072	248 – 251
212.	Dolomite—medium grained, near pearl gray, thickly bedded.	3	1075	245 – 248
213.	Dolomite—microgranular, mottled light gray and old ivory, thickly bedded. Chert subchalcedonic, crypto-oölitic, dirty white to brown, translucent, in part brecciated, occurs as lenses and irregular masses along the bedding planes.	10	1085	235 – 245
214.	Dolomite—medium grained, light gray to cement gray, thickly to irregularly bedded. Chert subchalcedonic, crypto-oölitic, dirty white to brown, translucent, in part brecciated, occurs as lenses and irregular masses along the bedding planes. Also some interstitial porcelaneous white chert is situated between dolomite rhombs.	5	1090	230 – 235
215.	Dolomite—microgranular, mottled light gray to old ivory and brownish gray, thickly bedded.	4	1094	226 – 230
216.	Dolomite—medium grained, light gray, thickly bedded.	4.5	1098.5	221.5– 225
217.	Dolomite—microgranular, mottled light gray to old ivory and reddish buff to cinnamon, thickly bedded. A thin bed of medium grained dolomite is located at 219 feet. Chert in top 5 feet subchalcedonic, crypto-oölitic, dirty white to brown, translucent, in part brecciated, occurs as lenses and irregular masses along the bedding planes. Chert in bottom 4 feet is quartzose excrescences on weathered surfaces. Sand is disseminated through 2 inches of dolomite at 202 and 207 feet.	19.5	1118	202 – 221.5
218.	Dolomite—medium to fine grained, pearl gray. Chert occurs as quartzose excrescences on weathered surfaces.	1	1119	201 – 202
219.	Dolomite—microgranular, mottled light gray to yellowish gray, thickly bedded. Chert in top 10 feet subchalcedonic, crypto-oölitic, translucent, white to medium gray, weathers chalky, slightly dolomoldic, occurs as masses up to 4 inches thick along bedding.	18	1137	183 – 201

Description	Thickness in feet: Interval	Cumulative	Feet above base
220. Dolomite—medium grained, pearl gray.	0.5	1137.5	182.5– 183
221. Dolomite—microgranular, mottled light gray to yellow beige, thickly bedded. Chert chalcedonic, dirty white to shades of brown, occurs as flat masses and disseminated in the dolomite.	8.5	1146	174 – 182.5
222. Dolomite—medium grained, light to pearl gray, somewhat mottled, thickly bedded. Chert chalcedonic, white to shades of brown, cryptooölitic, occurs as small irregular fragments.	12	1158	162 – 174
223. Dolomite—microgranular, mottled light gray to old ivory to brownish gray with some small areas of reddish buff to cinnamon, thickly bedded. Chert at 131 to 151 feet chalcedonic, white to shades of brown, occurs as flat masses and disseminated particles in lower part to irregular masses and lacy interfingerings in top 5 feet. Chert at 126 to 131 feet same as above but highly oölitic.	36	1194	126 – 162
Station 11 (elevation 1014) is painted on a rock surface near the foot of the bluff at 145 feet in the section. Section continues upstream to Station 10 (elevation 1014) painted on the Gorman-Tanyard contact at bottom of 36-foot interval. Shift along Gorman-Tanyard contact 900 feet northward to Station 9 (elevation 1077) and continue downward in section.			
Tanyard formation			
Staendebach member: upper 126 feet present			
224. Limestone and dolomite—limestone sublithographic, medium to light gray, thickly bedded, contains network of coarse grained dolomite.	4	1198	122 – 126
225. Limestone—sublithographic, light to medium gray, thickly to irregularly bedded with some thinly bedded mud cracked limestone near center. Chert semiporcelaneous to quartzose, dolomoldic, white to dark gray, translucent, occurs as irregular masses. In upper part some white lacy chert is disseminated along bedding planes. *Rhabdoporella* chert is present and resembles worm castings. Silicified fossils in the chert at the top of the interval are *Ophileta* sp., *Helicotoma* sp., *Paraplethopeltis*, cystid plate, *Rhabdoporella* (16T–2–41D).	17	1215	105 – 122
226. Dolomite—coarse grained, light to medium gray, thickly bedded. Chert subchalcedonic to quartzose, white to dark gray, translucent.	2	1217	103 – 105
227. Limestone—sublithographic, light gray, thickly bedded, bottom 4 feet grades laterally into thinly bedded and solution frescoed limestone.	10	1227	93 – 103
228. Dolomite—coarse grained, light gray, vuggy, thickly bedded. A small amount of interstitial porcelaneous, white chert occurs near the base.	21	1248	72 – 93
229. Dolomite—coarse grained, light to medium gray, thickly bedded. Chert porcelaneous to chalky, white, smooth fracturing, dolomoldic, massive. A small amount of interstitial porcelaneous, white chert is present.	15	1263	57 – 72
Station 8 (elevation 1021) painted on rock surface at 61 feet in section.			
230. Dolomite—coarse grained, light gray, thickly bedded.	5	1268	52 – 57
231. Dolomite—coarse grained, light to medium gray, thickly bedded. Chert porcelaneous, white, somewhat dolomoldic, in part interstitial to dolomite rhombs.	18	1286	34 – 52

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
232. Dolomite—fine grained, brownish gray, weathers to a sugary texture.	1	1297	33 – 34
233. Dolomite—medium grained with some coarse grained near center, light to medium gray and brownish gray, thickly bedded. Chert porcelaneous, white, ranging from interstitial to dolomoldic to massive layers without dolomolds.	13	1300	20 – 33
234. Dolomite—coarse grained with some fine grained at 16 feet, light to medium gray, thickly bedded except for the fine grained which is thinly bedded and mud cracked. Chert porcelaneous, white, mostly interstitial.	7	1307	13 – 20
Station 3 (elevation 1025) painted on rock surface at 19 feet in section.			
235. Dolomite—microgranular, light gray. Chert porcelaneous, white to brown, concentrically banded, dolomoldic.	3	1310	10 – 13
236. Dolomite—fine to medium grained, old ivory and reddish buff top 5 feet and light gray bottom 5 feet, thickly bedded. Chert porcelaneous, white, dolomoldic, occurs disseminated and as fragments.	10	1320	0 – 10
Station 1 (elevation 1023) painted on rock surface at bottom of section.			

Downstream Pedernales River Section

Section 8-C, Pedernales River section (downstream segment); measured February, 1941, by V. E. Barnes and Louis Dixon.

Gorman formation (calcitic, upper portion)			
Fault			
Gorman formation (dolomitic, lower portion) (bottom 14 feet present)			
Station 45 (elevation 1115) at top of interval painted on rock surface.			
1. Dolomite—microgranular, nutria and old ivory mottled brownish gray to reddish buff. Chert subchalcedonic, streaked white to medium gray, subtranslucent.	9	9	370 – 379
2. Dolomite—breccia composed of angular blocks, microgranular, and light gray mottled with yellow ochre; in a matrix of medium grained dolomite. Chert semiporcelaneous, white, occurs as small angular particles throughout the breccia. Sand is scattered throughout most of the matrix.	5	14	365 – 370
Tanyard formation: upper 365 feet present			
Staendebach member: upper 365 feet present			
3. Dolomite—medium grained, light gray to flesh colored, thickly bedded. Chert porcelaneous, white, dolomoldic.	15	29	350 – 365
Station 43 (elevation 1112) at base of interval painted on rock surface.			
4. Dolomite—medium grained, light gray to yellowish gray, thickly bedded. Chert porcelaneous, white, dolomoldic, occurs disseminated and as masses. Silicified fossils are: *Helicotoma uniangulata* (Hall), *Ozarkina* aff. *O. complanata* (Ulrich & Bridge), *Schizopea* aff. *S. typica* (Ulrich & Bridge), *Sinuopea* 2 spp., *Ophileta* sp., "*Pelagiella*" cf. "*P.*" *paucivolvata*, *Hypseloconus* sp., *Clarkoceras cuneatum* U.F.M.F., *Ectenoceras* sp., *Conocerina* sp., *Ribeiria* aff. *R. calcifera* Billings, and a few other fossils not identified. Collection (16T-2-59A) located at 327 feet in section.	27	56	323 – 350
Station 43 (elevation 1112) at base of interval painted on rock surface.			

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
5. Dolomite—medium grained, light gray to nutria, thickly bedded Chert at top of interval porcelaneous, dirty white, dolomoldic, weathers with a chalky texture. Chert at 320 feet porcelaneous, white, occurs as elongated masses, which pass laterally into a bed 1 foot thick. Station 42 (elevation 1112) at base of interval painted on rock surface.	18	74	305 – 323
6. Dolomite—medium to fine grained, light gray to ivory, thickly bedded. Chert porcelaneous, dirty white, dolomoldic, occurs as masses, disseminated, and interstitial, abundant.	30	104	275 – 305
7. Dolomite—medium to coarse grained, light gray, vuggy, thickly bedded. Chert porcelaneous, dirty white, dolomoldic, occurs as masses, disseminated, and interstitial, abundant. Station 41 (elevation 1118) at base of interval painted on rock surface.	16	120	259 – 275
8. Dolomite—medium to coarse grained, light gray in part flesh tinted, vuggy, thickly bedded. Chert subporcelaneous, white, smooth fracturing, oölitic, occurs in large masses. A small amount of quartzose chert is also present. Station 40 (elevation 1115) at base of interval painted on rock surface.	32	152	227 – 259
9. Dolomite—medium grained, light gray to yellowish gray, in part vuggy, thickly bedded. Chert porcelaneous, white, quartzose, dolomoldic, occurs disseminated and as masses. Station 39 (elevation 1114) at base of interval painted on rock surface.	16	168	211 – 227
10. Dolomite—predominantly medium grained, light gray to brownish gray; 165 to 170 and 190 to 205 feet, fine to very fine grained, ivory to yellowish gray; 180 to 185 feet, coarse grained, light gray, medium to thickly bedded. Chert porcelaneous, white, dolomoldic, occurs disseminated and as masses. Some quartzose chert is also present. Station 38 (elevation 1112) at base of interval painted on rock surface.	46	214	165 – 211
11. Dolomite—160 to 165 feet fine to medium grained, yellowish gray; bottom 10 feet, medium to coarse grained, mottled light gray to yellowish gray; medium to thickly bedded. Chert porcelaneous, white, dolomoldic, occurs disseminated and as masses. Some quartzose chert is also present. Station 37 (elevation 1112) and Station 36 (elevation 1113) are on about the same bed due to a local reversal in dip. These stations are painted on rock surfaces. Station 36 was not recovered in 1944.	15	229	150 – 165
12. Dolomite—fine to medium grained, mottled, flesh to nutria, medium bedded. Chert porcelaneous, white, dolomoldic, occurs disseminated and as masses. Some quartzose chert is also present.	22	251	128 – 150
13. Dolomite—fine to very fine grained, mostly nutria to yellowish gray with some flesh, medium bedded. Station 35 (elevation 1115) located at 119 feet in section is painted on rock surface.	22	273	106 – 128
14. Dolomite—medium to fine grained, yellowish gray to beige, medium bedded. Chert semiporcelaneous, oölitic to oömoldic, gray, intimately intermixed with dolomite, occurs as masses up to 6 inches thick and several feet in length, weathers with a concentric pattern.	26	299	80 – 106

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Station 34 (elevation 1115) 3 feet above base of interval is painted on rock surface about 100 feet northwest of concrete slab crossing Pedernales River.			
15. Dolomite—fine to very fine grained, nutria except bottom 18 feet which is old ivory, medium bedded. Chert abundant throughout interval, semiporcelaneous to granular, light gray to beige; some quartz druse is present.	69	368	11 – 80
Station 33 (elevation 1123) at base of interval is painted on rock surface. This station was not recovered in 1944.			
16. Dolomite—fine to very fine grained, mottled, beige to brownish gray and flesh colored, medium bedded. Chert compact, semiporcelaneous, white, opaque. Near the top of the interval some subchalcedonic, translucent chert contains sponge spicules.	11	379	0 – 11
Station 32 (elevation 1123), at base of interval and on a fault, is painted on a rock surface. Fault cuts out about 200 feet of section. The tie between this section and the Towhead Creek section is without confirmatory evidence. From the general lithic similarities and thicknesses, it is thought that the Towhead Creek section starts at about the same stratigraphic level as the bottom of the downstream Pedernales River section.			

Towhead Creek Section

Section 8-B, Towhead Creek section, measured and sampled by Leo Hendricks, Bruce Harlton, L. E. Warren, and V. E. Barnes in 1941–42.

Tanyard formation			
Staendebach member: bottom 50 feet			
This section is inferred on the basis of general lithic similarity and balanced thickness to continue from about the same stratigraphic level as the bottom of the downstream Pedernales River section.			
Station 10 (elevation 1220) at top of a hill is 350 feet north of a fence at a point 950 feet west of Station 7. Cairns, which by 1944 were mostly destroyed, marked these stations.			
1. Dolomite—fine grained, mottled, mostly pinkish with some medium gray, medium bedded.	17	17	247 – 264
2. Dolomite—medium to coarse grained, light gray and some flesh colored, medium to thickly bedded. Chert in bottom of interval is porcelaneous, white, opaque, dolomoldic, honeycombed, and in part quartzose and drusy. Silicified fossils are *Schizopea* cf. *S. grandis* (Ulrich & Cooper), *Gasconadia* (?), *Ozarkina, Sinuopea* (small species), *Ophileta,* and cystoid plates.	17	34	230 – 247
Station 9 (elevation 1198) at bottom of interval is 130 feet north of a fence at a point 950 feet west of Station 7.			
3. Dolomite—medium to fine grained, pinkish to reddish buff, one bed.	1	35	229 – 230
4. Dolomite—medium to coarse grained, light gray to flesh colored, medium to thickly bedded. Chert is not present where the section crosses this interval, but a quarter of a mile to the west along the strike porcelaneous, white, dolomoldic chert is plentiful at the bottom of the interval.	15	50	214 – 229
Threadgill member: top 214 feet			
5. Dolomite—medium to fine grained, light gray with small purple mottlings.	3	53	211 – 214
6. Dolomite—coarse grained, light gray to flesh colored.	5	58	206 – 211
7. Dolomite and limestone—coarse grained, light gray to flesh colored dolomite and sublithographic, white limestone. This interval is a zone of transition, the bottom	5	63	201 – 206

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
of which is predominantly limestone with a meshwork of dolomite, becoming more dolomitic toward the top where there are only small areas of limestone surrounded by dolomite. Chert rare, minutely quartzose, dark, smoky or dirty gray, in part oölitic, occurs as small nodules.			
Station 8 (elevation 1177) at bottom of interval is along a fence 325 feet west of Station 7.			
8. Limestone—sublithographic, very light gray, thickly bedded, contains in part a meshwork of dolomite.	9	72	192 – 201
Station 7 (elevation 1168) at bottom of interval is at corner post where fence changes direction to the north.			
9. Limestone—sublithographic, very light gray to a very light grayish ivory with some corn yellow seams near top, alternating thinly and thickly bedded zones. The massive limestone toward the top of the interval contains some meshwork dolomite. Chert occurs only at the bottom of the interval and is minutely quartzose, dark smoky or dirty gray, opaque, and in small nodules.	51	123	141 – 192
Station 6 (elevation 1167) at bottom of interval is 20 feet west of a fence at a point 840 feet north of Station 7.			
10. Limestone—sublithographic, very light gray with some golden streaks, occurs as alternating thinly and thickly bedded zones. Chert scarce, finely granular, lusterless, dirty or smoky gray, opaque, occurs as small irregular masses.	8	131	133 – 141
Station 5 (elevation 1190) at bottom of interval is north of Towhead Creek, 70 feet east of a fence at a point 1320 feet north of Station 7.			
11. Limestone—sublithographic, between very light gray and ivory. Chert scarce, minutely quartzose, finely granular, dirty or smoky gray, lusterless, opaque, occurs as small nodules.	6	137	127 – 133
Station 4 (elevation 1203) at bottom of interval is along a fence north of Towhead Creek and 1690 feet north of Station 7.			
12. Limestone—sublithographic, very light gray to ivory with some golden streaks, occurs as alternating thinly and thickly bedded zones. Chert scarce, minutely quartzose, dark smoky or dirty gray, lusterless, opaque, occurs as honeycombed thin layers along bedding planes.	28	165	99 – 127
Station 3 (elevation 1193) at bottom of interval is 60 feet east of a fence at a point 2190 feet north of Station 7.			
13. Limestone—sublithographic, very light gray grading toward ivory, occurs as alternating thinly and thickly bedded zones. Chert scarce, minutely quartzose, dark smoky or dirty gray, lusterless, opaque, occurs as thin layers along bedding planes.	44	209	55 – 99
Station 2 (elevation 1161) at bottom of interval is along a fence 2560 feet north of Station 7.			
14. Limestone—sublithographic, very light gray with some yellowish gray to flesh colored streaks, mostly thickly bedded with strong meshwork of coarse grained dolomite, along which colors such as golden yellows and dark dull reds are common.	32	241	23 – 55
Station 1 (elevation 1142) at bottom of interval along a fence 2880 feet north of Station 7 and 500 feet south of Station 24 of Pedernales River section.			
15. Limestone and dolomite—sublithographic, very light gray limestone with heavy meshwork of coarse grained dolomite at top grading down to coarse grained light gray dolomite at bottom, containing only a small amount of limestone.	3	244	20 – 23

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Some waxy, light green substance is present interstitial to dolomite grains and along minute seams in the limestone. The same substance was also seen occasionally in the limestone up to Station 8.			
16. Dolomite—coarse grained, light gray with minute dull deep reddish purple specks between dolomite rhombs, thickly bedded.	20	264	0 – 20
The section ends at the edge of an alluvial flat along the fence, and 23 feet of beds are estimated to be covered between here and Station 24 on the north side of Pedernales River in the upstream Pedernales section. Station 24 is the tie point between the Towhead Creek and the upstream Pedernales River sections.			

Upstream Pedernales River Section

Section 8-C, Pedernales River section (upstream segment), measured by V. E. Barnes and Louis Dixon, February, 1941.

Threadgill member: bottom 90 feet present			
17. Dolomite—coarse grained, mostly light gray; two thin zones of fine grained dolomite yellowish gray to beige; medium to thickly bedded.	85	85	215 – 300
The information for this interval mostly was obtained from the samples collected in 1941. In transferring the samples from sample bags to permanent storage, the station numbers were left off, and the sample intervals had not been adjusted to the plane table measurements of thickness.			
The stations in this interval painted on rock surfaces are as follows:			
Station 32 (elevation 1123) at 300 feet in section.			
Station 31 (elevation 1121) at 264 feet in section.			
Station 30 (elevation 1117) at 221 feet in section.			
Station 29 (elevation 1122) at 219 feet in section.			
Station 28 (elevation 1117) at 219 feet in section.			
Station 27 (elevation 1121) at 238 feet in section.			
Station 26 (elevation 1123) at 238 feet in section.			
Station 25 (elevation 1117) at 219 feet in section.			
Station 24 (elevation 1117) at 215 feet at bottom of interval is along a north-south fence. The base of the Towhead Creek section, south along the fence, is 23 feet stratigraphically above Station 24. A slight reversal in dip accounts for the loss of section between Stations 25 and 28.			
18. Dolomite—coarse grained, light gray, thickly bedded.	5	90	210 – 215
Cambrian			
Wilberns formation			
Pedernales dolomite member: 195 feet thick			
19. Dolomite—microgranular, medium gray to yellowish gray, medium bedded.	5	95	205 – 210
Stations 23 (elevation 1127) and 22 (elevation 1129) painted on rock surface are about on the same bed at 209 feet in the section. These stations were not recovered in 1944.			
20. Dolomite—coarse grained, light gray to flesh with some other colors such as yellowish gray and beige, medium to thickly bedded.	10	105	195 – 205
Chert fine grained, dirty brown, concretionary, occurs as 2 beds between Stations 17 and 18. At Station 18 similar chert in one-half inch sized fragments is common.			
The stations in this interval, painted on rock surfaces, are as follows:			
Station 21 (elevation 1129), Station 20 (elevation 1129), Station 19 (elevation 1122), and Station 18 (elevation 1133) are about on the same bed at 204 feet in section, and Station 17 (elevation 1133) is located at the bottom of the interval. Stations 19, 20, and 21 were not recovered in 1944.			

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
21. Dolomite—coarse grained, varying widely in color being predominantly light gray and pinkish gray with abundant dull dark reddish purple mottlings. Some of the dolomite is yellowish gray to nutria in color and the bottom few feet is a medium dirty gray with an olive cast. The dolomite in this interval is massive with mostly irregular poorly developed bedding. Chert is scarce with some reddish brown chert at 173 feet in section. The stations in this interval painted on rock surfaces are as follows:	94	199	101 – 195
Station 16 (elevation 1137) at 184 feet in section.			
Station 15 (elevation 1135) at 169 feet in section.			
Station 14 (elevation 1133) at 151 feet in section.			
Station 13 (elevation 1134) at 137 feet in section.			
Station 12 (elevation 1138) at 114 feet in section.			
Station 11 (elevation 1139) at 101 is at bottom of interval.			
Stations 12, 15, and 16 were not recovered in 1944.			
22. Chert—very fine grained minutely quartzose, brown with some black mottlings, occurs as a 2-foot discontinuous bed along an irregular contact between coarse grained dolomite described above and medium to fine grained dolomite described below.	2	201	99 – 101
23. Dolomite—fine grained, yellowish gray to beige with top 8 feet brownish gray to nutria, whole interval mottled with specks of dull dark reddish purple, medium to thicky bedded. Chert not developed in section, but on bluff to north the top 15 feet of the interval contains quartzose chert, dirty white to rusty, porous to compact, fossiliferous. Silicified fossils are: *Xenorthis* sp., found elsewhere only in the basal part of the Upper Cambrian Frederick limestone at Frederick, Maryland (Ulrich and Cooper, 1938, pp. 76, 77); *Anconochilus barnesi* Knight; *Hypseloconus* sp., *Plethopeltis* (?), and unidentified trilobite (16T–2–4A).	46	247	53 – 99
Station 10 (elevation 1133) at 86 feet in section.			
Station 9 (elevation 1134) at 80 feet in section.			
Station 8 (elevation 1136) at 70 feet in section.			
Station 7 (elevation 1134) at 59 feet in section.			
Station 6 (elevation 1141) at 54 feet in section.			
None of these stations was recovered in 1944.			
24. Dolomite—fine grained oölitic, beige to yellowish gray, mottled with specks of dull dark reddish purple, medium to thickly bedded.	15	262	38 – 53
Station 5 (elevation 1143) at 48 feet in section.			
Station 4 (elevation 1145) at bottom of interval.			
Neither of these stations was recovered in 1944.			
25. Dolomite—fine grained, beige, mottled with specks of dull dark reddish purple, medium to thickly bedded.	7	269	31 – 38
26. Dolomite—fine grained, brownish gray to yellowish gray in top part and brownish gray to brown in lower part, medium bedded, has ripple marks up to 24 inches from crest to crest and mud cracks, both in lower part. A small amount of glauconite is present. Station 3 (elevation 1133) is at 25 feet in section. This station was not recovered in 1944.	16	285	15 – 31
Point Peak shale (?) member: 15 feet measured			
27. Argillaceous dolomitic limestone—fine grained, brownish gray to dark greenish gray, glauconitic, occurs as ⅓ to 2-inch thick beds separated by thin laminae of green shale. Cross bedding and ripple marks are common.	11	296	4 – 15

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
28. Limestone—stromatolitic, subspherical masses up to 5 feet in diameter composed of very fine grained, light greenish gray limestone with mottled greenish argillaceous inclusions mostly along stylolites. The stromatolite masses are separated by medium to coarse grained, light gray to brown limestone. The stromatolitic biostrome appears to be slightly dolomitic throughout.	4	300	0 – 4

Station 1 (elevation 1132) is located at the top of interval. This station was not recovered in 1944.

Scott Klett Ranch Section

Section 8-A, Scott Klett ranch section, measured by Louis Dixon and V. E. Barnes, February, 1941.[11]

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Cambrian			
Wilberns formation			
Pedernales dolomite member: bottom 77 feet exposed			
1. Dolomite—massive and indistinctly bedded.	41.4	41	210 – 251
2. Dolomite—thickly bedded.	23.1	64	187 – 210
3. Dolomite—thinly bedded.	12.2	76	175 – 187
Point Peak shale (?) member: 25 feet thick			
4. Dolomite—thinly bedded, argillaceous. This unit may be more calcareous than sight examination indicated.	14.4	90	161 – 175
5. Limestone—stromatolitic and massive.	11.2	101	150 – 161
Morgan Creek limestone member: 140 feet thick			
6. Limestone—brownish gray, contains silicified *Billingsella.*	2.7	104	147 – 150
7. Limestone—stromatolitic, massive.	1.3	105	146 – 147
8. Limestone—gray.	6.8	112	139 – 146
9. Limestone—stromatolitic, massive.	1.5	114	137 – 139
10. Limestone—gray.	6.8	121	130 – 137
11. Limestone—stromatolitic, massive.	1.5	123	128 – 130
12. Limestone—gray.	6.2	129	122 – 128
13. Limestone—stromatolitic, massive.	1.8	131	120 – 122
14. Limestone—gray.	11.9	143	108 – 120
15. Limestone—gray, argillaceous.	7.4	150	101 – 108
16. Limestone—gray, has scattered stromatolites in lower part.	15.5	166	85 – 101
17. Limestone—stromatolitic.	2.5	168	83 – 85
18. Limestone—gray.	11.2	179	72 – 83
19. Shale.	3.0	182	69 – 72
20. Limestone—gray.	13.3	195	56 – 69
21. Limestone—oölitic.	7.5	203	48 – 56
22. Limestone—stromatolites interspersed with shingle conglomerate.	0.8	204	47 – 48
23. Limestone—gray.	6.7	211	40 – 47
24. Limestone—oölitic.	1.2	212	39 – 40
25. Limestone—gray with mud ball bed 3 feet from bottom.	13.6	226	25 – 39
26. Limestone—oölitic.	0.5	227	24 – 25
27. Limestone—gray.	3.2	230	21 – 24
28. Limestone—dark reddish brown becoming progressively more arenaceous toward bottom.	11.3	241	10 – 21
Welge sandstone member: 10 feet thick			
29. Sandstone—brown quartz sand in part reconstituted.	10	251	0 – 10

The Welge sandstone rests disconformably on the glauconitic Lion Mountain sandstone member of the Riley formation.

This section was not sampled and is described in a generalized manner. The dolomite, intervals 1 to 3, is similar to the dolomite described in section 8-C at corresponding intervals. Interval 4 is similar to interval 27 of section 8-C. The intervals described as "stromatolitic," intervals 5, 7, 9, 11, 13, and 17, are similar to interval 28 of section 8-C. Intervals 8, 10, 12, 14, 16, 18, 20, 23, 25, and 27, described as gray in the field description, are, judging from samples from similar positions elsewhere, more accurately described as brownish gray with a greenish cast from the contained bright green glauconite. These limestones are distinctly grained rocks differing markedly from the sublithographic limestones of the Ordovician.

[11]Barnes, V. E., Dawson, R. F., and Parkinson, G. A., Building stones of central Texas: Univ. Texas Pub. 4246, p. 133, 1942 [1947].

NOTES ON THE STRATIGRAPHY OF AREAS NOT MAPPED IN DETAIL

As an aid to fuller comprehension of the stratigraphy and geologic history of the Ellenburger group it is advantageous to consider briefly certain areas other than those discussed in the preceding pages. Reconnaissance studies were made at many places in the Llano uplift in order to determine what facies changes take place within the Ellenburger group and related rocks between areas mapped in detail, what rocks form the stratigraphic summit of the Ellenburger at the extreme margins of its surface exposures, and what strata overlay it at various places. Pertinent observations from some of these areas follow, the localities themselves being indicated on the index map of the region (Pl. 1).

BIG SALINE CREEK AREA, KIMBLE COUNTY

The most westerly exposures of Ellenburger rocks that display normal overlapped relationships with pre-Canyon (upper Pennsylvanian) strata are those that extend north and south from the confluence of Big Saline Creek with Llano River, in northeastern Kimble County. Outcrops in the immediate vicinity of the stream juncture were studied by Cloud in July, 1945.

At this place the calcitic facies of the Gorman formation is overlain by Marble Falls limestone of post-Morrow age, except for a small patch of the Barnett formation 75 feet southeast of Llano River on its right bank at the bend opposite the mouth of Big Saline Creek. Here a structural sink about 75 feet in diameter is filled with white limesands of the Barnett formation from which were obtained "*Spirifer*" cf. *S. washingtonensis* Weller, *Syringothyris* sp., *Dictyoclostus* cf. *D. burlingtonensis* (Hall), *Platyceras* sp., and small cup corals (TF–423). These probably represent a zone of Keokuk age near that displayed at White's Crossing in the Bear Spring area.

Both *Lecanospira* and *Rhombella* were seen in limestone and chert just below the Gorman-Marble Falls contact. The *Archaeoscyphia* zone of the Gorman formation was located about 380 feet down Llano River (northeast) from this contact and traced for about 700 feet along the right bank of the river. Between the *Archaeoscyphia* bed and the base of the Marble Falls limestone are approximately 140 feet of limestone and minor dolomite, belonging to the calcitic facies of the Gorman formation. The limesands of the Barnett formation, however, have collapsed to a point only about 70 feet stratigraphically above *Archaeoscyphia*.

No unusual features were noted in the Gorman strata displayed at this locality.

CALF CREEK AREA, MASON COUNTY

At the juncture of Calf Creek and San Saba River, on the Blockhouse ranch in the northeastern corner of Mason County, strata of the Canyon group (upper Pennsylvanian) overlap faulted Ellenburger and Upper Cambrian rocks. Outcrops in this vicinity were studied by the authors on several occasions and some of the stratigraphic boundaries and faults were mapped on aerial photographs. Strata of the Canyon group rest directly on the Threadgill and Staendebach members of the Tanyard formation, as well as on Wilberns strata, and faults which transect the older beds do not offset the Canyon strata. Neither rocks of the Gorman formation nor Carboniferous strata of pre-Canyon age were seen in the small area studied.

The Wilberns formation at this locality is of special interest both because of the conspicuous development of sand in the San Saba limestone member, and because of the reversal in the normal succession of limestone and dolomite in the upper part of the Wilberns. Outcrops of a thick sand zone are conspicuous in the bed of San Saba River at the Blockhouse crossing, the river being near the crest of a gentle anticline, so that one rises in the section both north and south from it. Southeast from the river, only Wilberns strata were encountered to where the sequence is disturbed by faulting, but one reaches the Cambrian-Ordovician boundary near the top of the bluffs that form the north banks of San Saba River

and Calf Creek at their confluence. The sequence of Wilberns strata in downward succession below the Cambrian-Ordovician boundary is about as follows: 55 feet of mostly glauconitic granular limestone with minor calcareous sandstone, containing *Apheoorthis, Owenella,* and *Stenopilus;* 16 feet of calcitic and dolomitic sandstone; 10 feet of arenaceous limestone containing trilobites; 47 feet of calcitic and dolomitic sandstone with minor limestone beds; very fine grained to fine grained dolomite identical lithically to the finer grained beds typical of the Pedernales dolomite member at many places to the east. Perhaps 50 feet of the latter is displayed below the lower thick sandstone in good exposures on the north (left) bank of San Saba River about 1000 yards east of the Blockhouse crossing, but the succession is interrupted by faulting to the east and neither the total thickness of the dolomite nor the nature of the underlying rocks was determined.

The arenaceous, glauconitic, granular San Saba limestone member of the Wilberns formation is overlain by nonarenaceous, essentially nonglauconitic, largely sublithographic limestone of the Threadgill member of the Tanyard formation on the north bank of San Saba River and Calf Creek in the vicinity of the Blockhouse. *Lytospira gyrocera* (Roemer) and *Ophileta polygyrata* (Roemer) were seen to the base of the Ordovician.

At the north-south fence 1.2 miles up Calf Creek (northwest) from its mouth dolomites of the Staendebach member of the Tanyard formation are faulted against limestones of the Threadgill member. The fault angles west from the creek so that the stream bed continues in limestone for another 700 yards, but shortly another angle to the north repeats the Staendebach member at the south end of a long north-south reach. The Threadgill-Staendebach boundary was not seen, but the outcrops observed indicate that it would probably be drawn at a limestone-dolomite contact, and that the members would be much as they are in the Bald Ridge area. The outcrops of the Staendebach member on Calf Creek contain much chalcedonic to porcelaneous white-weathering chert and fossils obtained just below the overlapping Canyon strata (TF–228) suggest a position high in the Tanyard formation. Four miles northeast of the mouth of Calf Creek, on the downthrown east side of a prominent fault, chert comprised of aggregated *Rhabdoporella* and the type of chert described as "oölitic laminar" weathers from fine to medium grained dolomite in an area of bald rolling hills on the northwest side of San Saba River. This is a typical expression of the upper dolomites of the Tanyard formation in the northern half of the Llano region.

RUMSEY CREEK AREA, McCULLOCH COUNTY

So far as is known the most northwesterly outcrops of the Carboniferous rocks that normally overlap the Ellenburger are at the head of Rumsey Creek, in southwestern McCulloch County. Outcrops at the northeast end of a small outlying patch of Marble Falls limestone and Mississippian strata on the T. Gray ranch were studied by Cloud in July, 1945. The ground observed was between 1.5 and 1.9 miles south a little east from Davis School, 0.2 to 0.6 mile north a little west from the windmill at Blue Well (a local name), and approximately 5.5 miles east-northeast from the settlement called Calf Creek.

At this place locally arenaceous limestones of the Gorman formation are directly overlain by the Chappel limestone. Exact location of the top Ellenburger strata within the Gorman formation was prevented by a fault that raises older strata to the east and by Lower Cretaceous overlap at the north and west. Although not proved by field evidence, it is inferred from general appearances and from estimates of degree of regional truncation that the top of the Ellenburger here is below the *Archaeoscyphia* zone of the Gorman formation.

At a point 1.62 miles airline S. 12° E. from Davis School and 800 yards N. 2° E. from Blue Well a few feet of fossiliferous Chappel limestone was seen in depositional contact with the Gorman for-

mation. Here *Rotiphyllum* cf. *R. hians* Easton, *Delthyris* cf. *D. farmeri* Branson, and a few trilobites were collected from greenish gray, dull olive, and pink crinoidal limestone (TF–424). These fossils indicate correlation with the limestones of Chouteau age of the Bald Ridge and Bear Spring areas. Between the Chappel limestone and the lowest exposures of Marble Falls limestone is a covered linear flat that supports a thick growth of mesquite and is probably underlain by shales of the Barnett formation. The lowest beds of the Marble Falls limestone contain fusiform fusilines probably assignable to *Fusiella*, and are hence of post-Morrow age.

LOST CREEK AREA, McCULLOCH COUNTY

Eastward from the mouth of Lost Creek (Loafer Creek of some maps), on both sides of San Saba River and south of the Long Valley road, in southeastern McCulloch County along the San Saba County line, is a complexly faulted area that is of critical interest to the Ellenburger problem. It shows that in an area about 9 miles east of the Bald Ridge area and 22 miles west of the Cherokee area the Ellenburger and related rocks have already assumed many of the features that characterize them to the east. It indicates that a "normal" development of these rocks may be expected in the complexly faulted southwestern part of San Saba County, where photographic reconnaissance offers little hope of continuous sections. Studies by the authors in this area were made separately, together, and with others on several occasions. The ground covered was on the T. E. Edmiston, J. J. Burns, and M. Burns ranches, and especially on the left bank of the San Saba River near the mouth of Joe Davis Hollow.

In the Lost Creek area the upper beds of the Wilberns formation would probably be assigned to the San Saba limestone member at most places, but locally they contain interbedded dolomite of the Pedernales type. It is probable therefore that the Pedernales dolomite member assumes its normal place above the San Saba limestone member a short distance east of here. A good development of the Pedernales dolomite was observed by Barnes about 15 miles southeast of the Lost Creek area in Lone Oak Mountain, northwest of Valley Spring in the northwestern corner of Llano County and adjacent San Saba County.

The Threadgill member of the Tanyard formation appears to have gone largely if not entirely into dolomite, and the Staendebach member of the Tanyard formation seems to include considerably more limestone in its upper portion than was noted in the Bald Ridge area. Both members thus tend to assume the characters more normal to their expression in areas east of here and less like those displayed to the west.

Like the Tanyard formation, the Gorman formation seems to have taken on a more "normal" expression than it displays in the Bald Ridge area. However, although microgranular to very fine grained dolomites are conspicuous compared to their development in the Bald Ridge area, the studies made were not sufficient to establish the actual characters of the Tanyard-Gorman boundary, and it may be within a zone of fine grained dolomite and intergrading reticulate limestones. Fossils of the upper 100 feet of the Tanyard formation were found apparently within less than 100 feet of microgranular dolomite, so the Tanyard-Gorman boundary is at least approaching the characters by which it is recognized to the east. The calcitic facies of the Gorman formation extends at least 50 feet below the *Archaeoscyphia* zone of the Gorman formation and probably more at some places.

The Honeycut formation is missing, and measurements along and east of Joe Davis Hollow show that the normally overlapping base of the Mississippian ranges from 60 to 80 feet above the *Archaeoscyphia* zone of the Gorman formation. At two places the Chappel limestone was observed to occupy structural sinks in the top beds of the Gorman formation, but the Barnett formation overlaps the margins of these sinks to rest directly on the Gorman strata. A structural sink 400 feet southwest of the mouth of Joe Davis Hollow contains Barnett strata

that have collapsed to a position at least 25 feet below the *Archaeoscyphia* zone of the Gorman formation and considerably farther into the Gorman formation than the lowest Chappel limestone seen. It is quite unusual to find Barnett strata in such a position.

It is not known by the authors how far west the Honeycut formation extends in the Llano region, but Mississippian rocks rest on the Gorman formation along King Creek 12 miles northeast of the Lost Creek area and 10 miles west-northwest of the northwestern corner of the Cherokee area. At the locality to which reference is made, 0.6 to 0.75 mile south of Maxwell Crossing of San Saba River and extending north from the spring house at Flemming Spring, the Ives breccia and Chappel limestone rest directly on heavy bedded, ripple-marked limestones containing *Lecanospira*. If truncation is essentially uniform between the Cherokee area and the Lost Creek area these beds should be near the top of the Gorman formation.

The Mississippian strata of the Lost Creek area include the Barnett formation, the Chappel limestone, and possibly representatives of the Ives breccia.

The Chappel limestone is well displayed in two structural sinks 1000 to 1500 feet east-northeast of the mouth of Joe Davis Hollow, one being on either side of a north-south fence. The more easterly of these two "sinks" displays about 33 feet of a sequence estimated to be about 45 feet thick. An excellent fauna of Chouteau age was here obtained (TF–390 to 393) from crinoidal limestones of a color varying from pinkish brown to grayish and yellowish brown to brownish gray, olive, and olive gray. This limestone consists of scattered to abundant crinoid fragments and columnals in a microgranular to medium grained matrix. A pinnacle of the Gorman formation divides this outcrop, and a minor fault truncates its east side.

The more westerly of the two structural sinks (Pl. 28, fig. A) yielded few fossils (TF–395 and 396), but it furnishes the best physical display of a structural sink known. The river-bank cross section displays two sides and parts of its bottom, and about three-fourths of its circumference may be seen in plan view. Repetition of a recognizable Gorman stratum below it and at its east side shows that the base of the Chappel limestone has subsided about 25 feet vertically at that place. The east to west dimension of this structural sink is about 220 feet and it is about 230 feet long as preserved. The Chappel strata at its center are nearly horizontal, but are dragged to steep dips at its margins. About 30 feet of the Chappel limestone is exposed, most of it being similar to to that of the fossiliferous limestone to the east.

Two occurrences of possible pre-Chappel rock were seen at the base of the Mississippian sequence at the east edge of the more westerly structural sink. One, about 25 feet west of the limestone bluff of the Gorman formation at its east edge, consists of 8 inches of yellow arenaceous limestone with green argillaceous patches and with small angular chert fragments in the top 2 inches. It rests directly on the Gorman formation and is overlain by the Chappel limestone. This yielded no macrofossils, but W. H. Hass (letter to Cloud dated February 7, 1946) states that samples from it produced "a Grassy Creek conodont fauna that is not mixed with the Bushburg kinds." It thus may represent a stratigraphic equivalent of the Ives breccia. Fifteen feet east of the 8-inch arenaceous limestone with the Grassy Creek conodont assemblage, the basal foot of the Mississippian sequence (TF–395) is a coquina of ambocoeliinid brachiopods with occasional *Sedenticellula* aff. *S. hamburgensis* (Weller). This zone was thought by Dr. G. A. Cooper (letter to Cloud dated May 26, 1945) to be probably equivalent to the Glen Park limestone of Missouri, until a different species of *Sedenticellula* was found in association with the fauna of Chouteau age of the Chappel limestone. Its objective faunal correlation is now in question, but still possibly with the Glen Park limestone. However, the basal bed of the true Chappel limestone that rests on the arenacous limestone containing an unmixed Grassy Creek conodont

assemblage (*fide* W. H. Hass) is 3 feet above the bed with *Sedenticellula*, as may be seen 15 feet to the east. Relations between the *Sedenticellula* bed and the bed with the Grassy Creek conodont assemblage are obscured by poor exposures; but both are in direct visible contact with the Gorman formation, and the Chappel stratum that rests on the latter is 3 feet above the former. The situation suggests essential contemporaneity between the zone with the Grassy Creek conodont assemblage and the *Sedenticellula* bed, but the evidence is nevertheless still equivocal. Another possible equivalent of the Ives breccia seen was a small patch of siliceous and calcareous breccia 12 inches thick collapsed into the eastern structural sink and separated from Gorman rocks beneath by a 2- to 4-inch zone of sparingly crinoidal gray limestone containing a very few small macrofossils of uncertain age. This outcrop was demolished in collecting.

Strata of the Barnett formation in the Lost Creek area appear to be mostly shales with lenses and discontinuous beds of hard petroliferous limestone. The Barnett strata exposed in the structural sink 400 feet southwest of the mouth of Joe Davis Hollow, however, comprise about 15 feet of medium to coarse grained partly glauconitic crinoidal limesands overlain by about 5 feet of marly weathering limestone that is a coquina-like mass of squashed telotremate brachiopods. Among these were found a few specimens of *Leiorhynchus*, and the lithology strongly recalls that of the Barnett formation at places in the Bear Spring area. It is the most northerly and easterly occurrence of Barnett strata of the limesand facies known to the authors. However, a limesand outcrop 11 miles northeast of here on the left bank of San Saba River at Lemon's Camp, that was shown to Cloud by Mr. F. B. Plummer on March 5, 1944, may be a more northerly and easterly occurrence still. The limesand facies of the Barnett formation was not understood at the time this exposure was seen and the locality was not revisited by either Cloud or Barnes.

The Marble Falls limestone in the Lost Creek area was observed but not studied by the present authors.

VICINITY OF ELLENBURGER HILLS, SAN SABA COUNTY

An area in southeastern San Saba County, between Little Llano and Colorado Rivers, south of the line of Carboniferous overlap that parallels the Chappel-Bend road, and mostly north of Fall Creek, displays a typical development of Ellenburger and associated rocks. Reconnaissance studies by the authors, Josiah Bridge, and others show that the chances of measuring a reasonably accurate section of the Ellenburger in this area are poor, and it was abandoned in favor of the more promising Tanyard and Gorman Falls areas. It is, nevertheless, of special interest, because the Ellenburger Hills are in it.

A range of bald and live-oak dotted hills, such as characterize the Tanyard formation where dolomitic, trends northeast-southwest through the area outlined, including the Indian Hills, Marley Peaks, and Ellenburger Hills. Reconnaissance studies revealed only strata of the Tanyard formation in the Ellenburger Hills, with the lower, microgranular dolomites of the Gorman formation first appearing in low open pastureland to the north. Between the two is a more wooded belt including limestones of the Staendebach member of the Tanyard formation. In the Indian Hills the topographic break between formations seems to be less well marked. A fault throws the Pedernales dolomite member of the Wilberns formation up against Tanyard strata at the southeast side of the Ellenburger Hills.

For the area as a whole the Ellenburger and related rocks might be described about as they are under the Cherokee area, with these exceptions: (1) the Honeycut formation is thicker than in the Cherokee area, Mississippian strata resting mostly on rocks of the zone of *Ceratopea* sp. 5; (2) the calcitic facies of the Gorman formation at least locally extends lower than it does in the Cherokee area, and limestone beds are commoner in the dolomitic facies of the Gorman formation; (3) the Pedernales dol-

omite member of the Wilberns formation shows considerable compact, smooth-fracturing, oölitic, white-weathering chert generally similar to the cherts in the Staendebach member of the Tanyard formation in the Cherokee area and unlike any chert seen in the Pedernales dolomite of that area; (4) both Potosi and Eminence faunas were obtained from the Pedernales dolomite east and south of the Ellenburger Hills.

PILLAR BLUFF AREA, BURNET COUNTY

The most northeasterly outcrops of Ellenburger strata in the Llano region occur as inlying patches in an area of Cretaceous rocks southwest of Lampasas in southwestern Lampasas and northwestern Burnet counties. Outcrops 4 to 7 miles southwest of Lampasas, along Pillar Bluff Creek, show no rocks older than the Honeycut formation.

Exposures are good along the creek banks and in the several prominent bluffs, and strata of all three facies of the Honeycut formation were seen. However, the overlapping Cretaceous strata make it difficult to trace beds and detect faulting, and it would not be possible to measure a reliable section at this place. The lowest beds seen were in the most westerly exposures, and they were probably in the vicinity of the zone of *Ceratopea capuliformis*, as judged from other fossils (TF–247). The highest strata exposed that are in measurable relationship to a recognizable zone contain *Ceratopea "keithi,"* are just above the middle dolomitic facies of the Honeycut formation, and are overlapped by Cretaceous sands in the bluff west of Pillar Bluff itself. They are about 70 feet above the large *Tarphyceras* which in other areas has been found only from 280 to possibly 330 feet above the base of the Honeycut formation. Thus the top of the Ellenburger group in the Pillar Bluff area is probably at least 350 to 400 feet above the base of the Honeycut formation, and possibly as much as 450 feet above its base to the east of Pillar Bluff, where Mississippian and Devonian rocks rest on limestones of the upper calcitic facies.

GOODRICH RANCH AREA, BURNET COUNTY

Reconnaissance studies on the Goodrich ranch and adjacent properties in northwestern Burnet County between Beaver Creek and the North Fork of Morgan Creek indicate that a section of Ellenburger and related rocks could be measured in this area. Detailed mapping would be necessary to delineate the faults and establish a line of section southwest from a prominent Carboniferous outlier toward Buchanan Lake. The final section would undoubtedly be composite. The various units of the Ellenburger group and the Wilberns formation in this area display characters similar to those in the Tanyard, Gorman Falls, and Cherokee areas. Although the highest beds seen could not be closely placed, they are probably well up in the zone of *Ceratopea* sp. 5 and possibly higher.

VICINITY OF MARBLE FALLS, BURNET AND LLANO COUNTIES

Reconnaissance studies were made, by the authors, of three possible sections in the vicinity of Marble Falls, in southwestern Burnet County. One was northeast of Marble Falls and south of the Southern Pacific flag station of Sudduth in an elongate fault block along and east of U.S. highway 281. It was provisionally considered in a progress report on the Ellenburger group (Cloud, Barnes, and Bridge, 1945, Pl. 7) and referred to as the Sudduth section. The other two sections are south of Marble Falls, one being east of U.S. highway 281 on Flatrock Creek, and the other being west of U.S. highway 281 on Slickrock Creek, in the southeastern corner of Llano County.

Dips are so gentle in the Flatrock Creek section that measurement is difficult and inaccurate, and only the upper beds of the Ellenburger were studied with any degree of care. They are in the *Ceratopea "keithi"* zone of the Honeycut formation and are overlapped by shales of the Barnett formation 100 feet above a bed containing a large species of *Tarphyceras*. The observed range of this *Tarphyceras* in measured sections indicates that the top of the Ellenburger

is 380 to 430 feet above the base of the Honeycut formation at this place, which is a mile south of Marble Falls. The upper calcitic facies of the Honeycut formation apparently runs considerably lower in the section here than it does in the Pillar Bluff area.

The Slickrock Creek section, in the extreme southeastern corner of Llano County, displays a "normal" sequence of Ellenburger rocks insofar as it was observed. All three facies of the Honeycut formation are represented, and it was estimated that about 450 feet of Honeycut strata are present. The Gorman formation is notably more arenaceous in this section than in areas seen north and west of here. It is thought to be nearly 500 feet thick. The Tanyard formation is poorly exposed and disrupted by faulting, but appears to present a fairly "normal" expression.

Work on the Sudduth section was considerably more extensive than on Flatrock and Slickrock Creeks, inasmuch as hope was held of measuring a complete section of the Ellenburger there.

In the preliminary examination of the Sudduth section all units of the Ellenburger group were seen. The Honeycut formation is in contact with the Marble Falls limestone in a narrow fault block 2.5 miles north of Marble Falls and just west of U.S. highway 281. An average dip of about 20 degrees and an outcrop breadth of 1500 feet in an area of slight relief indicates the Honeycut formation to be about 500 feet thick, but it is actually doubtful if the Honeycut is so thick at this place. The Gorman formation, with an average dip of about 17 degrees and an outcrop breadth near 1500 feet is indicated to be about 440 feet thick. The base of the section originally considered was near the base of the Pedernales dolomite member of the Wilberns formation about 2 miles northeast from its top, but the Wilberns-Tanyard contact was not located, and other factors made an estimate of thickness of the Tanyard formation unfeasible.

Later mapping by Barnes and Warren, in an effort to establish a line of section, revealed a fault which excluded the best outcrops of the Tanyard formation from the section. The remainder of the fault block in question, essentially uncomplicated by other faults, and containing a complete section from low in the Pedernales dolomite member of the Wilberns formation to the top of the Marble Falls limestone, is not suitable for measuring a section. This is due to poor exposures in the lower half of the sequence and large collapsed areas in the upper part of the Honeycut formation.

In the Sudduth area, as in the Johnson City area, coarse grained dolomite in the Pedernales dolomite member of the Wilberns formation is at least locally in contact with similar dolomite in the Threadgill member of the Tanyard formation, working against close location of the Wilberns-Tanyard boundary. South of Sudduth coarse to medium grained dolomite extends from a short distance above the *Scaevogyra* zone in the Pedernales dolomite to the contact of the Threadgill and Staendebach members of the Tanyard formation, and is almost devoid of fossils. This zone is almost 2 miles wide. Structurally and topographically it is almost flat, chert is scarce, and the few fossils obtained serve only to narrow the belt in which the Cambrian-Ordovician boundary must be located to a breadth of about 1 mile.

A feature of the Pedernales dolomite member of the Wilberns formation in the Sudduth area is the occurrence in it of minor patches of sublithographic limestone. These were seen south of Sudduth, as well as north of Sudduth along Honey Creek and south and southwest of Burnet in the vicinity of Post Mountain. These limestones are very similar to those in the Threadgill member of the Tanyard formation in the eastern part of the Llano uplift. Occasionally they have a greenish cast, suggesting that they might be remnants of bioherms.

ROWNTREE WELL NO. 1 KOTT, GILLESPIE COUNTY

A well in Gillespie County, drilled by L. U. Rowntree on the Richard Kott ranch about 12 miles south of the Threadgill Creek section, had reached a depth of 2215 feet in September, 1946,[11a] and was under observation by Barnes. This important well helps to fill a gap in the surface evidence on the south side of the Llano uplift, demonstrating a change in facies not seen at the surface and providing clues that should facilitate carrying the surface units into the subsurface to the southwest and thence to the west from the Llano region.

The calcitic facies of the Gorman formation is absent in the Kott well, although a few feet of limestone is present near the middle of the formation. The Honeycut formation appears to be dolomite for about 140 feet above its base, with the Gorman-Honeycut contact in a dolomite. The Gorman-Honeycut contact is placed at 895 feet, beneath a prominent sandy zone that is about 58 feet below the highest observed sand in what is thought to be the basal sandy portion of the Honeycut formation. The base of the Gorman formation is placed at 1357 feet, at the base of the lowest microgranular dolomite and about 15 feet beneath the lowest sandy zone. The thickness of rocks assigned to the Gorman formation in this well is 462 feet, which is very near the average thickness (466 feet) of this formation in measured surface sections.

The change from dolomite to limestone, which marks the approximate boundary between the Staendebach and Threadgill members of the Tanyard formation in the southwestern part of the Llano uplift, is at 1571 feet. The Staendebach member is thus 214 feet thick, which is near the thickness (205 feet) measured in the Pete Hollow section of the Bear Spring area. The bottom of the Threadgill member is placed at 1846 feet on the basis of the highest appearance of a significant amount of glauconite and the fact that sublithographic to microgranular limestones predominate above this point and granular limestones beneath.

The limestone of the Threadgill member is darker colored and much more silty than any known from surface sections. If its limits are correctly placed it is somewhat thinner (277 feet) than the 313 feet found in the Pete Hollow section.

Samples from 500 to 510 feet in the No. 1 Kott well suggest Ellenburger rocks, but Mr. Rowntree was of the opinion that a conglomerate was drilled to 645 feet. Samples from 645 to 660 feet are quite vuggy and leached in appearance, suggesting the correctness of his conclusion. No samples were available between 510 and 645 feet.

[11a] This well was completed early in 1947. Depths to the tops of formations and members of the Cambrian are as follows:

	Feet
Wilberns formation	1848
San Saba limestone member	1848
Point Peak shale member	2136
Morgan Creek limestone member	2320
Welge sandstone member	2390
Riley formation	2420
Lion Mountain sandstone member	2420
Cap Mountain limestone member	2465
Hickory sandstone member	2980
Pre-Cambrian basic igneous rock	3137
Total depth	3189

PART 3

SUPPLEMENTARY DATA

SECTION AT THE NORTH END OF BEACH MOUNTAIN, CULBERSON COUNTY, TEXAS

The base of the section here considered is at the base of the Bliss (?) sandstone, at an altitude of about 4500 feet, 0.4 mile southwest of State highway 54 from a point about 10 miles by speedometer north of Van Horn, Culberson County, Texas. Its top is about 0.5 mile south of the base, immediately below the bluff-forming Montoya limestone and at an altitude of about 5420 feet. Its location may readily be found on the geologic map of the Sierra Diablo region prepared by P. B. King and J. B. Knight (1944). For convenience it is known as the Beach Mountain section. The correlations here suggested are shown on Plates 15 and 16 and the units delimited are indicated on profile photographs on Plate 29. Thicknesses given were obtained by direct measurement and observed structural discontinuities were allowed for as indicated in the description.

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
Montoya limestone (Upper Ordovician): Thickness not determined. Base consists of pink and yellowish silty and sandy dolomite and dolomitic sandstone and siltstone. Forms an abrupt and imposing bluff at the top of the section. Top of measured section at disconformity at base of Montoya beds.			
El Paso formation (Lower Ordovician): 1115 feet thick			
Unit C (zone of earthy dolomites, probably equivalent to strata of Black Rock and Odenville age): 50 feet thick			
1. Interbedded earthy and calcitic dolomite and compact dolomite, in part grading to limestone in the earthy portions (altitude about 5420 feet at top of interval—the earthy dolomite and limestone is inequigranular, brownish gray, nodular, and weathers to "shaly-looking" benches. The compact dolomite is microgranular to very fine grained; yellowish, beige, and yellowish brown; locally arenaceous; and weathers to prominent intermittent ledges 4 to 14 inches thick. The entire interval makes a gently sloping bench between scarps.	50	50	1190 –1240
Poorly preserved small *Maclurites*, high-spired gastropods, and a small cephalopod provisionally referred to *Buttsoceras* were collected from 7 to 12 feet above the base of interval 1 (TF–327). Final determination of the age of this interval must await careful study of these and other fossils from it. However, small *Maclurites* is common in high Lower Ordovician strata at other localities and *Buttsoceras* is known only from the Odenville limestone of Alabama, so it is reasonably probable that unit C of the Beach Mountain section is approximately equivalent to the Odenville limestone of Alabama and correlative with some part of the Black Rock formation of Arkansas and unit C of the Franklin Mountain section.			
Unit B (zone of very fine grained to microgranular dolomites; post-Gorman and pre-Black Rock faunal equivalent): 813 feet thick			
Subunit B2 (post-Honeycut and pre-Black Rock faunal equivalent): 665 feet thick			

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
2. Dolomite, with local shaly beds (altitude about 5400 feet at top of interval)—the dolomite is very fine grained to microgranular; brown to grayish brown or brownish gray, in part grading to beige or rose gray. Beds 1 to 36 inches thick, mostly forming steep slopes and bluffs. Gentler slope with "breaks" of argillaceous dolomite and dolomitic shale from 1098 to 1120 feet and a few lesser shaly "breaks" above 1140 feet. Minor quartz druse and scattered siliceous oöids occur in the lower part of the interval. From 1055 to 1060 feet are scattered small nodules of semichalcedonic to subchalcedonic chert. At 1075 feet are irregular inclusions of chert. From 1095 to 1098 feet are scattered rosettes of quartz druse and irregular inclusions of semichalcedonic, partly oölitic, white- to tan-weathering chert. Irregular plates and inclusions of semichalcedonic to subchalcedonic, bluish gray to white chert occur from 1110 to 1113 feet, are abundant from 1116 to 1125 feet, and are scattered from 1180 to 1182 feet. Silicified *Ceratopea* was seen in dolomite at 1062; *Ceratopea* sp., *Hormotoma*, and large fragmentary gastropods were collected at 1067 feet (TF–440); *Ceratopea* and poorly preserved gastropods were collected at 1075 feet (TF–441); *Ceratopea* and *Hormotoma* were seen at 1130 feet; *Ceratopea* was seen at 1155 feet; and *Ceratopea ankylosa* Cullison (a Cotter fossil in Missouri) was collected from 1172 to 1174 feet (TF–326). Comparison of the Beach Mountain and El Paso sections suggests that interval 2 and possibly lower beds might be of post-Cotter age. Although the available faunal evidence does not support this interpretation, the correspondence of arenaceous zones near the middle of Unit B2 of the two sections strongly suggests it.	160	210	1030 –1190
3. A rubble-covered bench, judged from projection to be underlain by dolomite which is probably locally argillaceous.	20	230	1010 –1030
4. Dolomite—very fine to fine grained, intermittently grading to microgranular; medium grayish brown and brownish gray, grading to brown or nutria and in minor part with pinkish tinges. Bluff-forming, well-exposed, irregularly and rather thickly bedded. The dolomite is argillaceous and recessive weathering from 944 to 945 feet, and an intraformational conglomerate was seen at 960 to 961 feet. Scattered quartz druse was seen from 926 to 932 feet. Concentrically-weathering, partly arenaceous nodules of subchalcedonic to semichalcedonic chert and minor chert-matrix sand occur at 941.5 feet. At 957 feet is a conspicuous but sporadically occurring zone of russet-weathering silicified pellets and oöids, fragmental chert, and quartz druse containing occasional small gastropods. Fragmental chalcedonic to subchalcedonic, bluish gray chert is conspicuous at 988 feet. Oölitic and fragmental chert and scattered free siliceous oöids occur from 994 to 995 feet. Sand was seen as abundant to scattered grains in dolomite from 909 to 910, 911 to 912, 915.5 to 916.5, 922 to 925, at 937, from 940 to 957, 980 to 983.5, and 985 to 987 feet. Sand grains also occur in some of the chert nodules at 941.5 feet, and an inch-thick lens of chert-matrix sand was noted at 958 feet. Two genera of high-spired gastropods were collected from chert at 957 feet (TF–439), and poorly preserved silicified *Ceratopea* and gastropods were seen in the chert zone from 994 to 995 feet.	101	331	909 –1010

Description	*Thickness in feet* Inter-val	Cumu-lative	*Feet above base*
In going up in the section the peak of a prominent pinnacle (altitude about 5255 feet) is reached just above the base of interval 4, and a fault which trends north-northwest through the narrow col (altitude about 5210 feet) between this pinnacle and the upper part of the section has dropped the section about 45 feet on the west side. The section is carried across the fault on the basis of the combined repetition of interval 6, the prominent oölitic chert at the middle of interval 5, and the sand zone at the base of interval 4.			
Subunit B2 may be further subdivided at the base of interval 4 into an upper portion 331 feet thick (B2b) and a lower portion 334 feet thick (B2a), to correspond with similar but better marked divisions in the El Paso section (which see).			
5. Dolomite—similar to interval 4, and separated from it on the basis of the marked zone of intermittently occurring sand in the lower 48 feet of interval 4.	24	355	885 – 909
Scattered nodules of chalcedonic to subchalcedonic, bluish white chert occur in the lower 4 feet. From 895 to 901 feet nodules and irregular inclusions of highly oölitic, brownish white, russet-weathering fossiliferous chert are locally very abundant, and a few pieces of subchalcedonic to semichalcedonic, bluish white chert were seen.			
Sand occurs as scattered to abundant grains in dolomite from 897 to 898 feet.			
Hormotoma and a few other small gastropods were seen in the oölitic chert from 895 to 901 feet.			
6. Dolomite—fine to medium grained, pearl gray.	2.5	357.5	882.5– 885
In its very light pinkish to brownish gray color and its relatively "coarse" grain size, this dolomite contrasts strongly with the strata of intervals 4, 5, and 7.			
7. Dolomite—similar to that of interval 4, except in the lower 6 to 8 feet where it is fine grained, grayish brown to brown, and weathers pitted. The freshly broken rock locally yields a weakly petroliferous odor; and fine grained, brown to nutria dolomites from 725 to 740 feet (500 to 515 feet below base of Montoya limestone) have a strong petroliferous odor.	184.5	542	698 – 882.5
Chert resembling that in the top 23 feet of interval 8 occurs from 2 to 7 feet above the base of interval 7. From 706 to 708 feet the chert is highly oölitic, semichalcedonic, brownish to bluish gray, shiny white to tan weathering, and is accompanied by free, druse-frosted siliceous oöids and scattered excrescences and irregular layers of quartz druse. From 715 to 718 feet are quartz druse and chert like that in the top 23 feet of interval 8. Quartz druse is sparingly intermittent from 718 to 735 feet and prominent with sicilified pellets and possibly oöids on the top ledge of a conspicuous bluff at 735 feet. From 770 to 805 feet are intermittent excrescences and layers of russet-weathering quartz druse and occasional nodules of semichalcedonic chert, with scattered free siliceous oöids at 791 feet.			
Scattered sand grains were seen in the dolomite from 752 to 755, 759 to 760, 772.5 to 774.5, 823.5 to 824.5, and 847 to 848 feet. They were mostly well rounded, frosted, fine to medium grained, and poorly sorted.			
A siphuncle like that of *Mcqueenoceras* was seen at 710 feet, and *Hormotoma* sp. and another siphuncle were noted at 735 feet.			

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
8. Dolomite—mostly very fine grained; grayish brown to brownish gray, in part with rose to purplish tinges. Irregularly but thickly bedded, with some beds as much as 3 feet thick. Forms the lower part of a prominent bluff. Chert occurs from 653 to 655 feet as scattered irregular inclusions and lenses that are subporcelaneous to semichalcedonic, dull white to brownish gray, and weather tan to bluish white. At 663 feet minor chert is subporcelaneous to semichalcedonic, dirty white, and russet weathering. From 675 to 698 feet are scattered, russet-weathering layers and excrescences of quartz druse and minor flat lenticles, plates, and nodules of chert that is subporcelaneous to chalcedonic, white to bluish and pinkish gray, and weathers shiny white. Sand grains are abundant in the basal 2.5 to 3 feet of interval 8 at the foot of a prominent bluff. They are subangular to subround and of medium size. The dolomite in which they occur is fine grained and stands in marked contrast to the upper 2 feet of microgranular dolomite of interval 9. Above interval 9 the dolomites are marked by recurring zones of scattered to abundant sand grains, and if faunal evidence or persistent physical differences, or comparable divisions in other sections could be found to substantiate it, the post-Honeycut faunal equivalent might be further divided at the base of interval 8. Likewise, if evidence could be found to substantiate it, the boundary between the Honeycut and post-Honeycut faunal equivalents might be placed here.	53	595	645 – 698
9. Dolomite (altitude about 5030 feet at top of interval)—mostly very fine grained, in part grading to microgranular or fine grained, microgranular in top 2 feet. Medium gray to brownish gray with local yellowish, beige, pinkish and purplish tinges. Irregularly bedded with beds as much as 3 feet thick. Makes a fairly steady grade to foot of bluff at 645 feet. Similar to interval 10 except that it tends to be slightly coarser grained and considerably less cherty. Quartz druse occurs from 604.5 to 607.5, 631 to 635, and 640 to 643 feet as scattered to abundant rosettes and hollow cauliflower-like concretions up to 3.5 inches in diameter. Minor chert and druse similar to that of interval 10 occur locally. *Ceratopea tennesseensis* Oder is very abundant and an occasional piloceratid siphuncle was seen in fine to very fine grained porous dolomite from 604.5 to 607.5 feet (TF–436), altitude about 5010 feet. *Ceratopea* cf. *C. tennesseensis* Oder and *C.* cf. *C. keithi* Ulrich were collected at 620 feet (TF–324). *Ceratopea* cf. *C. tennesseensis* Oder, *C.* sp. ?, and an endoceratid siphuncle were collected at 643 feet (TF–325). The boundary between the faunal equivalent of the Honeycut-Jefferson City strata (Subunit B1) and that of the post-Honeycut strata (Subunit B2) is arbitrarily placed at the base of interval 9. It is an unfortunate location inasmuch as the lower strata of this interval are disturbed and the base is not actually exposed. The chaotically displaced blocks, the breadth of the disturbed area, its indefinite direction and continuity, and the centripetal dips of the marginal beds suggest a structural sink rather than a fault. Due to limiting structure and exposures the authors were not able to get around this disturbed area and so	120	715	525 – 645

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
measured across it at the average dip of the section in order to approximate the actual thickness of interval 9. The probable presence of a structural sink at this place indicates differential solubility or permeability between the base of interval 9 and the top of interval 10, and to that extent supports the placement of the boundary at this point. Of the fossils that compare with those from interval 9, *Ceratopea tennesseensis* is known from the top ledge of the Honeycut formation in its thickest section and from both Jefferson City (equivalent to Honeycut) and Cotter strata in Missouri; *C. "keithi"* marks the upper Honeycut in the Llano region but has an uncertain upper limit. No fossils known to be restricted to beds of Honeycut-Jefferson City age have been found above interval 10. An alternate possible position for the boundary between Subunits B1 and B2 is the top of interval 9. The thickness of Subunit B2 as now recognized is 665 feet.			
Subunit B1 (Honeycut faunal equivalent): 148 feet thick			
10. Dolomite (altitude about 4945 feet at top of interval)—very fine grained to microgranular; medium gray to brownish gray, with local purplish and yellowish tinges; irregularly bedded, with beds up to 36 inches thick. Chert occurs intermittently from 440 to 490 and from 518 to 520 feet as scattered to fairly abundant nodules and irregular inclusions that are semichalcedonic to subchalcedonic and bluish to brownish gray. Excrescences and rosettes of druse occur locally throughout interval 10, and occasional zones of fragmental chert and silicified pellets and perhaps oöids were seen. A layer of semichalcedonic, bluish gray, russet-weathering, fossiliferous chert occurs at the top of the interval. A flat-ended siphuncle of the *Mcqueenoceras* type and possibly a large *Ceratopea* were seen at 449 feet. *Calathium*, *Ceratopea* sp., a *Mcqueenoceras* siphuncle, and another endoceratid siphuncle were collected at 458 feet (TF-322). *Calathium*, an unguliform *Ceratopea*, poorly preserved gastropods, and a fragment of a cephalopod were collected from, and an *Orospira* was seen in, the chert at 525 feet (TF-323).	85	800	440 - 525
11. Dolomite, grading to calcareous dolomite and dolomitic and argillaceous limestone from 422 to 440 feet—mostly very fine grained, grading to microgranular and less commonly to fine grained; brownish, yellowish and pinkish gray to gray; beds from 1 to 20 inches thick. Mostly microgranular, thin bedded, and gray to light yellowish gray in basal 3.5 feet. The thinly bedded, bench-forming, calcareous dolomite and dolomitic and argillaceous limestone in the upper 18 feet is locally purplish to lavender in the top part. Layers and discontinuous lenses of granular, pelleted, brownish gray chert up to 5 inches thick occur between 393.5 and 395 feet. Semichalcedonic bluish gray chert occurs as russet-weathering excrescences from 408 to 411 feet. Russet-weathering, cherty and conglomeratic sandstone, grading to arenaceous and siliceous dolomite occurs from 415 to 415.5 feet. *Hormotoma* and other gastropods occur locally in chert from 393.5 to 395 feet. *Hormotoma*, siphuncles of breviconе cephalopods, and an occasional fragment of *Calathium* were seen in chert from 408 to 411 feet and 415 to 415.5 feet. *Archaeoscyphia* cf. *A. annulata* Cullison and a	50	850	390 - 440

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
cephalopod fragment suggesting *Pycnoceras* were collected from 408 to 410 feet (TF–320). Silicified *Archaeorthis* and *Finkelnburgia* were seen in dolomite at 418 feet. A few poorly preserved *Ceratopea* were seen between 436 and 437 feet. Silicified *Archaeorthis costellata* Ulrich & Cooper and cystid plates were collected from the bench at the top of the interval at 440 feet (TF–321).			
12. Dolomite—fine to very fine grained in the lower 4 feet; fine to medium grained, vuggy, and partly calcitic in the upper 9 feet. Yellowish gray to light gray. Beds 1 to 30 inches thick. Scattered sand grains occur in the lower 4 feet. Silicified *Xenelasma syntrophioides* Ulrich & Cooper, a lower Honeycut fossil in the Llano region, was collected from 381 to 383 feet along with an unidentified sponge, *Hormotoma* sp., and *Polhemia?* (TF–319). *Orospira?* and abundant *Hormotoma* were seen from 380 to 385 feet. The boundary between the Gorman and Honeycut faunal equivalents (Unit A and Subunit B1) is provisionally placed at the base of interval 12, thus including all of the prominently arenaceous lower part of the El Paso formation in the Gorman (= Roubidoux) faunal equivalent. Thickness of Subunit B1 is 148 feet. Total thickness of Unit B is 813 feet.	13	863	377 – 390
Unit A (zone of sandstone, limestone, and dolomite; Gorman faunal equivalent): 252 feet thick			
13. Dolomitic sandstone, grading to very arenaceous dolomite (altitude about 4835 feet at top of interval)—sand grains fine to medium grained, mostly well rounded, poorly sorted, containing a few scattered feldspar grains. Dolomite fine grained, gray to pinkish gray.	4	867	373 – 377
14. Dolomite—very fine grained, gray, beds 1 to 24 inches thick. In large part moderately arenaceous, with the individual sand grains varying widely in size, mostly well rounded, and frosted. Occasional subangular feldspar grains were also seen. *Polhemia*-like gastropods, small brevicone cephalopods, and poorly silicified syntrophioid brachiopods were seen between 368 and 369 feet. The brachiopods were collected and freed from the dolomite but could not be identified positively. The ventral valves bear a spondylium, but the structure of the cardinalia is obscure. What could be seen of the cardinalia suggests *Diaphelasma,* a Gorman fossil in the Llano region. The fossils were discarded after study.	8	875	365 – 373
15. Arenaceous and argillaceous dolomite and dolomitic sandstone—mostly fine to very fine grained in dolomitic parts. Sand grains subround to round, fine to coarse grained, poorly sorted. The rock is yellowish to brownish gray with greenish tinges and there is a greenish argillaceous zone at the top of the interval. Gastropods suggesting *Euconia* and *Polhemia* were seen near the middle of interval 15. The base of interval 15 may be considered as an alternative possibility for the boundary between the Gorman and Honeycut faunal equivalents, should the present location for any reason be discredited.	11	886	354 – 365
16. Dolomitic sandstone (altitude about 4810 feet at top of interval)—medium to fine grained, tangentially laminated, yellowish to pinkish sandstone grading to the interval below. Tends to be coarse grained toward the top and con-	29	915	325 – 354

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
	tains granules of scattered to abundant feldspar grains in the upper part. Beds up to 5.5 feet thick. Interval 16 is a persistent, bluff-forming sandstone in the vicinity of Beach Mountain, but appears to be absent or inconspicuous on the Diablo Plateau 17 miles northwest of here in a section between Black Knobs and Cox Mountain.			
17.	Dolomitic siltstone, grading to very fine grained sandstone with occasional thin zones of coarser sandstone—tangentially laminated, yellowish to pinkish and yellowish gray. Where sand occurs the grains are well rounded and frosted. Beds up to 4.5 feet thick, with the lower 6.5 feet making a prominent "step" in the mountainslope. Grades to interval 16 above. Minor glauconite was seen at the base of interval 17.	21	936	304 – 325
18.	Dolomite—silty and sandy, fine grained, yellowish to brownish gray, rubbly and earthy weathering.	15	951	289 – 304
19.	Dolomite, locally slightly calcitic—mostly very fine grained, grading to microgranular and locally to fine grained; light to medium yellowish to brownish gray; beds 1 to 48 inches thick. Weathers dull brownish yellow to buff and makes a prominent "step" in the mountainslope in the lower 12 feet. Coarse silt or very fine grained sandstone occurs in the dolomite at 265 feet. Minor glauconite was seen at 265 feet and in a calcitic zone at 267 feet, and interstitial glauconite was seen in dolomite at 278 feet. Cystid plates and columnals were seen at 278 feet.	40	991	249 – 289
20.	Limestone, mostly dolomitic or with irregular dolomitic inclusions or layers, and with a layer of dolomite from 239.5 to 240.5—very fine to fine grained, medium gray to yellowish gray. Beds 1 to 12 inches thick, in part massive-looking but weathering thinner. The bed of dolomite from 239.5 to 240.5 is very fine grained to microgranular, dull taffy yellow, and grades laterally to limestone. Chert is abundant in the lower 3 feet as thin bands (1 inch or less) and lenticles that are highly oölitic and brown to brownish and pinkish gray. A sponge with affinities to *Archaeoscyphia, Diaphelasma, Allopiloceras* sp., and an unidentified trilobite were collected from 243 to 244 feet (TF–318).	17	1008	232 – 249
21.	Interbedded limestone and yellow-weathering calcareous shale—the limestone is fine grained, gray, in part thinly platy to nodular. Grades to intervals above and below. In part silty and cherty, with chert as in interval 20.	6	1014	226 – 232
22.	Limestone, with dolomitic streaks and in part grading laterally to dolomite—medium grained to very fine grained, medium to light gray. Breaks up to thinly irregular beds except in lower 3 and upper 4 feet, which tend to weather massive. Weathers bluish gray with yellowish dolomitic streaks, and the top 4 feet makes an inconspicuous "step" in the mountainslope. Glauconite is fairly common at 216 feet. The top 3.5 inches of interval 22 is a calcareous, cherty, conglomeratic sandstone containing abundant small gastropods. Piloceratid siphuncles (probably *Allopiloceras* and *Piloceras*) are abundant in the basal 3 feet. *Lytospira* and "*Euconia*" were collected at 212.5 feet (TF–315); *Diaphelasma oklahomense* Ulrich & Cooper and *Syntrophina* sp. at	16	1030	210 – 226

	Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*
	216 feet (TF–316); and *Ophileta (Ozarkispira)* cf. *O. rotuliformis* (Meek), *Ophileta* sp., *Hormotoma* sp., a raphistomoid gastropod, and a small cyrtendoceratid cephalopod from 225 to 226 feet (TF–317). The base of interval 22 is probably the only reasonable alternative location for the boundary between the Tanyard and Gorman faunal equivalents should the present dating of collections TF–433 and TF–434 be discredited. The 3-foot "*Piloceras*"—bed at the base of interval 22 is sharply distinct from the underlying beds for the 300 to 400 yards that it could be followed between talus cover to the east and a fault and cover to the west. However, the general aspect of interval 22 is so like that of the limestones in interval 23 that they were originally lumped in description.			
23.	Dolomite from 184 to 193, 195 to 197, and 206 to 210; limestone and dolomitic limestone from 193 to 195 and 197 to 206 (altitude about 4700 feet at top of interval)—the dolomite is fine to very fine grained; greenish to brownish gray, with pink to tan tinges; in beds from less than 1 to as much as 24 inches thick; and weathers dull yellowish brown. The limestone has dolomitic streaks and in part grades to dolomite, is granular, is medium to light gray, weathers bluish gray with yellowish streaks where dolomitic, and breaks up to thinly irregular beds. Silicified specimens of *Clarkella* sp., *Syntrophina* sp., *Ophileta (Ozarkispira)* cf. *O. rotuliformis* (Meek), and *Hormotoma* sp. were collected from 193 to 195 feet (TF–433). Cystid plates, a poorly preserved silicified dorsal valve of a reticulate species of *Tetralobula*, *Ozarkispira* sp., *Lytospira?*, *Piloceras* sp., *Allopiloceras* sp., and *Kirkoceras?* were obtained between 199 and 201 feet (TF–434). The affinities of this assemblage are obviously contradictory and are discussed at length in a preceding section of this report. It is provisionally concluded, on the basis of the fossils named, that the assemblage is of Gorman age. Fossils not positively identified or collected cannot bear on such a discussion, but it should be noted that a horizontal section of a large, widely phaneromphalous gastropod *(Rhombella?)* and a poorly preserved apparently pseudosinistral, sharply keeled gastropod *(Lecanospira?)* were seen between 193 and 195 feet. Few gastropods in the Tanyard formation could display such characters, no matter how much weathered.	26	1056	184 – 210
24.	Sandstone, with dolomitic cement and with patches of dolomite in top 4 feet (elevation about 4670 feet at top of interval)—mostly medium to coarse grained, tangentially laminated, yellowish gray to pink. Massive, with the lower 6 feet forming a low abrupt bluff prominent in the profile of the mountain. Grades to interval 25.	9	1065	175 – 184
25.	Siltstone, grading to very fine grained sandstone, with dolomitic cement—tangentially laminated.	12	1077	163 – 175
26.	Interbedded silty, sandy, and earthy dolomite; dolomitic siltstone; minor sandstone; and much argillaceous material, including thin green shale beds—weathers to a fairly even slope in which the exposures are poor and the strata are mostly deeply weathered. The lack of resistance to weathering is a prominent feature of this interval and it can be followed at a glance for about 1.5 miles along the sheer bluffs at the northwest end of Beach Mountain as a slightly recessive band that weathers a brighter yellow than the beds above and below.	38	1115	125 – 163

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
The basal bed of interval 26 is exposed intermittently for about 150 feet near the line of section. It is a 4- to 10-inch bed of dull rose to yellowish dolomite containing scattered sand grains, a few quartz granules, and occasional rounded pebbles and cobbles of sandstone. Two sandstone cobbles measured 6 × 2 × 2 inches each and one large and incompletely exposed sandstone cobble measured 10 × 5 × 2 inches in the exposed part. Its contact with the upper bed of interval 27 is irregular and abrupt. Following the basal bed is a 12- to 18-inch bed of yellowish to buff, fine grained dolomite which contains only rare grains of sand.			
The boundary between the Tanyard and Gorman faunal equivalents is provisionally placed at the base of interval 26. Fossils believed to be of upper Tanyard age occur 4 to 8 feet below this point (TF–437), and a fauna considered to be of Gorman age occurs 68 to 76 feet above it (TF–433 and TF–434). Although the basal bed of interval 26 can hardly be called a conglomerate, the presence in it of extraneous rounded pebbles, apparently derived from interval 27, and its abrupt and irregular contact with interval 27 suggest erosion and point to a disconformity between the Bliss (?) sandstone and the El Paso formation, and thus between the Tanyard and Gorman faunal equivalents.			
Thickness of Unit A is 252 feet, of El Paso formation proper 1065 feet.			
Bliss (?) sandstone (in part and probably wholly Lower Ordovician): 125 feet thick			
Provisional Tanyard faunal equivalent: 125 feet thick			
27. Sandstone alternating with argillaceous sandstone and shale (elevation about 4625 feet at top of interval)—the sandstone is very fine to coarse grained, with occasional quartz-pebble conglomeratic zones in the lower half. It is tangentially laminated; pinkish to yellowish gray, grading to dull maroon and greenish; friable to well indurated or almost quartzitic; and calcareous throughout, varying in degree of effervescence under dilute HCl from fairly strong to an effervescence that is audible but not visible. The sandstone is intermittently argillaceous, grading to green and purplish arenaceous shale, with green arenaceous shale conspicuous from 78 to 82 feet. Beds 1 to 24 inches thick. Weathers to alternating steps and even slopes at the base of the mountain profile.	125	1240	0 – 125
A 10-inch bed of fine grained, gray dolomite was seen 63 feet above the base of interval 27.			
A few very small green grains suggesting glauconite were seen near the middle of interval 27, but other green material examined proved to be shale and the interval is essentially nonglauconitic.			
The well-indurated layers commonly display vertical *Scolithus*-tubes or irregular borings and some show scattered to abundant molds of low-spired to planispiral gastropods reminiscent of *Lytospira, Ophileta,* etc. *Lingulepis* was collected from 75 feet above the base (TF–431); and *Lingulepis, Lingulella,* part of a gastropod whorl suggesting *Lytospira* and archaeostracan crustaceans were collected from 98 to 105 feet above the base of the interval (TF–432). On the surfaces of the beds in the vicinity of these collections impressions of unidentified gastropods are not uncommon. On the west side of Beach Mountain, about 2.2 miles airline southwest of the line of section, *Lytospira, Ophileta,* a gastropod suggesting *Helicotoma* of			

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
the type of *H. uniangulata* (Hall), *Clarkoceras,* and archaeostracan crustaceans were collected 4 to 8 feet below the top of the Bliss (?) (TF–437). A little south of here *Lingulepis* was obtained from rock in place and archaeostracan crustaceans from float that seemed to be close to its source about 20 feet below the top of the Bliss (?) (TF–438). In a discussion in a preceding part of this report it is concluded that collection TF–437 represents an upper Tanyard fauna and that *Lingulepis,* generally considered an Upper Cambrian fossil, is probably to be discounted and the entire Bliss (?) sandstone of the vicinity of Beach Mountain provisionally correlated with the Tanyard formation.			
It should be noted that interval 27 is described from the next spur west of the principal line of section, across two minor faults from it, where better exposures are offered than in the principal line of section. Collections TF–431 and 432, however, were obtained from the principal line of section.			
Base of Bliss (?) sandstone, provisional Tanyard faunal equivalent, and Beach Mountain section, and angularly unconformable contact with the Cambrian (?) or pre-Cambrian Van Horn sandstone at base of interval 27 (elevation in a wash east of the principal line of section about 4500 feet). The Van Horn sandstone at this place consists of arkosic, micaceous, and locally argillaceous to earthy sandstone, siltstone, and conglomerate. The exposures seen are mostly maroon, grading to yellowish and grayish, slightly calcareous at the top, and contain some beds of arenaceous shale but no glauconite.			
Thickness of Bliss (?) sandstone and provisional Tanyard faunal equivalent 125 feet, of measured Ordovician section 1240 feet.			

SECTION AT THE SOUTH END OF THE FRANKLIN MOUNTAINS, EL PASO COUNTY, TEXAS

The section here described is located at the south end of the Franklin Mountains, on the east or scarp slope, just outside the city limits of El Paso and is referred to as the El Paso section (figs. 5, 6; Pl. 15). Figure 5 shows the position and approximate geologic relationships of the section, and its larger geographic setting may be seen on the new 7.5 minute topographic map of the El Paso quadrangle (U.S. Geological Survey, 1943) from which the base data in figure 5 were taken. The measurements given for the El Paso section were derived as follows: the thickness of the Bliss sandstone was computed from data obtained just west of the city park at the head of McKelligon Canyon in the northwest corner of the 7.5 minute El Paso quadrangle; intervals 22 to 27 and 1 to 6 were measured directly and in part adjusted to computations; and thicknesses of all other intervals were geometrically derived from located points on an unexaggerated profile section (fig. 6) plotted from data on the 7.5 minute topographic map of the El Paso quadrangle. The located points were obtained from the adjusted mean of two essentially correspondent sets of elevations obtained at different times with a Paulin precision altimeter, supplemented by paced distances where topography was gentle and by direct measurement of the thinner intervals. Observed structural discontinuities were allowed for, but minor faults are common and some were probably not discovered. One suspected fault was not proved and is not allowed for in the section. The minor faults seen were aligned in a general northeast-southwest trend and probably dip steeply northwest. The northwest side was the downthrown side in all but one of the observed provable faults so that the net

effect of undetected faults would probably be to shorten the section. It is unlikely, therefore, that the computed and measured thickness of 1590 feet is excessive for the El Paso formation in the section measured, although it considerably exceeds the approximately 1000 feet given in previously published estimates. In fact to obtain a figure of 1000 feet for the thickness of the El Paso formation over the horizontal and vertical distances measured requires the assumption of an average apparent dip of less than 10° and no allowance for faulting. At no place observed by the authors in the line of section followed was the dip less than 20°, and it averaged about 30°.

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Montoya limestone (Upper Ordovician): Thickness not determined; about 80 feet exposed to crest or ridge at elevation of 4970 feet above principal line of section.			
The lower part comprises a prominent, ridge-capping bluff of massively bedded limestone that is fine to medium grained, medium to dark gray, and has an irregular internal meshwork of slightly dolomitic limestone. It weathers medium to light gray with numerous irregularly elongated, raised, dark gray mottles representing the dolomitic portions and resulting in a worm-eaten appearance. Locally it grades to calcitic dolomite.			
The basal 6 inches is highly arenaceous and slightly argillaceous and dolomitic.			
Well preserved, silicified *Rhynchotrema* cf. *R. capax* (Conrad), *Hebertella* sp., *Platystrophia* sp., *Strophomena* sp., and *Streptelasma* sp., indicating an Upper Ordovician age were seen along the foot trail at the mountain-crest about one-half mile north of the observation point on Scenic Drive (F on fig. 5). Small pelmatozoan fragments were seen to be numerous and sections of corals and large cephalopods common in the Montoya limestone at several places along the ridge-trail.			
The Montoya limestone rests disconformably on the El Paso formation with truncation possibly amounting to as much as 10 feet in the three-fourths mile between the observation point on Scenic Drive and the top of the principal segment of the section.			
El Paso formation (Lower Ordovician): 1590 feet thick			
Unit C (zone of inequigranular shell-limestones; equivalent to strata of Black Rock and Odenville age): 36 feet thick			
Comprises intervals 1 through 6 and measured on the north side of Scenic Drive at the observation point (elevation marker at 4222 feet).			
1. Dolomite, slightly calcitic—very fine grained, dull yellow, earthy looking.	3	3	1587 –1590
2. Limestone and minor calcareous shale—the limestone is inequigranular and crowded with fragments of fossils, medium to dark gray with yellowish mottles. It grades in part to earthy limestone and interbedded calcareous shale and weathers rubbly and marly-looking.	9	12	1578 –1587
Hesperonomia sp. (probably "*Taffia* near *iones*" of Kirk, 1934), a small orthoid brachiopod with affinities to *Archaeorthis*, and "*Asaphus*" cf. *A. curiosus* Billings were collected from interval 2 (TF–454).			
3. Dolomite, slightly calcitic, grading to slightly dolomitic limestone in the lower 12 and upper 8 inches—very fine grained to microgranular; medium yellowish to brownish gray, in part mottled. Weathers dull yellow.	6	18	1572 –1578

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
4. Limestone, with a 5- to 9-inch shale break about 2 feet above the base and a thin shale break at the top—the limestone is inequigranular, containing numerous fragments of trilobites and other fossils; medium to dark gray with minor yellowish mottles and streaks. A large species of *Tritoechia* was obtained from the upper 3 feet of interval 4 (TF–453).	5.5	23.5	1566.5–1572
5. Shale and limestone, thinly interbedded—the shale is gray and calcareous, and the limestone is nodular, fine to very fine grained and gray. One to 2 inches of intraformational breccia occur at the top of the interval.	5.5	29	1561 –1566.5
6. Limestone, in part argillaceous—inequigranular, containing many fragments of fossils; medium to dark gray with mottles and irregular layers that are yellowish to buff. Fossils are abundant throughout this interval and the following fauna was obtained from it: cystoid plates and columnals, *Hesperonomia* sp., *Tritoechia* large sp., *Syntrophopsis magna* Ulrich & Cooper (possibly "*Syntrophia* cf. *obscura*" of Kirk, 1934), *Isoteloides* (?), *Cybeloides* aff. *C. primus* (Raymond), an unidentified flabelliform trilobite pygidium with affinities to *Pliomerops*, and other trilobite remains (TF–452, TF–357). The trilobites named have affinities with those of lowest Middle Ordovician age, but high Lower Ordovician trilobites are poorly known and the brachiopods strongly indicate a high Lower Ordovician age. The fossils of Unit C indicate its homotaxial equivalence to the Odenville limestone of Alabama and the Black Rock formation of Arkansas. They also indirectly indicate its probable correlation with Unit C of the El Paso formation in the Beach Mountain section, Culberson County, Texas. Base of Unit C at base of interval 6. Thickness 36 feet. Shift about 0.7 mile south if going up in the section and north if going down. The actual shift occurs below the scarp in the Montoya limestone, but the point of shift is readily recognizable and it is easier walking on the foot trail at the crest of the mountain.	7	36	1554 –1561
Unit B (zone of predominating limestone; post-Gorman and pre-Black Rock faunal equivalent): 1014 feet thick			
Subunit B2 (post-Honeycut and pre-Black Rock faunal equivalent): 699 feet thick			
7. Limestone, locally argillaceous, and with occasional minor interbeds of dolomite—the limestone is microgranular to medium grained and locally sublithographic; medium gray to black, in part with yellow to buff mottles and streaks where argillaceous. The very minor dolomite is very fine grained to microgranular and medium to dark gray. The limestone that characterizes this interval is predominantly ribboned (beds less than 1 inch to slightly more than 1 inch thick) and conspicuously cherty. Its conspicuously ribboned weathered surfaces are marked by discontinuous yellow, buff, and russet streaks that denote the cherty layers. Chert is intermittently abundant as extensive thin lenses and layers of nodules that are semichalcedonic to subgranular and weather russet, buff, or yellow. A zone from 5 to 50 feet below the top of the interval seemed markedly cherty, but distribution of chert varies along the trace of the beds. *Calathium*, *Finkelnburgia?*, and unidentified gastropods were noted about 10 feet above the base of interval 7, and cystoid plates and columnals occur intermittently throughout. *Diparelasma*? and *Hesperonomia antelopensis*	220	256	1334 –1554

	Description	Thickness in feet: Interval	Cumulative	Feet above base	
	Ulrich & Cooper were collected 100 feet above the base of interval 7 (TF–356). *Hesperonomia* sp., the operculum of *Maclurites*?, and siphuncles of an endoceroid cephalopod suggesting *Mcqueenoceras* were collected 74 feet below the top of the interval (TF–358 projected). An unidentified sponge, *Archaeorthis*?, *Hesperonomia antelopensis* Ulrich & Cooper, and *Tritoechia* sp. were obtained 11 feet below the top of interval 7 (TF–451).				
8.	Dolomite—very fine grained to microgranular, medium gray to black.	8	264	1326	–1334
9.	Dolomite—fine to very fine grained, dark gray to black.	4	268	1322	–1326
10.	Dolomite—microgranular to very fine grained, medium to dark gray. Intermittently and prominently arenaceous in lower 50 feet.	67	335	1255	–1322
	Subunit B2 may be further subdivided at the base of interval 10 into an upper portion 335 feet thick (B2b) and a lower portion 364 feet thick (B2a). At present writing an arenaceous zone at the approximate position of the basal 50 feet of interval 10 has been recognized in a section 3 miles to the north, at the head of McKelligon Canyon and probably in the Beach Mountain section in Culberson County.				
11.	Dolomite, with minor interbeds of limestone—the dolomite is microgranular to fine grained, medium to dark gray. The minor limestone is like that of intervals 12 and 13.	25	360	1230	–1255
12.	Limestone—the interval begins basally with a 20-foot bluff of resistant limestones, and the upper 45 feet consists of limestone like that of interval 13. *Diparelasma typicum* Ulrich & Cooper and *Syntrophia?* were collected from the top 5 feet of interval 12 (TF–355), and cystoid plates and columnals occur intermittently throughout. *Diparelasma typicum* occurs also in the Odenville limestone of Alabama (Ulrich & Cooper, 1938, p. 237), a correlative of the Black Rock formation, and its probable occurrence in interval 12 might be considered by some as evidence for readjustment of the faunal boundaries here indicated.	65	425	1165	–1230
13.	Limestone, with intermittent largely covered zones probably underlain by interbedded limestone and shale or argillaceous limestone—the limestone is medium to fine grained, medium to dark gray to brownish gray. The interval is in part slightly dolomitic in the upper 60 feet, and the lower 9 feet is apparently underlain by calcareous shale and argillaceous limestone that weathers to a conspicuous bench in the line of section. Interval 13 is locally slightly cherty. In the lower 100 feet of the interval were seen *Calathium*, numerous cystoid plates and columnals, poorly preserved brachiopods, *Hormotoma* and other gastropods, and an occasional brevicone siphuncle.	155	580	1010	–1165
14.	Limestone, locally brittle and argillaceous, and with intermittent largely covered zones probably underlain by interbedded limestone and shale or argillaceous limestone—interval 14 is like interval 15 except for the presence of probable shaly breaks. Chert, similar to that of interval 15, is intermittently abundant. *Archaeorthis costellata* Ulrich & Cooper, *Finkelnburgia* sp., and *Polytoechia*, n. sp.,* were obtained about 20 feet below the top of interval 14 (TF–361 projected). *Finkelnburgia* sp. and *Polytoechia*, n. sp.,* were collected from the top ledge of the interval (TF–450), a ledge containing scattered chert nodules and segments of trilobites.	155	735	855	–1010

**Polytoechia bella* Cloud (in press).

Description	*Thickness in feet* Interval	Cumulative	*Feet above base*
Base of Subunit B2 at base of interval 14. Thickness about 699 feet. Subunit B2 is a faunal subdivision including all strata younger than the Honeycut and older than the Black Rock formation. Its fossils seem to have their strongest affinities with those of the Powell dolomite, but rocks correlative with Cotter dolomite and Smithville formation are probably also present.			
Subunit B1 (Honeycut faunal equivalent): 315 feet thick			
15. Limestone, with a few thin dolomite beds—the limestone is medium grained to microgranular and rarely sublithographic, medium to dark gray to brownish gray. The rare thin dolomite beds are fine to very fine grained and gray. Considerable stromatolitic structure is locally evident in the more massive limestone beds of interval 15 and *Calathium* and piloceratid siphuncles are commonly abundant in such beds. The top of the interval is marked by 10 feet of massive cherty limestone containing abundant *Calathium* and piloceratid siphuncles, and forming a low but marked step in the mountain slope.	195	930	660 – 855
Chert is intermittently abundant as nodules, excrescences, and irregular layers and inclusions that are subchalcedonic to chalcedonic and semichalcedonic and medium to dark gray. It was particularly noted, in connection with occurrences of fossils, from just above 702 feet, from about 750 to 760 feet, at 825 feet, and in the top 10 feet of the interval.			
Fossils were noted or collected as follows: at 680 feet *Calathium, Piloceras,* and silicified gastropods; at 687 feet *Ceratopea* cf. *C.* sp. 5 and a siphuncle of the *Mcqueenoceras*-type (TF–445); between 687 and 702 feet calcitic gastropods are intermittently abundant; at 700 feet *Orospira* sp., at 702 feet, in a layer of very fine grained dolomite just below a zone of abundant *Calathium* and chert, *Archaeorthis* sp., *Finkelnburgia* sp., and an unidentified orthoid brachiopod (TF–446); between 700 and 750 feet *Calathium* is locally abundant, occasional siphuncles of brevicone cephalopods were seen, and a number of bedding surfaces are crowded with unidentified small gastropods; at 750 feet, just below a 10-foot zone of abundant chert. *Finkelnburgia* sp., *Ceratopea* cf. *C.* sp. 5, *Allopiloceras* ? (TF–447); from 750 to 760 feet abundant *Calathium* and scattered piloceratid siphuncles; at 770 feet *Calathium, Allopiloceras* or *Piloceras,* and *Kirkoceras*?; at 795 feet, from a 4-foot ledge of limestone containing numerous piloceratid siphuncles and *Calathium,* cystoid plates and columnals, *Finkelnburgia* sp., *Orospira*?, and *Hormotoma*? (TF–448); at 825 feet was seen the lowest *Archaeorthis* recorded in the El Paso section; from 825 to 855 feet intermittent occurrences of *Calathium,* cystoid plates and columnals, poorly preserved brachiopods, *Hormotoma* and other gastropods, and siphuncles of brevicone cephalopods were noted; from 845 to 855 feet, from the 10 feet of massive cherty limestone at the top of interval 14, *Calathium, Finkelnburgia* sp., 2 genera of gastropods, a siphuncle of the *Mcqueenoceras*-type, piloceratid siphuncles (not collected), a tarphyceratid cephalopod with affinities to *Campbelloceras,* and a chiton plate (TF–449).			
A probable fault, trending northeast, was observed at about 50 feet above the base of interval 15. No other data were obtained on this fault, but if it is similar to others with like trend observed in the El Paso section it should be downthrown not over a few tens of feet on the			

Description	Thickness in feet: Interval	Cumulative	Feet above base
northwest side. This fault was not allowed for in measuring interval 15, but if it were it would probably add thickness.			
16. Limestone, with interbeds of dolomite—the limestone is medium grained to sublithographic and medium to dark gray. The dolomite is fine to very fine grained and medium to dark gray to brownish gray. Chert is abundant in interval 16, occurring as irregular beds and lenses that are granular to semiporcelaneous and gray. The sponge *Calathium* is intermittently abundant in this interval. Fossils recorded or collected are as follows: at about 625 to 630 feet, from fine grained dolomite, *Calathium*, *Finkelnburgia* sp., a small *Orospira* (not collected), a pilocceratid siphuncle (discarded), and a deltoceratid cephalopod with affinities to *Aphetoceras* (TF–444); at 638 feet *Calathium*, cystoid plates and columnals, *Finkelnburgia*, and brevicone cephalopods; at the top of the interval *Calathium* and *Finkelnburgia*.	50	980	610 – 660
17. Dolomite—fine to very fine grained; medium to dark gray, in part grading to brownish gray. Chert occurs as occasional inclusions and nodules that are semichalcedonic to subchalcedonic and gray to pinkish gray. Sand grains occur in a few thin zones whose exact position was not recorded.	70	1050	540 – 610
Base of Subunit B1 and Unit B at base of interval 17. Thickness of subunit about 315 feet, of unit about 1014 feet. The lowest fossils of Honeycut age occur in interval 16 and the highest of Gorman age at the top of interval 20, and if relationships between dolomite and limestone were constant the contact between Units A and B might have been placed between intervals 16 and 17. Because these relationships are not constant the arenaceous zone designated interval 18 is chosen as the approximate boundary marker.			
Unit A (zone of dolomite, with arenaceous intervals; Gorman faunal equivalent): 540 feet thick			
18. Arenaceous dolomite and dolomitic sandstone—fine grained, medium to dark gray, tangentially laminated.	6	1056	534 – 540
19. Dolomite, in part slightly calcitic—fine grained, medium to dark gray to brownish gray. Has a few sparingly sandy beds, and sand grains are abundant in dolomite from 476 to 477. Occasional cystoid plates and columnals, and a few unidentified gastropods were the only fossils seen.	64	1120	470 – 534
20. Dolomite at the crest of the spur which the section follows; in part calcitic, grading into and interbedded with limestone on the slope immediately south of the line of section—the dolomite is fine grained; medium to dark gray to brownish gray, in part with pinkish mottles. The limestone is similar to that of interval 21. Although no chert was recorded from this interval, brown dolomoldic chert was fairly abundant in siliceous residues from the top few feet and interstitial chert is probably abundant in some beds. Sand grains are abundant in dolomite at about 420 feet and very abundant at about 430 feet. Globular and interstitial glauconite is abundant in dolomite at 423 feet, and moderately abundant between 423 and 430 feet. Interstitial glauconite occurs sporadically in siliceous residues from the top of the interval.	95	1215	375 – 470

	Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
	Syntrophina, n. sp.,* was obtained at about 405 feet (TF–354). *Diaphelasma complanatum* Ulrich & Cooper and *Hystricurus*(?) as well as small pelmatozoan columnals and an unidentified brachiopod, were obtained from the top 2 feet of the interval (TF–443).			
21.	Limestone, with occasional interbeds of dolomite—the limestone is medium grained to sublithographic, medium to dark gray. The dolomite is fine grained and medium to dark gray. *Diaphelasma pennsylvanicum* Ulrich & Cooper and *Nanorthis* were collected at about 350 to 355 feet (TF–353). Fairly abundant sections of gastropods and large curved piloceratid siphuncles *(Piloceras?)* were seen in the upper part of interval 21.	105	1320	270 – 375
22.	Limestone—medium grained to sublithographic, medium to dark gray. Chert occurs as scattered irregular inclusions that are semichalcedonic and clouded, and as abundant, russet-weathering, dolomoldic films. Poorly preserved fossils are fairly abundant in interval 22, consisting of *Calathium*, cystoid plates and columnals, sections of gastropods, and siphuncles of brevicone cephalopods.	35	1355	235 – 270
23.	Dolomite—very fine grained to fine grained, medium to dark gray. Pelmatozoan columnals, *Ozarkispira*, and siphuncles of brevicone cephalopods were noted in the upper beds of interval 23.	20	1375	215 – 235
24.	Dolomite—fine to medium grained, medium to dark brownish gray to gray. A sill of light gray felsite about 22 feet above the base of interval 24 is not included in its measured thickness. This sill is about 5 feet thick and has slightly cross-cutting relationships. Chert occurs in interval 24 as occasional irregular inclusions that are semichalcedonic to chalcedonic or subporcelaneous, gray to brownish and pinkish gray. The basal 4 to 6 inches of interval 24 is highly arenaceous and contains numerous fairly well-rounded granules and small pebbles (up to 8 mm. in diameter) of a dark, aphanitic rock. A similar layer occurs between 3 and 4 feet above the base and aphanitic granules and sand grains occur between the two layers. In general interval 24 is very finely sandy to coarsely silty in the lower half, becoming much less arenaceous to nonarenaceous in the upper half. Cystoid plates and columnals and siphuncles of brevicone cephalopods were noted at the top of the interval. *Lytospira?*, a section of a large widely phaneromphalous gastropod, *Ophileta* sp., and a poorly preserved tarphyceratid cephalopod with the siphuncle at the venter *(Campbelloceras?)* were collected along the trace of interval 24 between 150 and 165 feet (TF–442). It should be noted that, if its affinities are correctly inferred, the tarphyceratid cephalopod listed is of a type that has previously been reported only from the upper Canadian (Ulrich, Foerste, Miller, and Furnish, 1942, p. 44). Its evidence is at odds with the other faunal evidence, however, and if it is related to or congeneric with *Campbelloceras* it probably represents a downward extension of the range of that type of cephalopod. At the same time one would hesitate to extend its range below strata of Gorman age.	80	1455	135 – 215

**Syntrophina percarinata* Cloud (in press).

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
An interruption in sedimentation between intervals 24 and 25 is suggested by the occurrence of granules of an aphanitic rock at the base of interval 24, and, in the absence of faunal evidence, this may be considered an alternative position for the boundary between the Tanyard and Gorman equivalents in the El Paso section. The boundary provisionally suggested, however, is 135 feet lower.			
25. Coarsely silty to finely sandy, and in part more coarsely arenaceous dolomite—fine to medium grained, medium to dark brownish gray and gray. At 118.5 feet is a 4-inch calcareous sandstone. The dolomite is very sandy from 130 to 131 feet and moderately sandy for the next 2.5 feet up. The dominant arenaceous particles, measured microscopically on a hand specimen, average about 0.12 mm. to 0.06 mm. in diameter and are thus very near the grain size boundary between silt and sand.	30	1485	105 – 135
26. Very finely sandy to coarsely silty dolomite, in part slightly calcitic—fine to medium grained, medium to dark gray to brownish and greenish gray, tangentially laminated.	80	1565	25 – 105
27. Arenaceous dolomite, grading to dolomitic sandstone in the basal 1 to 3 feet—fine to medium grained, medium to dark brownish gray, in part grading to yellowish gray; in part slightly calcitic. Tangentially laminated throughout and locally an intraformational breccia. The basal 1 to 3 feet is a dolomitic sandstone and the dolomite is highly arenaceous for 10 to 15 feet above this, becoming much less sandy toward the top. Occasional pebbles of granite, porphyry, quartzite, and sandstone were noted at the base of interval 27, and most were fairly well rounded. Porphyry and granite pebbles with visible dimensions of 3 × 2 inches were seen and the largest pebble (of quartzite) measured 6 × 2 × 2 inches. These pebbles indicate a disconformity between interval 27 and the Bliss sandstone, although it would be difficult to confirm if the pebbles were absent.	25	1590	0 – 25
Base of Unit A, of El Paso formation, and of the formally described El Paso section at base of interval 27. Thickness of Unit A 540 feet; of El Paso formation 1590 feet.			
The disconformity between the El Paso formation and the Bliss sandstone below, indicated by pebbles of foreign derivation, could represent either the Cambrian-Ordovician boundary or a break between equivalents of the Tanyard and Gorman formations. The first possibility is favored by the abundance of glauconite in some beds of the Bliss sandstone, and by the occurrence in it of *Lingulepis;* whereas the second is favored by analogy with the Beach Mountain section and by paleogeography. It is shown in the discussion of the Beach Mountain section that *Lingulepis* probably ranges into the Ordovician, while the formation of glauconite apparently depends on ecologic factors not of fixed correlative importance. If the Bliss-El Paso contact is not equivalent to the Tanyard-Gorman contact, the best apparent alternative position for it is 135 feet higher, between intervals 24 and 25. Provisionally the authors favor the first alternative, but the evidence is moot and the problem was not studied as carefully as it should have been because *Lingulepis* was considered valid evidence for an Upper Cambrian age at the time of their visits to the section. If the contact between the equivalents of the Tanyard and Gorman formations were to fall at 135 feet above the base of the El Paso formation in the El Paso section, thicknesses of these equivalents would be more nearly comparable with those of the			

Description	*Thickness in feet* *Interval*	*Cumulative*	*Feet above base*

Beach Mountain section, but in sequences physically so different and so far apart, close correspondence in thicknesses is not to be looked for.

Bliss sandstone (basal Ordovician or Upper Cambrian. Possible equivalent of the Tanyard formation): about 250 feet thick

The measurement given for the Bliss sandstone was computed from data obtained just west of the city park at the head of McKelligon Canyon, 3.7 miles airline north-northwest of the base of the El Paso section, where its contacts were well exposed. Fossils were obtained and observations made both at the base of the El Paso section and in the McKelligon Canyon section.

In McKelligon Canyon the Bliss sandstone rests nonconformably on a red rhyolite porphyry of pre-Cambrian age. Its basal 4 feet consist of greenish yellow siliceous shales. The next 130 feet is brown to gray, fine grained quartzite with glauconitic beds in the upper part, up to TF–359 *(Lingulepis)* about 115 feet below the top. Above TF–359 the formation continues to its top as described, with occasional glauconitic beds and locally with irregular borings. It is probaby noncalcareous, but was not tested.

In the El Paso section the lower part of the Bliss sandstone is covered by rubble from above. The beds exposed are mostly fine grained, gray to brown, in part tangentially laminated quartzite and sandstone. The uppermost beds are slightly calcareous, and the sandstone is locally dolomitic from 2 to 4.5 feet below the disconformity at the top, but most of the beds tested were noncalcareous. Several beds of highly glauconitic friable sandstone were seen in the line of section and many prominently green bands were noticed on the next spur north of the section, but the latter were not examined at first hand. A few irregular borings were seen but nothing assignable to *Scolithus* was noticed.

Lingulepis aff. *L. walcotti* Resser was found in place about 80 feet below the top of the Bliss sandstone in November, 1944. This rediscovery of *Lingulepis* was considered to confirm Walcott's original determination of the formation as of Upper Cambrian age (*in* G. B. Richardson, 1909) until a very similar if not identical brachiopod was found just below and perhaps associated with Lower Ordovician gastropods and cephalopods on the west side of Beach Mountain in Culberson County. The age of the Bliss sandstone therefore remains unsettled, but the evidence seems slightly to favor its tentative consideration as Lower Ordovician *(see* pp. 67–69).

SECTION IN WILLIAMS CANYON, EL PASO COUNTY, COLORADO

The Williams Canyon section (Pl. 30, fig. D; Pl. 15) was measured up the east wall of Williams Canyon, above the "Narrows" and just north of the corporate limits of Manitou. It was measured and described by Harry W. Oborne and the authors on October 3, 1946. A weighted line, knotted at 5-foot intervals, was dropped over the nearly vertical canyon wall at the point of a slight reentrant and measurements of the lower 165 feet were taken directly from this line. The upper 32 feet were measured with a Brunton compass.

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
Williams Canyon limestone (post-Lower Ordovician and pre-Mississippian): about 20 feet exposed below a covered interval which conceals its top at this place			
The lower 15 feet consists of yellowish gray to brownish gray, fine grained, thin bedded, slightly calcitic dolomite; earthy yellowish dolomite; dolomitic limestone; calcareous sandstone and arenaceous dolomite and limestone. From 15 to 20 feet above the base is pinkish and purplish stained, rubbly-weathering, calcareous sandstone and arenaceous dolomite and limestone. No fossils were found, but the age of the rocks is limited by the occurrence of the lower Mississippian Madison limestone above and the Manitou formation below them. They could, of course, be of very low Mississippian or very high Lower Ordovician age. The unit occupies the position of the Harding sandstone of Middle Ordovician age, and the pinkish and purplish stained calcareous sandstones suggest parts of the Harding strata.			
Manitou formation (Lower Ordovician): 197 feet thick			
1. Dolomite, with limestone from 182 to 182.7 feet—very fine grained, in part grading to fine grained and microgranular; yellowish to brownish or olive gray, grading to nutria and beige. The top 3 feet weathers thin and breaks into a gentle slope.	20	20	177 – 197
2. Limestone, in part slightly dolomitic, and grading laterally to dolomite—the limestone is like that of interval 6, but more thickly bedded.	6.5	26.5	170.5– 177
3. Dolomite, slightly calcitic—fine to very fine grained, yellowish gray.	7	33.5	163.5– 170.5
4. Limestone—similar to that of interval 6, but more thickly bedded. Inclusions of subchalcedonic to semichalcedonic spiculiferous chert occur at 161 feet. Silicified fossils were collected from 161 to 163.5 feet (CF–17) as follows: pelmatozoan columnals, *Diaphelasma complanatum* Ulrich & Cooper, *Barnesella* cf. *B. affinis* (Billings), *Macluritella* cf. *M. stantoni* Kirk, *Hormotoma* spp., and 4 to 6 other genera of gastropods. *Diaphelasma* suggests correlation with equivalents of the Gorman formation and *Barnesella* with strata of Honeycut or younger age. One of the two has a greater range at this place than it is known to have elsewhere.	15.5	49	148 – 163.5
5. Limestone—very fine grained to sublithographic, rose to brownish gray in color, thickly bedded.	15	64	133 – 148
6. Limestone, slightly dolomitic—very fine grained to fine grained, medium to light yellowish to brownish gray, with a slightly inhibited effervescence under dilute hydrochloric acid. In the canyon wall this interval weathers ribboned, indicating thin bedding, and the beds probably average less than 1 inch thick. A little silicification of fossils was noted at 28 and 33 feet, a thin zone of calcitic chert at 43 feet, banded siliceous excrescences at 63 feet, and inclusions of semichalcedonic to subchalcedonic spiculiferous chert at 78 feet. A few grains of glauconite were seen at 33 and 63 feet. Fossils were collected as follows: at 28 feet *Syntrophina* sp., *Ophileta?*, cyrtendoceratid cephalopod, and *Leiostegium?* (CF–7); at 33 feet cystoid plates, a clarkellid brachiopod, *Ophileta?*, and unidentified gastropods (CF–8); at 55.5 to 56 feet lingulid brachiopods, clarkellid brachiopods, a large and widely phaneromphalous gastropod, *Ozarkispira*, *Hystricurus* sp., and trilobite pygidia	114	178	19 – 133

Description	Thickness in feet: Interval	Thickness in feet: Cumulative	Feet above base
suggesting *Pliomerops* and *Leiostegium* (CF–9); at 62 feet "*Lingula*" sp. (CF–10); at 79 feet "*Lingula*" sp., *Diaphelasma complanatum* Ulrich & Cooper (float), *Hormotoma* sp., and a trilobite (CF–11); at 105 feet pelmatozoan columnals and *Clarkella* sp. (CF–12); at 110 feet *Diaphelasma* sp. (CF–13); at 114 to 116 feet an orthoid brachiopod, a clarkellid brachiopod, *Hormotoma* sp., and unidentified gastropods (CF–14); at 121 feet *Diaphelasma* sp. (CF–15); at 133 feet *Syntrophina, Diaphelasma, Kirkoceras,* and *Piloceras*? (CF–16).			
7. Dolomite, slightly calcitic and including minor dolomitic limestone—very fine grained, rose to light pink, beds less than 1 inch thick.	5	183	14 – 19
8. Limestone, slightly dolomitic—fine grained, yellowish gray to rose. A gastropod questionably assigned to *Ophileta* and suggesting *Raphistomina* was collected from interval 8 (CF–6).	1	184	13 – 14
9. Dolomite, slightly calcitic—very fine grained, rose to brick red, beds mostly less than 1 inch thick.	8.3	192.3	4.7– 13
10. Dolomite—earthy, fine grained, brick red. Thinly bedded at base, thicker above. *Apheoorthis* sp. and a trilobite suggesting *Leiostegium* were collected from the lower 6 inches of interval 10 (CF–5).	1.7	194	3 – 4.7
11. Dolomite—earthy, fine grained, brick red. Appears to be in part arkosic. *Apheoorthis* and inarticulate brachiopods were collected at 2 feet (CF–4).	3	197	0 – 3
Base of Williams Canyon section of present report and provisional base of Manitou formation at base of interval 11. Thickness of Manitou formation 197 feet.			
The rocks immediately below interval 11 are slightly calcareous, arkosic, earthy, and brick red, becoming dolomitic toward the top and with occasional thin zones that are conspicuously glauconitic. In the absence of an evident disconformity or sharp lithic break the boundary between the rocks considered equivalent to the Sawatch quartzite and the Manitou formation is placed immediately above the highest conspicuous glauconite. Brainerd, Baldwin, and Keyte (1933) measured 45 feet of sandstone of the Sawatch(?) quartzite between pre-Cambrian granite and the base of the Manitou formation.			
The fossils listed in the preceding description indicate the presence in the Manitou formation of rocks equivalent to the Tanyard, the Gorman, and possibly the Honeycut formations, but it is not possible at present writing to say where the boundaries fall. Briefly, the fossils listed seem to warrant the following suggestions: (1) the rocks above 13 feet and probably above 3 feet from the base of the measured section are definitely Ordovician; (2) the boundary between rocks equivalent to the Tanyard formation and those equivalent to the Gorman formation is less than 79 feet, probably less than 55 feet, and possibly less than 33 feet above the base of the measured section; (3) the faunal equivalent of the Gorman formation extends at least as high as 133 feet above the base and possibly to the top of the section.			

LOWER ORDOVICIAN AND UPPER CAMBRIAN FOSSILS IN THE WICHITA MOUNTAINS, OKLAHOMA

Fossils collected or recorded from the Kindblade ranch section, 10.5 miles south of Carnegie, Kiowa County, in the Wichita Mountains of Oklahoma during examination of that section by C. E. Decker, W. E. Ham, H. A. Ireland, and the authors on April 3, 1944, are listed below. The section considered is number 4 of Decker's report of 1939. It is described on pages 47 to 50 of that report and summarized on Plate 15 (section 6) of the present report. The fossils listed below, together with the lists published by Decker in 1939, are the basis for the correlations indicated on Plate 15. Additional fossils were listed by E. A. Frederickson in 1941, and for the Cambrian units by Ulrich in 1932. The numbers on the Kindblade ranch section on Plate 15 refer to collections here listed under OF-numbers, D refers to Decker's lists, and F refers to fossils recorded and listed below but not collected. The identifications here given were made by Cloud at Austin, Texas, without reference to identified comparative material, and consequently are subject to emendation. The zone numbers refer to Decker's section and the location of each collection in the section was arrived at by estimation of its position with reference to zone boundaries pointed out in the field by Dr. Decker. Listed in order from the base upwards, fossils from this section and the placement of faunal boundaries between them are as follows:

——————Boundary between faunal equivalents of Riley and Wilberns formations——————

OF–34. (Honey Creek formation, about 35 feet above base; zone 44)
Huenella aff. H. texana (Walcott)

OF–35a. (Fort Sill formation, about 85 feet above base; lower part of zone 40, and 30 feet below collection OF–35)
Ptychaspis
A spinose trilobite pygidium resembling that of Eurekia

OF–35. (Fort Sill formation, near middle; upper part of zone 40)
Chariocephalus wichitaensis Resser

OF–36. (Fort Sill formation, about 90 feet below top as placed by Decker; middle of zone 39)
Billingsella corrugata Ulrich & Cooper

OF–37. (Signal Mountain, near middle; middle of zone 36)
Billingsella

OF–38. (Signal Mountain formation, about 100 feet below top; zone 36)
Finkelnburgia cf. F. finkelnburgi (Walcott)
Apheoorthis cf. A. bella Ulrich & Cooper

——————————————Cambrian-Ordovician boundary?——————————————

E. A. Frederickson, Jr. (1941, p. 160) states that "in the Wichita Mountains *Hystricurus* and *Symphysurina* occur together 16 feet above the base of the McKenzie Hill formation."

OF–39. (McKenzie Hill limestone, about 200 feet above base; approximately 70 feet below top of zone 35)
Apheoorthis aff. A. melita (Hall & Whitfield)

Fl. (McKenzie Hill limestone, about 80 feet below top; about 80 feet below top of zone 31)
Lytospira sp. recorded

OF–40a. (McKenzie Hill limestone, about 15 feet below top; 15 feet below top of zone 31)
Nanorthis?

OF–40. (McKenzie Hill limestone, top surface to top bed; top of zone 31)
Finkelnburgia aff. F. skenidioides Ulrich & Cooper
Lytospira sp.

OF–41. (Cool Creek formation, about 40 feet above base; 40 feet above base of zone 31)
Finkelnburgia?
Leiostegium?
Unidentified trilobite genera

OF–42. (Cool Creek formation, about 80 feet above base; 80 feet above base of zone 30)
Pelmatozoan columnals (discarded)
Gasconadia cf. G. putilla (Sardeson)
Lytospira?
Ophileta sp.
Two or three unidentified gastropod genera

OF–43. (Cool Creek formation, about 100 feet above base; 100 feet above base of zone 30)
Gasconadia cf. G. putilla (Sardeson)
Ophileta sp.
Sinuopea(?)
Chepultapecia

————Possible boundary between faunal equivalents of Tanyard and Gorman formations————

OF–44. (Cool Creek formation, about 200 feet above base; middle of zone 30)
Finkelnburgia cf. F. bellatula Ulrich & Cooper
Hystricurus sp.

———Possible boundary between faunal equivalents of Tanyard and Gorman formations———

F2. (Cool Creek formation, about 350 feet above base; about 70 feet below top of zone 30)
Lecanospira

F3. (Cool Creek formation, about 120 feet below top; middle of zone 25)
Lecanospira

F4. (Cool Creek formation, about 30 feet below top; about 30 feet below top of zone 24)
Lecanospira

OF–45. (Cool Creek formation, about 10 feet below top; 10 feet below top of zone 24)
Diaphelasma oklahomense Ulrich & Cooper
Lecanospira sp.
Unidentified planispiral open-whorled gastropod
Unidentified endoceratid cephalopod

OF–46. (Kindblade formation, about 25 feet above base; 25 feet above base of zone 23)
Diaphelasma oklahomense Ulrich & Cooper
Lecanospira aff. L. biconcava Ulrich & Bridge

————Boundary between faunal equivalents of Gorman and Honeycut formations————

F5. (Kindblade formation, about 170 feet above base; near middle of zone 22)
Ceratopea sp.

OF–47. (Kindblade formation, about 430 feet below top of exposed beds; zone 13)
Pelmatozoan columnals (discarded)
Orospira sp.
Unidentified gastropod genera

OF–48. (Kindblade formation, about 400 feet below top of exposed beds; lower part of zone 12)
Tritoechia subaequiradiata Ulrich & Cooper

OF–49. (Kindblade formation, about 320 feet below top of exposed beds; zone 11)
Tritoechia cf. T. typica (Ulrich)

OF–50. (Kindblade formation, about 230 feet below top of exposed beds; zone 7)
Tritoechia aff. T. typica (Ulrich)

Kindblade formation overlapped by Permian strata at the top of this section. The highest fossil recorded at this place is *Tritoechia typica* (Ulrich) in Decker's zone 3. Cullison (1944) records the same species from the upper third of the Theodosia formation of the Jefferson City group in the Ozark uplift.

LOWER ORDOVICIAN AND UPPER CAMBRIAN FOSSILS IN THE ARBUCKLE MOUNTAINS, OKLAHOMA

Fossils are listed from a section along and near U.S. highway 77 between Davis and Ardmore, Murray and Carter counties, Oklahoma. This is approximately the same as section number 2 of Dr. Decker's report of 1939, commonly referred to as the Chapman ranch section. It is described on pages 42 to 46 of Decker's report and summarized on Plate 15 (section 6) of the present report. Most of the fossils listed below came from the pasture west of the highway and were collected during examination of this section by C. E. Decker, W. E. Ham, R. H. Dott, H. A. Ireland, and the authors on March 31 and April 2, 1944. A few were obtained earlier by Ireland, A. P. Wishart, R. L. Heller, and Cloud during a day on the section in December, 1943. These fossils, together with those listed by Decker in 1939; by Bridge in 1936; by Frederickson in 1941; and, for the Cambrian formations, by E. O. Ulrich in 1932; are the basis for the correlations indicated on Plate 15. The numbers at the left of the Arbuckle Mountain section on Plate 15 refer to collec-

tions here listed under OF-numbers, D refers to Decker's lists, B refers to Bridge's lists, and U refers to Ulrich's lists. The identifications here given under the OF-numbers were made by Cloud at Austin, Texas, without reference to identified comparative material and consequently are subject to emendation.

In the Chapman ranch section, the writers failed to locate their collections with reference to Dr. Decker's zone numbers and formation boundaries. At the end of the section, however, they were so fortunate as to have access to an aerial photograph (loaned by Mr. Ham) on which the fossil collections and provisional contacts between faunal units were located from memory. These data were then traced from the photograph, and later, using the average dip of 50° southwest given by Decker (1939, p. 42), thicknesses of faunal units were computed and collections located within them. Not having located Decker's original boundaries between the McKenzie Hill, Cool Creek, and Kindblade formations, the authors have placed their contacts on Plate 15 at the provisionally located faunal boundaries. Thicknesses were computed by multiplying by the sine of 50° the horizontal distance normal to the strike as scaled from the aerial photograph. Relief was slight along the line of traverse and the topographic factor was disregarded. Minor faulting was noticed, but was not considered in the computations. Measurements so obtained gave about 1000 feet for the McKenzie Hill limestone, about 1150 feet for the Cool Creek formation, and about 1400 feet for the Kindblade formation. The top of the Kindblade and base of the McKenzie Hill formations were located approximately as designated by Dr. Decker, and his cumulative measured thickness between these two points is approximately 4025 feet as against the 3550 feet computed by the authors. Application of the indicated average discrepancy of 12 per cent (11.8) to the total of 7384 feet of strata measured by Decker between the base of the Honey Creek limestone and the top of the Arbuckle group gives a total of about 6500 feet, which is slightly under the total of about 6700 feet independently measured by Dake and Ulrich (Bridge, 1936, p. 980). This, and the fact that they have no very good way of adjusting the positions of their collections and provisional faunal boundaries to Decker's section, encourages the present authors to use their own admittedly rough computed thicknesses for the McKenzie Hill, Cool Creek, and Kindblade formations on Plate 15. For the purposes of the columnar section on Plate 15 Decker's published thicknesses are used for all other units. As far as possible in the lists below reference is made to the estimated position of collections with respect to a zone containing *Ceratopea capuliformis* Oder (OF–6) and occurring about 170 feet above the base of the Kindblade as provisionally located in the field. It is not ordinarily possible to refer collections to Decker's numbered zones in this section and, because of the rough manner in which estimates of thickness were made, the reader is warned not to accept too literally the actual placement in feet of section of collections and therefore of boundaries.

In addition to the section along and west of U.S. highway 77, the writers and those named above spent April 1, 1944, on a section 4 to 6 miles southwest of the village of Mill Creek, Johnston County, Oklahoma, then being measured by Mr. Ham. Six collections of fossils obtained from the lower part of that section (OF–26 to 31) substantiate previously published correlations of the Honey Creek limestone with the lower part of the Wilberns formation, and indicate further that the Cambrian-Ordovician boundary, when crossed, was below the top of a dolomite that would ordinarily be called the Butterly dolomite. Transition of the chemical facies is evident, however, and the relation of the time boundary to the dolomite-limestone boundary is clearly not constant.

Listed in order from the base upwards, collections of fossils from the section along U.S. highway 77 between Davis and Ardmore (No. 2 of Decker) and the placement of provisional faunal boundaries between listed collections are as follows:

OF-33. (Signal Mountain formation, near top)
Apheoorthis ornata Ulrich & Cooper
E. A. Frederickson, Jr. (1941, p. 162) states that "*Plethopeltis*" occurs in the upper part of the (Signal Mountain) formation in the Arbuckle Mountains."

——————————Cambrian-Ordovician boundary——————————

Lower Ordovician cephalopods are recorded from the lower beds of the McKenzie Hill limestone by Bridge (1936) and were seen by Cloud in 1943.

OF-1. (McKenzie Hill limestone, about 500 feet above base)
Ophileta sp.
Ozarkina??
Unidentified gastropods
Leiostegium?

OF-2. (McKenzie Hill limestone, about 600 to 700 feet above base)
Finkelnburgia cf. F. subaequiradiata Ulrich & Cooper

————Boundary between faunal equivalents of Tanyard and Gorman formations————

OF-3. (Cool Creek formation, about 300 feet above base)
Clarkellid brachiopod—ventral valves only, form suggests Diaphelasma oklahomense Ulrich & Cooper

OF-4. (Cool Creek formation, near middle; about 240 feet stratigraphically below OF-5 and 5 to 15 feet above a prominent breccia zone)
Syntrophinella n. sp. aff. S. typica Ulrich & Cooper*
Diaphelasma aff. D. oklahomense Ulrich & Cooper

OF-5. (Cool Creek formation, about 350 feet stratigraphically below OF-6)
Diaphelasma cf. D. oklahomense Ulrich & Cooper

OF-5a. (Cool Creek formation, about 15 feet stratigraphically above OF-5)
Diaphelasma oklahomense Ulrich & Cooper

————Boundary between faunal equivalents of Gorman and Honeycut formations————

OF-6a. (Kindblade formation, near base; about 80 feet stratigraphically below OF-6)
Archaeoscyphia cf. A. annulata Cullison

OF-6. (Kindblade formation, about 170 feet above base)
Ceratopea capuliformis Oder, marking a zone to which collections above and below are referred.

OF-9. (Kindblade formation, about 100 feet stratigraphically above OF-6)
Hormotoma cf. H. dubia Cullison
Unidentified gastropods

OF-7. (Kindblade formation, about 150 feet stratigraphically above OF-6)
Archaeoscyphia sp.
Finkelnburgia?
Orospira cf. O. conica Cullison
Unidentified small gastropods
Endoceratid siphuncle cf. Mcqueenoceras
Unidentified small cephalopod
Wichitoceras sp.

OF-10. (Kindblade formation, about 160 feet stratigraphically above OF-6)
Ceratopea sp. 5a
Orospira sp.

OF-12. (Kindblade formation, about 180 feet stratigraphically above OF-6)
Ceratopea sp. 5b

OF-8b. (Kindblade formation, about 60 feet stratigraphically below OF-8a and probably about 260 feet above OF-6)
Ceratopea sp. 5

OF-8a. (Kindblade formation, about 60 feet stratigraphically above OF-8b and probably about 320 feet above OF-6)
Archaeoscyphia sp.
Ceratopea cf. sp. 5

OF-8. (Kindblade formation, about 400 feet stratigraphically above OF-6)
Archaeoscyphia sp.
Ceratopea sp. 5
Hormotoma sp.
Unidentified gastropod
Piloceratid? siphuncle
Unidentified nautilicone cephalopod

OF-13. (Kindblade formation, about 550 feet above OF-6)
Orthoid brachiopod aff. Nothorthis
Orospira sp.
Hormotoma sp.
Jeffersonia cf. J. missouriensis Cullison

Syntrophinella deckeri Cloud (in press).

OF–14. (Kindblade formation, about 620 feet above OF–6)
Finkelnburgia skenidioides Ulrich & Cooper

OF–15. (Kindblade formation, about 850 feet above OF–6)
Diparelasma sp.
Orospira sp.
Barnesella cf. B. affinis (Billings)
Hormotoma spp.
Raphistomina
Lesueurilla?
Cephalopod siphuncles

OF–16. (Kindblade formation, about 875 feet above OF–6)
Diparelasma?
Hormotoma cf. H. dubia Cullison
Orospira sp.
Raphistomina?

—Boundary between faunal equivalents of Honeycut-Jefferson City strata and Cotter dolomite—

OF–17. (Kindblade formation, about 950 feet above OF–6)
Nothorthis cf. N. delicatulla Ulrich & Cooper
Finkelnburgia cullisoni Ulrich & Cooper
Ophileta?
Ceratopea jenkinensis Cullison
Cephalopod siphuncles

OF–18. (Kindblade formation, about 1100 feet stratigraphically above OF–6)
Finkelnburgia cullisoni Ulrich & Cooper
Ceratopea cf. C. tennesseensis Oder

OF–21. (Kindblade formation, about 150 feet below top)
Barnesella cf. B. affinis Billings
Cephalopod siphuncle

OF–19. (Kindblade formation, about 1115 feet stratigraphically above OF–6)
Ceratopea cf. C. tennesseensis Oder

OF–22. (Kindblade formation, at or very near top)
Tritoechia typica (Ulrich)
Finkelnburgia cullisoni Ulrich & Cooper
Ceratopea cf. C. jenkinensis Cullison
Endoceratid siphuncle aff. Mcqueenoceras

————————Boundary between faunal equivalents of Cotter and post-Cotter beds————————

It is likely that equivalents of Powell, Smithville, and Black Rock strata occur in the West Spring Creek formation. The authors concentrated their efforts on the older rocks and did not obtain sufficient evidence to recognize specific faunal equivalents.

OF–24. (West Spring Creek formation, 808 feet below top of Arbuckle group in Decker's section)
Didymograptus protobifidus (Hall), a Smithville graptolite

OF–25a. (West Spring Creek formation, about 5 feet stratigraphically below OF–25)
Hormotoma cf. H. powellensis Cullison
Ceratopea sp.

OF–25. (West Spring Creek formation, about 300 feet below top of Arbuckle group; about zone 38 of Decker)
Tritoechia planodorsata Ulrich & Cooper
Diparelasma typicum Ulrich & Cooper
Tritoechia sp.

OF–25b. (West Spring Creek formation, about 10 feet stratigraphically below top of Arbuckle group)
Hormotoma
Unidentified gastropods

The West Spring Creek formation is overlain by strata of the Middle and Lower Ordovician Simpson group at the top of the Chapman ranch section. The presence of a Black Rock faunal equivalent at the top of this section is indicated by the occurrence of *Syntrophopsis magna* Ulrich & Cooper "near the top of the Arbuckle limestone" in the S. ½, sec. 14, T. 2 S., R. 1 E. (Ulrich & Cooper, 1938, p. 235), a locality that could hardly be more than 2 miles from the top of the Chapman ranch section. The boundary between strata of Black Rock age and older beds in the line of the section here being considered is provisionally placed at the base of Decker's zone 45. This location is based on the reported occurrence (Decker, 1939, p. 43) of *Syntrophopsis laevicula* Ulrich & Cooper, a species that "somewhat resembles *Syntrophopsis magna* in its adult form" (Ulrich & Cooper, 1938, p. 234), in an interval that extends from 209 to 342 feet below the top of the Arbuckle group according to Decker's measurements. The fossils in collections OF–25 and OF–25a, from about 300 to 305 feet below the top of the Arbuckle group, are consistent with this assignment, although they do not require it.

CHEMICAL DATA

ANALYSES OF DOLOMITES IN THE JOHNSON CITY AREA[12]

Sample No.	Feet above base	Feet sampled	Insoluble	Fe_2O_3	Al_2O_3	CaO	MgO	Calculated CO_2	Calculated Total	Calculated Calcite	Calculated Dolomite	Calculated $CaCO_3$	Calculated $MgCO_3$
						PEDERNALES RIVER SECTION							
						Upstream Segment							
Cambrian													
Wilberns formation													
Point Peak shale member													
1	0–4	4	8.30	0.50	0.24	49.50	0.86	39.9	99.3	86.3	3.9	88.4	1.8
2	4–15	11	27.87	1.17	0.59	37.20	1.66	31.0	99.5	62.3	7.6	66.4	3.5
Pedernales dolomite member													
Fine grained dolomite													
3	15–25	10	4.74	1.04	0.14	30.72	18.60	44.5	99.7	8.6	85.2	54.7	38.9
4	25–38	13	2.27	0.42	0.06	31.80	18.86	45.6	99.0	10.0	86.3	56.8	39.5
5	38–48	10	2.06	0.17	0.09	30.70	20.20	46.2	99.4	4.6	92.5	54.8	42.3
6	48–59	11	2.30	0.17	0.13	30.50	20.40	46.3	99.8	3.7	93.5	54.5	42.7
7	59–70	11	5.12	0.21	0.11	29.52	19.88	44.9	99.7	3.4	90.9	52.7	41.6
8	70–80	10	8.55	0.30	0.19	28.65	19.16	43.5	100.3	3.6	87.7	51.2	40.1
9	80–91	11	4.64	0.25	0.22	29.35	19.38	44.3	98.1	4.3	88.7	52.5	40.5
10	91–99	8	14.40	0.48	0.37	26.30	17.41	39.8	98.8	3.7	79.8	47.0	36.5
Average Nos. 3 through 10			5.13	0.38	0.15	29.9	19.3	44.6	99.5	5.5	88.3	53.4	40.4
Coarse grained dolomite													
11	101–114	13	4.10	0.25	0.24	29.87	19.89	45.3	99.7	4.1	91.0	53.4	41.7
12	114–125	11	0.81	0.34	0.26	30.85	20.28	46.4	98.9	4.6	92.9	55.1	42.4
13	125–137	12	1.31	0.21	0.17	30.95	20.13	46.3	99.2	5.2	92.2	55.3	42.1
14	137–151	14	0.42	0.23	0.19	31.70	20.63	47.5	100.7	5.4	94.5	56.6	43.3
15	151–160	9	0.50	0.12	0.08	30.90	20.22	46.5	98.3	5.0	92.6	55.2	42.4
16	160–169	9	0.83	0.17	0.17	32.17	20.04	47.2	100.6	7.7	91.7	57.4	42.0
17	169–179	10	4.69	0.16	0.12	29.65	19.61	44.7	98.9	4.1	89.8	52.9	41.0
18	179–189	10	0.69	0.14	0.05	30.90	20.24	46.5	98.5	4.8	92.8	55.2	42.4
19	189–199	10	0.82	0.13	0.21	31.05	20.16	46.4	98.8	5.4	92.2	55.4	42.2
20	199–204	5	0.52	0.10	0.20	31.00	20.98	47.2	100.0	3.2	96.0	55.3	43.9
21	204–214	10	1.01	0.16	0.46	31.45	19.94	46.5	99.5	6.6	91.3	56.2	41.7
Average Nos. 11 through 21			1.53	0.19	0.19	30.9	20.2	46.4	99.4	5.0	92.5	55.2	42.3

[12]Analyst R. M. Wheeler, Bureau of Economic Geology

Sample No.	Feet above base	Feet sampled	Insoluble	Fe_2O_3	Al_2O_3	CaO	MgO	Calculated CO_2	Calculated Total	Calculated Calcite	Calculated Dolomite	Calculated $CaCO_3$	Calculated $MgCO_3$
Ordovician													
Tanyard formation													
Threadgill member, dolomite facies (starts at 210 feet)													
22	214–222	8	0.26	0.10	0.29	31.10	20.98	47.3	100.0	3.4	96.0	55.5	43.9
23	222–234	12	0.20	0.16	0.29	32.15	19.49	46.5	98.8	8.9	89.2	57.4	40.7
24	234–249	15	0.73	0.16	0.38	32.58	19.26	46.7	99.8	10.4	88.2	58.2	40.4
25	249–262	13	2.4	0.17	0.16	30.3	19.83	45.5	98.4	4.8	90.8	54.1	41.5
26	262–278	16	0.58	0.14	0.09	31.15	21.07	47.5	100.5	3.2	96.5	55.6	44.1
27	278–288	10	0.64	0.17	0.14	31.70	19.91	46.6	99.2	7.1	91.1	56.6	41.6
28	288–300	12	0.98	0.17	0.24	31.75	19.95	46.7	99.8	7.0	91.4	56.6	41.8
Average Nos. 22 through 28			0.86	0.15	0.23	31.7	20.2	47.0	100.1	6.4	92.5	56.6	42.3
Fault													
					Downstream Segment								
Staendebach member, dolomitic facies													
29	0–28	28	4.35	0.19	0.25	30.30	20.22	45.9	101.2	3.9	92.5	54.1	42.3
30	28–64	36	4.25	0.32	0.28	30.30	20.45	46.2	101.8	3.4	93.6	54.1	42.9
31	64–94	30	1.25	0.16	0.12	31.00	20.44	46.7	99.7	4.6	93.5	55.3	42.8
32	94–122	28	4.07	0.16	0.13	30.10	20.00	45.6	100.1	4.1	91.6	53.8	41.9
33	122–149	27	3.30	0.12	0.26	30.75	19.84	45.8	100.1	5.5	90.9	54.9	41.5
34	149–175	26	3.32	0.16	.....	30.40	20.21	46.0	100.1	4.1	92.5	54.3	42.3
35	175–195	20	6.50	0.12	.....	29.60	19.12	44.2	99.5	5.4	87.5	52.9	40.0
Average Nos. 29 through 35			3.78	0.18	0.16	30.4	20.1	45.9	100.5	4.5	91.9	54.3	42.1
					HONEYCUT BEND SECTION								
					Upstream Segment								
Gorman formation, dolomitic facies													
36	131–141	10	4.94	0.56	1.34	30.00	18.85	44.2	99.9	6.8	86.3	53.6	39.5
37	141–151	10	3.52	0.42	0.68	30.10	19.73	45.2	99.6	4.8	90.2	53.7	41.3
38	151–161	10	4.50	0.30	0.42	29.30	20.10	45.0	99.6	2.5	91.9	52.3	42.1
39	161–171	10	2.40	2.25	0.35	31.10	18.88	45.0	98.0	8.7	86.3	55.5	39.5
40	171–181	10	5.64	0.76	0.56	29.80	18.54	43.6	98.9	7.1	84.8	53.2	38.7
41	181–191	10	4.94	0.74	0.62	29.30	19.28	44.1	99.0	4.5	88.2	52.3	40.4
42	191–202	11	7.56	0.70	0.50	28.90	18.89	43.3	99.9	4.6	86.5	51.6	39.5

43	202–211	9	4.94	0.70	0.50	30.30	19.04	44.6	100.0	6.8	87.1	54.1	39.8
44	211–221	10	3.08	0.40	0.76	31.00	19.26	45.4	99.9	7.5	88.2	55.4	40.3
45	221–231	10	4.40	0.34	0.70	31.10	18.58	44.7	99.8	9.5	84.9	55.5	38.9
46	231–241	10	6.52	0.27	0.73	29.60	18.65	43.6	99.4	6.6	85.3	52.9	39.0
47	241–251	10	4.90	0.21	0.41	31.30	18.36	44.7	99.9	10.4	84.0	55.9	38.5
48	251–263.5	12.5	2.50	0.33	0.47	31.60	18.92	45.5	99.3	9.5	86.5	56.4	39.6
49	263.5–276.5	13	2.88	0.50	0.58	31.20	18.88	45.1	99.2	8.9	86.3	55.7	39.5
Average Nos. 36 through 49			4.43	0.46	0.54	30.4	19.0	44.7	99.5	7.1	87.0	54.3	39.8
						Downstream Segment							
Honeycut formation, dolomitic facies													
50	835–845	10	4.42	0.51	0.79	29.80	19.13	44.3	98.9	5.7	87.5	53.2	40.0
51	845–855	10	4.80	0.69	0.55	31.40	18.10	44.4	99.9	11.1	82.8	56.0	37.9
52	855–865	10	2.72	0.83	0.77	32.30	18.07	45.2	99.9	12.9	82.7	57.7	37.9
53	865–875	10	2.96	0.36	0.72	32.20	18.33	45.3	99.8	12.0	83.8	57.5	38.3
54	875–885	10	2.70	0.31	0.51	32.50	18.46	45.6	100.1	12.1	84.5	58.0	38.6
55	885–895	10	3.50	0.48	0.42	32.40	17.95	45.0	99.8	13.2	82.2	57.8	37.6
56	895–905	10	3.54	0.42	0.68	31.80	18.34	45.0	99.7	11.2	83.9	56.8	38.3
57	905–915	10	2.90	0.35	0.53	32.10	18.20	45.1	99.2	12.1	83.3	57.3	38.1
58	915–925	10	4.30	0.37	0.73	31.30	18.29	44.6	99.6	10.5	83.7	55.9	38.3
59	925–935	10	1.98	0.35	0.59	32.10	18.86	45.8	99.7	10.5	86.3	57.3	39.5
60	935–945	10	2.64	0.35	0.67	31.80	18.72	45.5	99.5	10.4	85.6	56.8	39.2
61	945–955	10	3.30	0.32	0.56	32.20	18.22	45.2	99.8	12.3	83.3	57.5	38.1
62	955–965	10	3.50	0.27	0.39	31.90	18.49	45.3	99.9	11.1	84.6	57.0	38.7
63	965–975	10	3.38	0.37	0.47	32.10	18.33	45.2	99.8	11.8	83.8	57.3	38.3
64	975–985	10	2.42	0.35	0.67	32.20	18.25	45.2	99.0	12.1	83.5	57.5	38.1
65	985–995	10	1.96	0.35	0.69	32.60	18.25	45.6	99.4	12.9	83.5	58.2	38.2
66	995–1006	11	2.42	0.25	0.41	32.50	18.17	45.4	99.2	12.9	83.2	58.0	38.1
Average Nos. 50 through 66			3.14	0.41	0.59	31.95	18.34	45.1	99.5	11.5	83.9	57.0	38.4

ANALYSES OF CARBONATE ROCKS IN THE CHEROKEE AREA[18]

Sample No.	Feet above base	Feet sampled	Insoluble	Fe_2O_3	Al_2O_3	CaO	MgO	Calculated CO_2	Calculated Total	Calculated Calcite	Calculated Dolomite	Calculated $CaCO_3$	Calculated $MgCO_3$
						Cherokee Section							
Ordovician													
Tanyard formation													
Threadgill member—dolomitic facies, non-cherty portion													
67	0–27	27	0.57	0.16	0.11	33.5	18.80	46.8	99.9	13.2	85.9	59.8	39.3
68	27–50	23	0.50	0.21	0.15	33.1	18.66	46.4	99.1	12.9	85.3	59.2	39.0
69	50–68.3	18.3	0.97	0.26	0.18	33.3	18.70	46.6	100.0	13.0	85.5	59.5	39.0
70	68.3–84.9	16.6	0.51	0.24	0.20	33.5	18.60	46.6	99.7	13.7	85.0	59.8	38.9
71	84.9–101.5	16.6	0.69	0.13	0.15	33.5	18.40	46.4	99.3	14.1	84.2	59.8	38.5
72	101.5–118.1	16.6	0.69	0.13	0.15	33.3	18.40	46.3	99.0	13.7	84.3	59.5	38.5
73	118.1–134.7	16.6	0.68	0.14	0.20	33.4	18.70	46.6	99.7	13.2	85.5	59.6	39.1
Average Nos. 67 through 73			0.65	0.18	0.16	33.4	18.63	46.6	99.6	13.4	85.2	59.6	39.0
Threadgill member—dolomitic facies, cherty portion													
74	134.7–149.5	14.8	17.51	0.35	0.37	26.0	17.00	39.0	100.2	4.3	77.7	46.4	35.6
75	149.5–162.5	13	17.39	0.24	0.42	26.1	16.90	39.0	100.1	4.6	77.4	46.6	35.4
76	162.5–175.5	13	3.14	0.12	0.23	30.7	19.40	45.3	98.9	6.6	88.8	54.8	40.6
77	175.5–188.5	13	16.24	0.25	0.32	26.8	16.70	39.3	99.6	6.4	76.4	47.9	34.9
78	188.5–201.5	13	4.71	0.18	0.19	30.0	19.40	44.8	99.3	5.4	88.8	53.6	40.6
79	201.5–214.5	13	0.95	0.15	0.36	33.5	18.70	46.7	100.4	13.4	85.5	59.8	39.1
80	214.5–227.5	13	1.34	0.14	0.41	33.9	18.20	46.5	100.5	15.4	83.2	60.5	38.1
81	227.5–240.5	13	0.68	0.28	0.02	32.4	19.20	46.5	99.1	10.2	87.9	57.9	40.2
82	240.5–253.5	13	1.23	0.15	0.34	35.3	16.76	46.0	99.8	21.4	76.7	63.1	35.0
83	253.5–260	6.5	33.80	1.17	0.21	21.8	12.70	31.0	100.7	7.3	58.2	38.9	26.6
Average Nos. 74 through 83			8.56	0.26	0.29	30.0	17.7	42.9	99.7	9.6	81.1	53.6	37.0
Staendebach member—calcitic facies													
84	462–473	10.6	7.92	0.17	0.14	45.7	5.10	41.5	100.5	69.0	23.3	81.6	10.7
85	473–483.6	10.6	6.53	0.19	0.22	50.1	1.27	40.7	99.0	86.2	5.9	89.4	2.7
86	483.6–494.5	10.9	11.23	0.23	0.21	46.0	2.90	39.3	99.9	75.0	13.2	82.1	6.1
87	494.5–505.5	11	1.68	0.27	0.40	38.4	14.20	45.7	100.6	33.4	64.9	68.6	29.7
88	505.5–516.5	11	1.48	0.16	0.10	50.5	3.90	44.0	100.1	80.6	17.8	90.2	8.2

[18]Analyst R. M. Wheeler, Bureau of Economic Geology.

89	516.5–527.5	11	7.24	0.27	0.22	49.1	2.35	41.2	100.3	81.9	10.7	87.7	4.9
90	527.5–538.3	10.8	7.63	0.21	0.14	46.4	4.36	41.2	100.0	72.0	20.0	82.9	9.1
91	538.3–549	10.7	2.79	0.11	0.14	53.4	1.07	43.1	100.6	92.7	4.9	95.4	2.2
92	549–560	11	8.78	0.19	0.26	47.5	2.90	40.5	100.1	77.6	13.3	84.8	6.1
Average Nos. 84 through 92			6.14	0.20	0.20	47.4	4.24	41.8	100.0	74.1	19.4	84.6	8.9
Gorman formation, dolomitic facies													
93	560–570	10	12.82	0.47	0.46	27.6	17.50	40.8	99.7	5.9	80.0	49.3	36.6
94	570–580	10	8.80	0.40	0.31	31.4	16.60	42.8	100.3	14.8	76.0	56.0	34.8
95	580–590	10	8.57	0.51	0.34	32.6	15.60	42.6	100.2	19.5	71.3	58.2	32.6
96	590–600	10	7.35	0.40	0.30	31.00	17.40	43.4	99.9	12.1	79.7	55.4	36.4
97	600–615	15	3.58	0.13	0.40	31.00	19.20	45.4	99.7	7.7	87.9	55.4	40.2
98	615–626	11	7.45	0.37	0.28	31.3	17.20	43.4	100.0	13.2	78.7	55.9	36.0
99	626–638	12	8.09	0.20	0.31	32.1	16.54	43.3	100.5	16.2	75.7	57.3	34.6
100	638–650	12	3.12	0.18	0.32	32.7	17.88	45.2	99.4	13.9	81.9	58.4	37.4
101	650–661	11	3.69	0.30	0.40	33.00	17.28	44.8	99.5	16.1	79.0	58.9	36.2
102	661–672	11	12.12	0.22	0.46	28.9	16.60	40.8	99.1	10.4	75.9	51.6	34.7
Average Nos. 93 through 102			7.31	0.31	0.36	31.2	17.3	43.3	99.7	12.8	79.0	55.7	36.1
Gorman formation—calcitic facies													
103	877–888	11	12.08	0.88	0.66	45.90	2.12	38.4	100.0	76.8	9.6	82.0	4.4
104	888–899	11	5.52	0.80	0.50	42.04	8.37	42.1	99.3	54.2	38.3	75.0	17.5
105	899–910	11	2.60	0.74	0.56	45.12	7.02	43.1	99.1	63.1	32.1	80.5	14.7
106	944.5–955	10.5	2.72	0.60	0.44	53.38	0.0x	41.9	99.1	95.3	0	95.3	0
107	955–965	10	2.20	0.21	0.29	54.30	0.0x	42.6	99.6	96.9	0	96.9	0
108	965–975	10	2.70	0.21	0.31	54.00	0.0x	42.4	99.6	96.4	0	96.4	0
109	975–986	11	1.48	0.27	0.33	54.60	0.0x	42.9	99.6	97.5	0	97.5	0
Average Nos. 103 through 109			4.25	0.54	0.44	50.0	2.57	42.1	99.9	82.9	11.8	89.3	5.4
KIRK RANCH SECTION													
Ordovician													
Tanyard formation													
Threadgill member—calcitic facies													
110	66.5–108		8.48	0.28	0.32	50.80	0.0x	39.9	99.8	90.7	0	90.7	0
111			18.74	0.55	0.35	45.00	0.00	35.3	99.9	80.3	0	80.3	0
112			7.45	0.27	0.47	50.90	0.06	40.1	99.3	90.8	0.3	91.0	0.1
113			4.90	0.23	0.41	39.46	11.28	43.3	99.6	42.5	51.6	70.5	23.6
Average Nos. 110 through 113			9.90	0.33	0.39	46.54	2.83	39.6	99.7	76.1	13.0	83.1	5.9

ANALYSES OF CORE HOLE SAMPLES, VICTORIA GRAVEL COMPANY QUARRY FOR MAGNESIUM ORE[14]

Core Hole Number 1

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 1′	1′	42.20	56.45	.39	.45	.01	.02
2	1′– 2′	1′	41.44	56.99	.35	.43	.02	.02
3	2′– 3′	1′	41.64	56.16	.28	.44	.02	.01
4	3′– 4′	1′	42.82	55.91	.32	.38	.01	.04
5	4′– 5′	1′	41.67	56.31	.28	.58	.01	.04
6	5′– 6′	1′	41.31	56.58	.25	.48	.01	.04
7	6′– 7′	1′	42.07	56.54	.45	.53	.06	.04
8	7′– 8′	1′	41.10	56.44	.33	.55	.03	.05
9	8′– 9′	1′	42.57	56.16	.29	.46	.02	.04
10	9′–10′	1′	42.38	56.10	.50	.46	.11	.04
11	10′–11′	1′	41.54	55.86	.50	.35	.06	.05
12	11′–12′	1′	42.14	55.75	.50	.36	.03	.06
13	12′–13′	1′	41.60	55.47	1.47	.43	.03	.04
14	13′–14′	1′	43.22	54.87	1.19	.32	.10	.04
15	14′–15′	1′	41.75	56.15	.85	.39	.03	.04
16	15′–16′	1′	42.10	56.30	1.01	.40	.02	.07
17	16′–17′	1′	41.84	56.98	.30	.35	.04	.02
18	17′–18′	1′	42.54	56.30	.53	.39	.03	.07
19	18′–19′	1′	40.73	57.93	.38	.59	.06	.04
20	19′–20′	1′	40.71	57.61	.79	.56	.07	.04
21	20′–21′	1′	40.35	58.04	.72	.38	.09	.04
22	21′–22′	1′	39.90	58.60	.78	.46	.06	.07
23	22′–23′	1′	40.03	58.58	.45	.51	.02	.04
24	23′–24′	1′	41.23	57.30	.44	.48	.10	.07
25	24′–25′	1′	41.70	56.95	.51	.50	.08	.05
26	25′–26′	1′	41.24	57.22	.67	.51	.08	.04
27	26′–27′	1′	42.00	56.58	.37	.45	.31	.02
28	27′–28′	1′	39.64	58.77	.65	.42	.23	.01
29	28′–29′	1′	41.48	57.20	.45	.70	.09	.01
30	29′–30′	1′	42.11	56.13	.42	.56	.41	.03
31	30′–31′	1′	42.35	56.20	.91	.40	.03	.04
32	31′–32′	1′	42.41	55.54	1.11	.44	.03	.01
33	32′–33′	1′	42.21	56.43	.73	.31	.01	.04
34	33′–34′	1′	43.61	52.50	.57	.47	.04	.03
35	34′–35′	1′	38.67	59.84	.66	.63	.05	.03
36	35′–36′	1′	38.09	57.86	.69	.69	.02	.05
37	36′–37′	1′	38.64	59.37	1.04	.79	.07	.05
38	37′–38′	1′	42.63	56.26	.39	.55	.02	.01
39	38′–39′	1′	42.03	57.05	.34	.49	.02	.03
40	39′–40′	1′	40.88	55.93	.20	.53	.04	.01
41	40′–41′	1′	18.85	79.94	.69	.29	.10	.03
42	41′–42′	1′	38.35	59.19	.19	.45	.03	.03
43	42′–43′	1′	28.95	67.65	.24	.37	.06	.01
Averages			40.58	57.58	.56	.47		

Core Hole Number 2

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	38.75	59.74	.51	.46	.09	.09
2	5′– 9′	4′	42.01	56.52	.58	.71	.01	.07
3	9′–13′	4′	42.05	56.51	.62	.54	.03	.04
4	13′–17′	4′	42.07	56.19	.75	.54	.05	.04
5	17′–21′	4′	42.02	56.52	.62	.57	.01	.03
6	21′–25′	4′	41.86	56.42	.48	.68	.06	.06
7	25′–29′	4	42.04	56.82	.33	.52	.08	.03
8	29′–33′	4′	41.46	56.95	.38	.53	.08	.04
9	33′–37′	4′	40.02	58.16	.41	.73	.11	.03
10	37′–41′	4′	38.98	58.12	.75	.69	.11	.03
11	41′–45′	4′	40.01	56.47	.99	.91	.09	.09
12	45′–49′	4′	39.35	58.37	.44	.37	.01	.10
13	49′–53′	4′	36.42	60.21	1.67	.79	.12	.09
14	53′–56′	3′	37.61	59.25	1.23	.70	.13	.12
Average			40.33	57.58	.70	.62		

[14]Analyses furnished through courtesy of Mr. H. C. Counts, Victoria Gravel Company, Burnet, Texas.

Core Hole Number 3

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	40.73	55.62	2.43	.60	.01	.06
2	5′– 9′	4′	41.75	56.58	.74	.61	.01	.06
3	9′–13′	4′	41.17	54.28	3.51	.64	.03	.03
4	13′–17′	4′	40.95	56.45	1.51	.65	.01	.03
5	17′–21′	4′	41.64	56.44	.71	.41	.03	.01
6	21′–25′	4′	41.82	56.44	.85	.63	.02	.03
7	25′–29′	4′	41.87	55.90	1.11	.57	.02	.03
8	29′–33′	4′	42.16	55.75	1.19	.42	.03	.01
9	33′–37′	4′	41.90	56.30	1.03	.41	.02	.04
10	37′–41′	4′	41.29	56.02	1.25	.68	.02	.09
11	41′–45′	4′	41.38	56.58	.39	.61	.01	.01
12	45′–49′	4′	42.05	56.57	.28	.72	.02	.03
13	49′–53′	4′	40.72	57.56	.58	.71	.02	.07
14	53′–57′	4′	40.70	57.57	.47	.77	.01	.06
15	57′–59′	2′	40.96	56.91	1.31	.69	.01	.04
Average			41.41	56.33	1.16	.61		

Core Hole Number 4

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	38.17	56.33	4.07	1.21	.08	.07
2	5′– 9′	4′	27.80	69.93	.99	.94	.08	.06
3	9′–13′	4′	31.74	65.67	1.10	1.03	.08	.03
4	13′–17′	4′	30.57	67.72	.31	1.17	.07	.03
5	17′–21′	4′	30.92	67.60	.43	.83	.04	.04
6	21′–25′	4′	13.66	85.00	.53	.31	.06	.04
7	25′–29′	4′	26.34	71.58	.85	.84	.06	.04
8	29′–33′	4′	25.69	72.31	.87	.74	.05	.06
9	33′–37′	4′	24.40	72.98	.68	.79	.08	.07
10	37′–41′	4′	32.37	64.17	1.33	1.11	.07	.07
11	41′–45′	4′	42.17	55.51	1.05	1.02	.04	.04
12	45′–49′	4′	42.28	55.81	.69	.91	.02	.04
13	49′–53′	4′	24.41	73.96	.60	.61	.05	.04
14	53′–57′	4′	21.38	77.30	.37	.41	.03	.01
15	57′–59′	2′	17.28	80.92	.43	.45	.06	.01
Average			28.61		.95	.82		

Core Hole Number 5

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	32.49	42.95	21.56	.75	.01	.04
2	5′– 9′	4′	41.57	54.78	2.30	.30	.03	.04
3	9′–13′	4′	40.98	53.97	3.99	.28	.01	.04
4	13′–17′	4′	38.11	49.84	9.92	.45	.02	.05
5	17′–21′	4′	41.20	54.78	2.04	.21	.03	.06
6	21′–25′	4′	41.70	55.34	2.43	.25	.03	.07
7	25′–29′	4′	41.94	55.06	1.69	.21	.02	.06
8	29′–33′	4′	42.07	54.79	2.06	.28	.01	.09
9	33′–37′	4′	40.96	53.69	4.18	.29	.01	.09
10	37′–41′	4′	34.89	45.42	17.91	.92	.03	.07
11	41′–42′	1′	38.95	51.21	8.62	.43	.01	.04
Average			39.53		6.97	.40		

Core Hole Number 6

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	42.95	55.71	.65	.25	.02	.01
2	5′– 9′	4′	42.94	55.91	.59	.20	.02	.01
3	9′–13′	4′	42.99	55.62	.65	.17	.05	.01
4	13′–17′	4′	38.37	50.75	10.17	.22	.02	.01
5	17′–21′	4′	42.98	55.60	.58	.18	.02	.02
6	21′–25′	4′	43.08	55.63	.68	.14	.01	.01
7	25′–29′	4′	42.63	55.34	1.13	.25	.01	.01
8	29′–33′	4′	43.09	55.59	.56	.22	.02	.06
9	33′–37′	4′	43.38	55.15	.66	.26	.01	.02
10	37′–41′	4′	43.47	54.25	.79	.19	.01	.05
11	41′–45′	4′	42.94	55.36	.68	.22	.01	.03
12	45′–49′	4′	42.58	55.39	.86	.17	.02	.04
13	49′–53′	4′	43.11	54.53	.65	.23	.01	.06
14	53′–57′	4′	42.85	55.98	.58	.17	.01	.03
Average			42.67	55.06	1.37	.21		

Core Hole Number 7

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	42.43	56.95	.27	.31	.04	.06
2	5′– 9′	4′	40.72	58.32	.41	.28	.08	.07
3	9′–13′	4′	37.11	61.09	.56	.27	.07	.12
4	13′–16′	3′	36.69	59.39	1.70	.56	.13	.17
5	17′–21′	4′	23.69	75.12	.27	.19	.08	.06
6	21′–25′	4′	19.07	79.56	.33	.13	.04	.04
7	25′–29′	4′	12.82	83.13	1.88	.47	.05	.13
8	29′–33′	4′	20.34	78.44	.69	.20	.07	.06
9	33′–37′	4′	17.45	79.09	.45	.15	.03	.03
10	37′–41′	4′	11.69	86.79	.94	.18	.06	.06
11	41′–45′	4′	25.25	72.71	1.44	.33	.09	.07
12	45′–49′	4′	11.56	86.45	.89	.17	.04	.07
13	49′–53′	4′	13.77	95.19	.53	.11	.24	.04
14	53′–57′	4′	9.69	88.09	.42	.14	.05	.04
15	57′–61′	4′	11.85	88.14	.71	.13	.46	.06
16	61′–65′	4′	9.35	89.13	.85	.13	.11	.09
17	65′–69′	4′	12.19	85.03	1.26	.12	.09	.13
18	69′–71′	4′	10.82	87.80	.42	.11	.07	.04
Average			20.36		.78	.22		

Core Hole Number 8

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	39.44	59.15	.72	.39	.03	.01
2	5′– 9′	4′	39.01	59.53	.69	.26	.07	.09
3	9′–13′	4′	38.70	59.30	1.30	.33	.09	.07
4	13′–17′	4′	38.20	58.90	1.22	.24	.13	.09
5	17′–21′	4′	39.72	58.20	1.66	.12	.14	.07
6	21′–25′	4′	39.45	58.80	1.25	.35	.06	.06
7	25′–29′	4	38.66	57.74	1.77	.42	12	.07
8	29′–33′	4′	39.60	56.61	1.14	.42	.07	.07
9	33′–37′	4′	38.35	58.52	1.48	.45	.13	.10
10	37′–41′	4′	37.70	58.91	1.95	.35	.13	.13
11	41′–45′	4′	37.51	59.29	1.51	.39	.12	.13
12	45′–49′	4′	38.21	58.22	1.37	.62	.08	.06
13	49′–53′	4′	38.67	58.55	1.34	.49	.09	.04
14	53′–57′	4′	34.37	62.43	1.91	.36	.12	.09
15	57′–61′	4′	28.37	67.52	1.80	.40	.09	.13
16	61′–65′	4′	29.49	67.92	1.32	.42	.07	.07
17	65′–69′	4′	23.83	74.17	.80	.22	.08	.03
18	69′–71′	2′	28.22	68.74	1.15	.46	.03	.13
Average			35.98		1.35	.37		

Core Hole Number 9

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	39.10	59.30	.83	.47	.11	.06
2	5′– 9′	4′	38.52	58.44	1.89	.63	.15	.06
3	9′–13′	4′	40.76	57.28	.41	.55	.07	.03
4	13′–17′	4′	39.95	57.85	1.31	.57	.12	.06
5	17′–21′	4′	39.24	58.21	1.43	.65	.08	.06
6	21′–25′	4′	39.75	58.37	1.04	.51	.12	.04
7	25′–29′	4′	40.08	57.14	1.16	.67	.14	.03
8	29′–33′	4′	39.46	57.44	1.85	.69	.13	.06
9	33′–37′	4′	41.19	57.29	.60	.61	.09	.03
10	37′–41′	4′	41.87	56.23	.66	.51	.12	.07
11	41′–45′	4′	39.22	58.79	.92	.56	.21	.13
12	45′–49′	4′	38.81	58.70	1.28	.70	.11	.06
13	49′–53′	4′	39.21	59.22	.33	.54	.10	.07
Average			39.78		1.05	.59		

Core Hole Number 10

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3	% $CaSO_4$	% Al_2O_3
1	0′– 5′	4′	34.10	44.48	19.77	1.27	.05	.07
2	5′– 9′	4′	41.75	53.45	3.60	.58	.02	.10
3	9′–13′	4′	42.51	54.36	2.37	.40	.03	.12
4	13′–17′	4′	36.43	46.66	15.56	1.06	.03	.07
5	17′–21′	4′	39.10	50.04	9.65	.85	.03	.04
6	21′–25′	4′	42.44	55.39	1.34	.49	.02	.07
7	25′–29′	4′	42.91	55.19	.50	.47	.01	.09
8	29′–33′	4′	42.43	55.50	.68	.51	.01	.10
9	33′–37′	4′	43.43	54.58	.53	.48	.01	.07
10	37′–41′	4′	43.34	54.32	.34	.48	.03	.06
11	41′–45′	4′	42.90	56.02	.30	.44	.01	.09
12	45′–49′	4′	42.93	55.59	.51	.53	.04	.10
13	49′–53′	4′	42.58	55.77	.63	.49	.05	.14
14	53′–57′	4′	42.02	55.94	.85	.46	.03	.09
15	57′–61′	4′	42.72	55.45	.92	.46	.06	.12
16	61′–65′	4′	41.78	55.12	1.53	.57	.08	.06
17	65′–69′	4′	41.14	56.61	.62	.65	.14	.03
18	69′–73′	4′	41.70	55.48	.98	.52	.03	.06
19	73′–77′	4′	42.07	55.81	1.20	.56	.01	.10
20	77′–81′	4′	40.72	55.76	2.54	.58	.06	.14
21	81′–85′	4′	42.16	55.98	.87	.45	.06	.10
22	85′–89′	4′	39.86	56.80	1.25	.63	.13	.14
23	89′–93′	4′	39.92	57.49	1.03	.55	.06	.14
24	93′–97′	4′	40.58	56.65	1.12	.57	.10	.10
25	97′–101′	4′	35.51	56.52	5.14	.82	.11	.23
Average			41.08		2.95	.59		

Core Hole Number 11

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–9′	5	43.29	51.52	4.55	.34
2	9′–12′ 6″	3′ 6″	44.94	53.88	.70	.18
3	12′ 6″–17′ 6″	5′	43.00	55.18	1.27	.26
4	17′ 6″–21′ 6″	4′	44.11	54.61	.84	.22
5	21′ 6″–23′ 6″	2′	44.71	54.64	.34	.14
6	23′ 7″–26′ 6″	3′	43.96	55.20	.40	.17
7	26′ 6″–29′ 6″	3′	42.62	56.50	.43	.25
8	29′ 6″–33′	3′ 6″	44.13	54.93	.51	.19
9	33′–36′	3′	43.31	55.34	.89	.21
10	36′–40′	4′	44.42	54.77	.42	.16
11	40′–45′	5′	43.92	54.73	.87	.21
Average			43.81	54.52	1.16	.23

Core Hole Number 12

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	2′ 6″–7′ 6″	5.0	41.60	49.49	8.42	.24
2	7′ 6″–10′ 8″	3.2	44.69	54.16	.71	.18
3	10′ 8″–13′ 8″	3.0	42.54	56.34	.61	.24
4	13′ 8″–15′	1.3	43.75	55.04	.73	.24
5	15′–17′ 2″	2.2	42.83	54.38	2.07	.45
6	17′ 2″–19 ′2″	2.0	42.39	55.48	1.60	.28
7	19′ 2″–20′ 4″	1.2	44.02	54.61	.95	.18
8	20′ 4″–23′ 10″	3.5	44.69	54.59	.29	.16
9	23′ 10″–25′ 2″	1.3	44.11	54.20	.29	.16
10	25′ 2″–27′ 8″	2.5	44.77	54.22	.56	.22
11	27′ 8″–29′ 10″	2.2	45.03	53.59	.93	.22
12	29′ 10″–34′ 4″	4.5	44.98	54.16	.42	.16
13	34′ 4″–37′ 6″	3.2	45.40	53.86	.42	.11
14	37′ 6″–40′	2.5	44.57	54.47	.54	.15
15	40′–41′ 6″	1.5	45.46	53.93	.21	.14
16	41′ 6″–42′ 6″	1.0	45.26	54.14	.21	.13
17	42′ 6″–47′ 6″	5.0	45.19	53.56	.79	.20
Average			44.17	53.83	.51	.17

Core Hole Number 13

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–7′ 2″	3.2	41.22	50.65	7.73	.18
2	7′ 2″–12′ 2″	5.0	41.72	51.99	5.85	.22
3	12′ 2″–16′ 5″	4.3	44.08	54.45	.95	.26
4	16′ 5″–19′ 11″	3.5	44.38	54.48	.72	.16
5	19′ 11″–21′ 7″	1.7	44.21	54.29	1.09	.15
6	21′ 7″–26′ 6″	4.9	44.06	55.02	.52	.16
7	26′ 6″–31′ 6″	5.0	43.94	54.59	1.01	.18
8	31′ 6″–36′ 6″	5.0	44.19	54.91	.51	.13
9	36′ 6″–38′ 6″	2.0	44.13	55.20	.33	.10
10	38′ 6″–42′ 8″	4.2	42.85	55.82	.90	.18
11	42′ 8″–45′ 2″	2.5	44.04	54.93	.62	.14
Average			43.48	54.18	1.75	.18

Core Hole Number 14

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–5′ 6″	1.5	41.62	50.99	6.84	.30
2	5′ 6″–9′ 10″	4.3	44.69	52.86	2.03	.18
3	9′ 10″–12′ 6″	2.7	45.46	52.71	1.30	.21
4	12′ 6″–15′ 6″	3.0	44.86	53.02	1.66	.22
5	15′ 6″–20′ 6″	5.0	41.51	56.86	1.27	.08
6	20′ 6″–25′ 6″	5.0	45.03	54.38	.25	.12
7	25′ 6″–30′ 6″	5.0	40.82	58.50	.25	.16
8	30′ 6″–35′ 6″	5.0	33.50	65.80	.31	.13
9	35′ 6″–36′ 6″	1.0	33.38	65.64	.57	.15
10	36′ 6″–41′ 6″	5.0	44.40	54.43	.75	.18
11	41′ 6″–45′	3.5	46.03	52.98	.55	.17
Average			42.26	56.25	.61	.16

Core Hole Number 15

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–8′ 6″	4.5	39.48	50.68	9.06	.51
2	8′ 6″–12′ 8″	4.2	42.16	50.50	6.64	.44
3	12′ 8″–17′ 0″	4.3	38.79	52.72	7.92	.28
Average			40.11	51.30	7.85	.38

Core Hole Number 16

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	2′ 3″–5′ 3″	3.0	43.79	53.65	2.03	.27
2	5′ 3″–7′ 6″	2.3	37.16	52.11	10.05	.42
3	7′ 6″–12′ 6″	5.0	41.97	54.09	3.42	.24
4	12′ 6″–17′ 6″	5.0	35.89	43.81	19.57	.50
5	17′ 6″–19′ 0″	1.5	29.70	37.41	31.68	.87
6	19′ 0″–23′ 6″	4.5	43.65	53.65	2.27	.21
7	23′ 6″–28′ 6″	5.0	41.70	52.73	4.98	.31
8	28′ 6″–30′ 6″	2.0	39.82	57.41	2.29	.27
Average			40.11	51.09	8.17	.31

Core Hole Number 17

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′ 4″–5′ 4″	2.0	41.05	49.34	8.97	.38
2	5′ 4″–10′ 4″	5.0	43.52	52.88	3.14	.21
3	10′ 4″–13′ 0″	2.7	44.25	54.25	1.01	.22
4	13′ 0″–16′ 7″	3.6	43.42	53.54	2.48	.32
5	16′ 7″–21′ 4″	4.8	39.25	47.77	12.19	.58
6	21′ 4″–22′ 10″	1.5	33.36	40.37	25.06	.97
Average			41.51	50.61	7.21	.39

Core Hole Number 18

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–6′ 10″	3.8	44.50	54.45	.70	.15
2	6′ 10″–8′ 10″	2.0	44.65	54.36	.57	.17
3	8′ 10″–13′ 10″	5.0	44.73	54.27	.55	.17
4	13′ 10″–17′ 4″	3.5	44.69	54.66	.30	.12
5	17′ 4″–19′ 8″	2.3	44.67	54.61	.31	.14
6	19′ 8″–24′ 5″	4.8	44.82	54.70	.27	.13
7	24′ 5″–29′ 5″	5.0	23.88	74.83	1.03	.16
8	29′ 5″–34′ 5″	5.0	19.34	79.65	.57	.18
9	34′ 5″–39′ 5″	5.0	17.73	81.50	.38	.15
10	39′ 5″–42′ 5″	3.0	9.68	89.66	.28	.12
11	42′ 5″–46′ 5″	4.0	24.26	75.13	.36	.13
Average			31.96	67.19	.47	.14

Core Hole Number 19

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–5′	2.0	43.44	55.41	.87	.10
2	5′–8′	3.0	44.75	54.29	.60	.13
3	8′–12′	4.0	44.59	54.38	.63	.14
4	12′–14′	2.0	44.17	54.36	1.04	.18
5	14′–19′	5.0	44.25	54.86	.46	.15
6	19′–24′	5.0	42.54	54.20	1.92	.13
7	24′–28′	4.0	43.52	55.09	.92	.24
8	28′–33′	5.0	44.11	53.63	1.78	.29
9	33′–35′	2.0	44.71	54.45	.46	.21
10	35′–39′ 4″	4.3	44.59	54.61	.42	.18
11	39′ 4″–44′ 4″	5.0	44.31	54.93	.35	.16
12	44′ 4″–46′ 4″	2.0	45.17	54.00	.34	.21
13	46′ 4″–49′	2.7	45.17	54.13	.31	.19
14	49′–51′	2.0	38.19	58.55	2.51	.52
15	51′–55′	4.0	25.66	73.38	.50	.20
16	55′–60′	5.0	31.35	67.12	1.11	.21
Average			41.51	57.04	.71	.21

Core Hole Number 20

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–4′	1.0	43.94	54.11	1.57	.18
2	4′–9′	5.0	44.46	53.98	1.18	.14
3	9′–14′	5.0	44.92	54.00	.76	.13
4	14′–15′	1.0	42.62	56.36	.56	.18
5	15′–18′ 5″	3.4	42.81	55.89	.93	.15
6	18′ 5″–23′ 5″	5.0	43.06	56.20	.39	.10
7	23′ 5″–28′ 5″	5.0	39.86	59.00	.71	.15
8	28′ 5″–33′ 5″	5.0	27.19	71.69	.77	.14
9	33′ 5″–37′ 5″	4.0	31.31	67.42	.91	.15
10	37′ 5″–41′ 2″	3.8	21.46	77.84	.37	.09
11	41′ 2″–46′ 2″	5.0	19.41	79.59	.68	.09
12	46′ 2″–51′ 2″	5.0	11.92	86.07	1.68	.14
13	51′ 2″–56′ 2″	5.0	24.84	74.33	.49	.06
14	56′ 2″–61′ 2″	5.0	18.05	80.38	1.21	.15
Average			31.06	67.74	.81	.18

Core Hole Number 21

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′ 1″–6′ 7″	3.5	43.46	55.23	.19	.16
2	6′ 7″–10′ 6″	3.9	43.55	54.83	.81	.26
3	10′ 6″–14′ 6″	4.0	44.99	53.79	.92	.21
4	14′ 6″–18′ 6″	4.0	43.70	55.34	.97	.34
5	18′ 6″–21′ 6″	3.0	44.13	54.62	1.33	.24
6	21′ 6″–24′ 10″	3.3	44.21	55.44	.49	.17
7	24′ 10″–28′ 1″	3.3	44.31	55.22	.38	.17
8	28′ 1″–32′ 7″	4.5	42.84	56.67	.50	.17
9	32′ 7″–37′ 7″	5.0	41.92	56.66	.54	.16
10	37′ 7″–42′ 7″	5.0	40.08	58.49	.54	.17
11	42′ 7″–44′ 10″	2.3	40.09	58.90	.50	.21
12	44′ 10″–49′ 10″	5.0	38.26	58.91	.44	.19
13	49′ 10″–53′	3.2	40.42	57.48	.29	.17
14	53′–57′	4.0	33.97	63.97	.50	.17
15	57′–58′	1.0	35.59	55.83	5.55	.58
16	58′–60′	2.0	30.91	67.72	.74	.14
Average			41.23	57.27	.69	.20

Core Hole Number 22

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′ 10″–8′ 10″	4.0	42.30	57.16	.33	.09
2	8′ 10″–10′ 4″	1.5	43.26	55.96	.31	.10
3	10′ 4″–13′ 4″	3.0	43.75	55.86	.29	.11
4	13′ 4″–15′ 4″	2.0	43.55	56.05	.12	.11
5	15′ 4″–19′ 2″	3.8	39.92	58.66	.54	.10
6	19′ 2″–20′ 10″	1.7	40.22	59.26	.80	.13
7	20′ 10″–25′ 10″	5.0	40.52	58.06	.93	.14
8	25′ 10″–30′ 10″	5.0	43.43	55.46	1.56	.14
9	30′ 10″–35′ 10″	5.0	43.67	55.46	.90	.10
10	35′ 10″–37′ 6″	1.7	43.61	54.85	2.02	.13
11	37′ 6″–41′	3.5	38.58	61.06	.92	.13
12	41′–45′ 6″	4.5	11.18	88.19	.69	.07
13	45′ 6″–50′ 6″	5.0	19.73	79.48	.87	.09
14	50′ 6″–55′ 6″	5.0	8.97	89.79	1.06	.07
15	55′ 6″–60′	4.5	14.31	82.58	2.62	.14
Average			32.21	66.71	.99	.11

Core Hole Number 23

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	2′ 6″–3′ 8″	1.2	40.31	58.26	.36	.14
2	3′ 8″–8′ 8″	5.0	43.67	56.04	.32	.09
3	8′ 8″–13′ 8″	5.0	36.17	63.20	.53	.11
4	13′ 8″–17′ 8″	4.0	20.19	79.12	.71	.10
5	17′ 8″–20′	2.3	18.08	75.04	5.67	.27
6	20′–25′	5.0	11.51	87.36	.49	.07
7	25′–30′	5.0	8.86	88.79	.64	.03
8	30′–35′	5.0	12.03	85.47	.49	.04
9	35′–40′	5.0	14.30	84.23	1.54	.14
10	40′–45′	5.0	18.31	79.76	1.17	.14
11	45′–50′	5.0	16.04	81.16	1.89	.07
12	50′–55′	5.0	13.10	85.93	.64	.01
13	55′–60′	5.0	13.01	85.71	.62	.03
Average			19.23	79.08	1.01	.08

Core Hole Number 24

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–6′ 3″	3.3	40.99	57.69	.67	.16
2	6′ 3″–11′ 3″	5.0	37.95	59.32	.53	.17
3	11′ 3″–16′ 3″	5.0	30.16	68.54	.67	.12
4	16′ 3″–19′ 3″	5.0	15.81	82.82	.57	.10
5	19′ 3″–21′ 7″	2.3	11.35	87.14	.82	.09
6	21′ 7″–26′ 7″	5.0	18.08	80.14	1.32	.11
7	26′ 7″–31′ 7″	5.0	18.17	81.21	.80	.09
8	31′ 7″–36′ 7″	5.0	22.95	76.09	1.01	.09
9	36′ 7″–41′ 7″	5.0	5.96	91.46	.38	.07
10	41′ 7″–46′ 7″	5.0	12.72	75.34	1.44	.10
11	46′ 7″–51′ 7″	5.0	17.38	81.33	1.19	.01
12	51′ 7″–56′ 7″	5.0	7.12	90.83	.99	.07
13	58′ 1″–63′ 1″	5.0	16.57	80.77	1.20	.09
Average			19.40	78.05	.90	.10

Core Hole Number 25

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–6′	2.0	43.34	53.15	3.71	.24
2	6′–11′	5.0	44.74	54.95	.98	.16
3	11′–15′	4.0	44.25	54.75	1.08	.19
4	15′–18′	3.0	44.19	55.06	.88	.16
5	18′–21′	3.0	44.52	55.35	.58	.10
6	21′–25′ 6″	4.5	43.13	56.05	.60	.16
7	25′ 6″–28′ 6″	3.0	42.95	55.76	1.15	.11
8	28′ 6″–33′	4.5	43.46	55.56	.66	.10
9	33′–36′ 6″	3.5	42.80	55.36	.90	.14
10	36′ 6″–41′ 6″	5.0	43.20	55.65	.91	.09
11	41′ 6″–43′ 6″	2.0	43.25	55.26	.90	.13
12	43′ 6″–48′ 6″	5.0	35.61	45.65	18.38	.49
13	48′ 6″–50′ 6″	2.0	43.74	55.36	.91	.13
14	50′ 6″–54′	3.5	44.16	55.65	.63	.09
15	54′–59′	5.0	43.01	55.46	1.24	.11
16	59′–62′ 6″	3.5	43.55	55.86	.92	.11
Average			42.94	54.53	2.48	.16

Core Hole Number 26

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	2′ 6″–5′ 6″	3.0	42.28	56.11	.33	.16
2	5′ 6″–8′ 8″	3.2	41.23	57.54	.38	.20
3	8′ 8″–12′ 8″	4.0	41.22	55.90	.61	.19
4	12′ 8″–17′ 8″	5.0	36.02	59.92	.62	.27
5	17′ 8″–22′ 8″	5.0	38.83	59.62	1.49	.29
6	22′ 8″–26′ 8″	4.0	43.57	55.10	1.14	.17
7	26′ 8″–31′ 8″	5.0	42.68	56.14	.55	.21
8	31′ 8″–36′ 4″	4.7	40.32	57.35	1.08	.24
9	36′ 4″–39′ 4″	3.0	41.93	57.16	.84	.30
10	39′ 4″–42′ 4″	3.0	42.08	56.76	.56	.21
11	42′ 4″–46′ 6″	4.2	39.65	57.56	1.32	.27
12	46′ 6″–49′ 6″	3.0	40.79	58.27	1.28	.26
13	49′ 6″–54′ 6″	5.0	39.88	57.56	1.31	.24
14	54′ 6″–56′	1.5	41.99	56.75	1.17	.21
15	56′–60′	4.0	40.71	57.56	1.37	.21
Average			40.65	57.39	.95	.23

Core Hole Number 27

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–6′ 7″	3.6	24.13	72.86	2.16	.26
2	6′ 7″–11′ 7″	5.0	21.04	77.38	1.71	.29
3	11′ 7″–16′ 7″	5.0	10.44	87.37	1.52	.23
4	16′ 7″–21′ 7″	5.0	19.66	79.16	.89	.20
5	21′ 7″–26′ 7″	5.0	25.43	73.08	.66	.13
6	26′ 7″–31′ 7″	5.0	20.73	77.56	1.54	.13
7	31′ 7″–36′ 7″	5.0	15.96	83.66	.50	.06
8	36′ 7″–41′ 7″	5.0	11.36	87.77	.59	.06
9	41′ 7″–46′ 7″	5.0	12.94	85.89	1.13	.10
10	46′ 7″–51′ 7″	5.0	11.81	86.12	.81	.11
11	51′ 7″–56′ 7″	5.0	11.58	87.55	.48	.07
12	56′ 7″–60′	3.4	11.88	85.01	.79	.11
Average			16.35	82.09	1.05	.14

Core Hole Number 28

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	3′–7′ 2″	4.2	42.61	56.26	1.27	.10
2	7′ 2″–9′ 8″	2.5	41.19	53.05	5.55	.13
3	9′ 8″–11′ 8″	2.0	42.41	54.05	3.16	.14
4	11′ 8″–15′ 3″	3.6	42.37	55.36	1.25	.09
5	15′ 3″–17′ 3″	2.0	42.92	55.36	.94	.10
6	17′ 3″–20′ 8″	3.4	35.79	44.74	19.10	.61
7	20′ 8″–21′ 8″	1.0	42.95	54.56	1.66	.21
8	21′ 8″–26′ 3″	4.6	41.83	50.85	7.76	.30
9	26′ 3″–29′ 3″	3.0	38.86	47.35	14.19	.41
10	29′ 3″–30′ 3″	1.0	17.45	20.52	61.32	1.83
Average			40.15	49.88	8.72	.30

Core Hole Number 29

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′–7′ 5″	3.4	44.25	52.67	2.46	.36
2	7′ 5″–10′ 5″	3.0	43.57	53.27	2.77	.15
3	10′ 5″–12′ 7″	2.2	44.15	52.89	2.55	.14
4	12′ 7″–16′ 1″	3.5	43.93	54.44	1.24	.14
5	16′ 1″–20′ 1″	4.0	43.22	52.02	4.32	.20
6	20′ 1″–24′ 1″	4.0	45.41	49.74	4.45	.19
7	24′ 1″–28′ 1″	4.0	43.39	53.65	2.57	.14
8	28′ 1″–33′ 1″	5.0	40.87	50.17	8.32	.37
9	33′ 1″–37′ 1″	4.0	43.94	52.90	2.74	.16
10	37′ 1″–41′ 7″	4.5	48.02	50.48	1.08	.16
11	41′ 7″–46′ 7″	5.0	44.97	50.05	4.49	.22
12	46′ 7″–50′ 7″	4.0	39.88	48.93	10.57	.38
13	50′ 7″–55′ 7″	5.0	44.18	46.95	8.26	.35
14	55′ 7″–60′	4.4	44.85	53.05	1.67	.18
Average			43.91	51.20	4.33	.23

Core Hole Number 30

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	4′ 2″–8′ 5″	4.3	42.05	53.22	4.25	.24
2	8′ 5″–13′	4.6	44.90	54.37	.29	.14
3	13′–15′ 6″	2.5	44.70	54.37	.52	.16
4	15′ 6″–19′ 6″	4.0	43.96	55.02	.54	.20
5	19′ 6″–23′	3.5	44.45	54.66	.45	.20
6	23′–28′	5.0	44.34	54.62	.61	.17
7	28′–32′	4.0	43.91	54.99	.68	.15
8	32′–37′	5.0	44.89	53.81	.94	.13
9	37′–39′ 6″	2.5	44.49	54.68	.43	.15
10	39′ 6″–42′ 6″	3.0	44.43	54.25	.84	.24
11	42′ 6″–44′ 6″	2.0	44.56	54.84	.10	.24
12	44′ 6″–48′ 6″	4.0	44.92	54.06	.56	.19
13	48′ 6″–53′ 6″	5.0	43.22	55.21	1.11	.22
14	53′ 6″–57′	3.5	43.37	54.99	1.14	.27
15	57′–60′	3.0	42.00	55.84	1.66	.24
Average			44.02	54.55	1.00	.19

Core Hole Number 31

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	6′–10′ 6″	4.5	46.97	50.02	2.58	.16
2	10′ 6″–13′ 4″	2.8	44.16	52.74	2.75	.10
3	13′ 4″–16′ 4″	3.0	35.63	42.05	20.92	.74
4	16′ 4″–17′ 10″	1.5	32.48	38.36	28.35	.56
5	17′ 10″–21′ 2″	3.3	43.53	51.80	4.27	.17
6	21′ 2″–25′ 8″	4.5	42.83	50.39	6.34	.20
7	25′ 8″–27′ 8″	2.0	51.45	46.40	1.76	.13
8	27′ 8″–31′ 2″	3.5	53.25	44.45	1.90	.15
9	31′ 2″–36′ 2″	5.0	49.27	48.89	1.44	.17
10	36′ 2″–41′	4.8	47.50	44.70	7.21	.34
11	41′–45′	4.0	50.31	45.58	3.66	.18
12	45′–50′	5.0	52.33	44.40	2.81	.22
13	50′–53′	3.0	52.60	45.46	1.54	.14
14	53′–57′	4.0	50.70	47.61	1.25	.19
15	57′–60′	3.0	55.92	42.49	1.19	.17
Average			47.90	46.75	4.84	.21

Core Hole Number 32

Sample No.	Depth	Cut	% $MgCO_3$	% $CaCO_3$	% SiO_2	% Fe_2O_3
1	13′–18′	5.0	43.20	43.74	12.64	.18
2	18′–21′ 6″	3.5	49.43	47.83	2.32	.16
3	21′ 6″–25′	3.5	46.64	50.81	2.15	.14
4	25′–29′ 8″	4.7	48.14	48.65	2.65	.29
5	29′ 8″–33′ 6″	3.8	47.25	51.06	1.25	.18
6	33′ 6″–36′ 3″	2.8	53.49	45.02	1.07	.15
7	36′ 3″–39′ 10″	3.6	45.66	51.93	2.15	.22
8	39′ 10″–42′ 7″	2.8	44.23	53.86	1.47	.22
9	42′ 7″–46′ 6″	3.9	45.89	51.81	1.86	.18
10	46′ 6″–49′ 2″	2.7	43.85	53.75	1.96	.19
11	49′ 2″–54′ 2″	5.0	48.33	49.95	1.31	.17
12	54′ 2″–58′	3.8	45.44	52.67	1.40	.22
13	58′–60′	2.0	44.84	54.03	.70	.17
Average			46.65	50.00	2.90	.19

REPRESENTATIVE THIN SECTIONS OF ELLENBURGER ROCKS

DESCRIPTION OF THIN SECTIONS FROM THE CHEROKEE AREA

CAMBRIAN

Wilberns formation

San Saba limestone member

1. Girvanella in dolomite, //[15] 2.4 miles north of Cherokee.[16]

The girvanella is composed of limestone of about 0.03 mm. grain size containing an occasional dolomite rhomb and is surrounded by dolomite having a grain size of about 0.07 mm.

2. Limestone, 2.4 miles north of Cherokee.

The limestone is composed mostly of crystals 0.02 mm. or less in size with some ranging up to about 1 mm. in size. Fossil fragments are common and a few pellet-like objects are present.

Pedernales dolomite member

3. Lower dolomite, 2.6 miles north of Cherokee.

The dolomite crystals average about 0.25 mm. in size and a few small areas of calcite are interstitial to the dolomite grains. A few highly birefringent inclusions are present; otherwise, the dolomite is not cloudy.

4. Lower dolomite, R, 2.6 miles north of Cherokee.

Similar to section 3 except that considerable calcite in crystals a millimeter or more in size is situated among the dolomite rhombs.

5. Upper dolomite, 3.5 miles north of Cherokee.

The dolomite crystals average about 0.2 mm. in size. Some areas of the slide are clear and others are cloudy.

5a. Chert, 3.5 miles north of Cherokee.

The chert is cloudy and dolomoldic and contains silt sized detrital quartz grains. The chert grains are about 0.005 to 0.01 mm. in size.

6. Upper dolomite, R, 3.5 miles north of Cherokee.

The dolomite grains average about 0.2 mm. in size and a few small calcite crystals are interstitial to the dolomite rhombs. The dolomite is only slightly cloudy.

7. Upper dolomite, 3.5 miles north of Cherokee.

The dolomite has a grain size of about 0.5 mm. and is only slightly cloudy.

ORDOVICIAN

Tanyard formation

Threadgill member

8. Lower dolomite, R, 3.7 miles north of Cherokee.

The dolomite rhombs are up to about 1 mm. in size and are interspersed with a few calcite crystals up to 2 mm. in size. The dolomite is somewhat cloudy.

9. Lower limestone, R, 3.9 miles north of Cherokee School.

The grain size of the calcite is 0.02 mm. or less and some calcite crystals up to 0.1 mm. are present.

10. Upper dolomite, R, 5.5 miles north of Cherokee, B-36.

Dolomite rhombs which are only slightly cloudy range up to about 0.8 mm. in size.

11. Upper chert, R, 5.5 miles north of Cherokee, B-36.

Dolomite rhombs and dolomolds averaging about 0.25 mm. in size are numerous. Chert grains average about 0.005 mm. with some areas of coarser grain ranging into quartz mosaics with crystals as much as 0.6 mm. in size. The coarser material appears to line cavities. A small amount of chalcedony is present.

Staendebach member

Dolomitic facies

12. Basal dolomite and chert, Cherokee Creek section.

The dolomite has a grain size of about 0.3 mm. and is uniformly cloudy except for a few grains in contact with chert which are clear. The chert appears to be a breccia in which a few fragments are composed of beautifully banded brown chalcedony oöids and many angular to rounded pieces of chert mostly less than 1 mm. in size. The chert fragments have a grain size of about 0.002 mm. and are surrounded by chert having a grain size up to about 0.05 mm. The remaining interstices are mostly filled by an almost opaque chalcedony grading inward where the space is large to light brown chalcedony. A few of the interstices are filled with calcite and dolomite.

14. Lower dolomite, 4.5 miles north of Cherokee, TF-51.

The dolomite averages about 0.8 mm. with some crystals as much as 2 mm. in size. Large calcite crystals are common, with one being present which is nearly a centimeter long.

15. Lower chert, 4.5 miles north of Cherokee, TF-51.

The chert is a pellet chert with the pellets averaging from about 0.1 to 0.15 mm. in size. The chert grains in the pellets average about 0.003 mm. and in the surrounding network about 0.04 mm. in size. A few dolomolds are present which average about 0.2 mm. in size.

16. Lower chert, 4.5 miles north of Cherokee, TF-51.

Dolomolds averaging about 0.25 mm. in size are very abundant. Some of the dolomolds are filled with a clay-like mineral. The chert is made up of areas having a grain size of about 0.005 mm. surrounded by an irregular network of 0.05 mm. sized material which at some intersections and bordering some cavities merges into quartz mosaics having grains up to 0.5 mm. in size.

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[15]Symbols used: // = section cut parallel to bedding; / = section cut oblique to bedding; R = random orientation of section; all other sections are cut perpendicular to bedding.

[16]All distances from Cherokee are given from benchmark 1523, at the northwest corner of the schoolhouse.

17. Middle chert, 6.5 miles north of Cherokee.

In part a pellet chert and in part a structureless light brown chert, the grains of which average about 0.002 mm. in size and a few irregular linear bands in which the grains average about 0.02 mm. in size. The chert has the appearance of having been fractured followed by the introduction of chalcedony which in a few places also seems to be fractured. The elongated areas of chalcedony mostly have quartz mosaic centers with crystals up to 0.6 mm. in size.

18. Middle chert, 6.5 miles north of Cherokee.

A pellet chert in which the pellets average about 0.2 mm. in size and are made up of particles about 0.01 mm. in size surrounded by a network of somewhat coarser particles. A small amount of chalcedony is situated mostly between pellets. Dolomite rhombs are common averaging 0.4 mm. in size, and the outlines of pellets are very distinct within the rhombs as if the dolomite had first replaced calcite then been surrounded by chert.

19. Lower dolomite, north of Buffalo Creek.

The dolomite rhombs average about 0.2 mm. in size and are somewhat cloudy.

Calcitic facies

20. Upper chert, Cherokee Creek section.

Uniform textured chert with extremely small grain size averaging less than 0.001 mm. with only a few areas of larger grain size. A few 0.5 mm. dolomolds are present. Along one edge a crust of quartz with needles 2 mm. long preserves by attractive brown outlines ghosts of former growth stages.

21. Lowest limestone, R, 9.5 miles south of San Saba,[17] B–52.

This section is made up predominantly of limestone having a grain size of about 0.01 mm. and contains considerable dolomite in crystals up to 2 mm. or more in size. Calcite inclusions within the dolomite are common.

22. Chert from lowest limestone, /, 9.5 miles south of San Saba.

The chert is composed of pellets and mostly brown oöids in which the various layers are made up of different size grains, alternating between 0.001 to 0.005 mm. and 0.05 mm. sized grains. Some quartz mosaics up to 0.1 mm. in grain size are present.

23. Chert from lower limestone, /, Cherokee Creek section.

The chert is oölitic with very light brown oöids averaging about 0.5 mm. in diameter. The chert is mostly 0.01 mm. grained with some thin bands and oöid-centers made up of 0.003 mm. sized particles. A few oöids have very fine grained calcite in the middle. Quartz mosaics with grains up to 0.1 mm. in size and chalcedony are common between oöids.

24. Chert, above A bed in Cherokee Creek section.

The chert grains vary between about 0.005 and 0.02 mm. in size and are fairly uniformly distributed, and areas of chalcedony are common with many surrounding mosaics of quartz containing crystals up to 0.6 mm. in size. Part of the chert is brown stained and the rest is gray.

25. Limestone, R, Cherokee Creek section.

Predominantly limestone of 0.01 mm. or less grain size, with a few rhombs of dolomite averaging about 0.3 mm. in size.

26. Dolomite, Cherokee Creek section.

The dolomite crystals average about 0.5 mm. in size and are only slighty cloudy. A few crystals of calcite are present.

27. Chert, R, Cherokee Creek section, TF–49.

The chert forms a very closely spaced network pattern in which the polygons are cloudy and of about 0.005 mm. grain size, and the meshes are clear and slightly coarser grained. Some quartz mosaics with grains up to 0.06 mm. in size are present.

28. *Rhabdoporella* chert, R, 8 miles south of San Saba, TF–130.

The algae cylinders are up to 14 mm. long and about 1.5 mm. in diameter. The borders of the algae are sharp with either porosity or a quartz mosaic with grains up to 0.2 mm. in size between them. Only at two places is there suggestion of wall structure; some of the algae are made up of pellet-like bodies 0.1 mm. in size composed of chert particles about 0.002 mm. in size surrounded by slightly coarser particles. Considerable highly birefringent material is included in the chert.

70. True dolocastic chert, R, 9.5 miles south of San Saba, B–52.

The rhombic areas in this section are up to 1.5 mm. in size and are made up of mosaic quartz and some areas finely enough granular to be chert. The rest of the section is of rather coarse grained chert and some chalcedony.

70a. True dolocastic chert, R, 9.5 miles south of San Saba, B–52.

Same except chert seems to be a little more dominant within the rhombs.

Gorman formation

Dolomitic facies

30. Basal chert, Cherokee Creek section, TF–61.

Quartz predominates and forms mosaics having grains up to a millimeter in size in which various growth stages are marked by faint light brown lines. A portion of the section is very fine grained chert which contains dolomite rhombs averaging about 0.4 mm. in size.

31. Lower chert, R, section through one side of a finger stromatolite, Cherokee Creek section, TF–61.

The chert is in extremely minute grains 0.001 mm. or less in size and appears to contain detrital grains up to 0.02 mm. in size. A few dolomolds are about 0.07 mm. in size and without the microscope colored elliptical bands can be seen.

[17]All distances from San Saba given from intersection of U.S. highway 190 and State highway 16, at the center of town.

32. Lower chert, R, Cherokee Creek section, vicinity of TF–61.

The chert is in part composed of pellets which vary considerably in size. One elliptical pellet 7 mm. in length is composed of 0.06 mm. sized pellets. Much of the section is of fairly uniform 0.005 mm. sized chert grains and between some of the pellets the chert grains average about 0.02 mm. in size. Dolomolds are rather uniformly distributed and are about 0.2 mm. in size.

33. Lower microgranular dolomite, R, Cherokee Creek section, vicinity of TF–61.

Areas of 0.02 mm. and others of 0.1 mm. dolomite are present between which the boundaries are irregular. Two small areas composed of individual calcite crystals are present.

34. Lower microgranular dolomite, R, Cherokee Creek section, vicinity of TF–61.

The grain size appears to average about 0.06 mm.

35. Lower microgranular dolomite, R, Cherokee Creek section, vicinity of TF–61.

The grain size appears to average about 0.06 mm.

36. Chert float in lower part, R, Cherokee Creek section.

Chert with 10 mm. sized areas, circular to colliform, the centers of which are made up of 0.02 to 0.06 mm. sized grains, mostly surrounded by quartz in mosaics with grains up to 0.6 mm. in size. The centers of some of the quartz areas are composed of chalcedony. The remainder of the area between circular masses is composed of 0.01 to 0.02 mm. grained chert.

37. Oölitic chert, near bed D, Cherokee Creek section.

The oöids average about 0.6 mm. in size and the centers are mostly composed of chert with grains about 0.003 mm. in size followed by radial quartz nearing chalcedony in appearance. A few oöids have centers of chalcedony and several centers are sand grains up to 0.3 mm. in size. Most of the sand grains are secondarily enlarged.

38. Sand in bed D, Cherokee Creek section.

The sand is poorly sorted ranging up to 0.9 mm. in size, is well rounded, and is composed predominantly of quartz with some microcline, plagioclase, and chert. Clear dolomite rhombs have formed between the sand grains and excluded an interstitial brown isotropic material. An occasional microcline grain shows secondary enlargement with the added material being without twinning.

Calcitic facies

39. *Archaeoscyphia* from Gorman formation, vertical tangential section, Cherokee Creek section, TF–99.

In thin section there is very little indication of the typical *Archaeoscyphia* structure and that which is visible is more apparent between crossed nicols where cross sections of some of the spicular columns and an occasional cross spicule between columns is seen. The spicules are clear and made up of chert mosaics of about 0.02 mm. grain size and are surrounded by light brown chert having a grain size of about 0.005 mm. In the central cavity of the sponge the chert is very fine grained and contains slightly curved spicules and fragments of spicules. In a portion of the section small areas of chalcedony are commonly interspersed with chert of variable grain size. A few calcite veinlets cut the chert and some of the brown chert and calcite veinlets are cut by veinlets of gray chert.

40. *Archaeoscyphia* from Gorman formation, cross section, Cherokee Creek section, TF–99.

Very similar to section 39 except that more spicular structure is present and some of the spicules seem to be predominantly calcite.

41. Limestone, bed F, Cherokee Creek section.

The grain size of the calcite averages about 0.01 mm. A few sand grains up to about 0.1 mm. in size are present.

42. Sand, bed F, Cherokee Creek section.

Well rounded sand grains range up to 0.6 mm. in size composed of quartz with some microcline and chert, intermixed with a great number of chert oöids up to 0.9 mm. in size. A thin film of chalcedony encloses the sand grains and oöids, and the remainder of the interstices are filled with calcite.

43. Cherty pellet limestone, /, 800 feet in Cherokee Creek section.

The pellets are rather irregular in shape and are cloudy. They are surrounded at least in part by a coarse chert or quartz mosaic in which the grains are 0.05 mm. or more in size.

44. Dolomitic limestone high in Gorman formation, Cherokee area, TF–85.

This section is an intimate intermixture of calcite and dolomite in which the grain size of both constituents averages about 0.08 mm.

45. Fine grained dolomite high in Gorman formation, R, Cherokee area, TF–85.

The dolomite rhombs average about 0.25 mm. in size. A small amount of calcite is present, and in some areas interstitial chert is abundant.

46. Limestone high in Gorman formation, Cherokee area, TF–85.

The grain size of the calcite is about 0.005 mm. A few dolomite rhombs present average about 0.5 mm. in size.

46a. Limestone high in Gorman formation, Cherokee area, TF–85.

The calcite averages about 0.005 mm. in grain size, with some areas of coarse grained calcite with crystals up to 0.5 mm. in size. The limestone is made up of numerous irregularly shaped pellet-like bodies.

47. Chert high in Gorman formation, Cherokee area, TF–85.

The chert is banded with irregular bands of various textures and colors of chert, chalcedony, and quartz. The grain size of the chert ranges from about 0.003 to 0.02 mm. and of the quartz up to about 0.3 mm.

48. Pellet chert, Cherokee area, TF–85.

The pellets average about 0.1 mm. in size and are composed of a very cloudy hazy aggregate of material which seems to have a higher birefringence than chert and may be a mixture of chert and calcite. Between the closely spaced

pellets, chert up to 0.02 mm. grain size and some calcite are present. The chert is layered, and a few somewhat irregular bands of uniformly textured, very fine grained chert are present.

Honeycut formation

49. Basal sandy chert, R, Cherokee area, east of Rock Waterhole.

A few grains of sand up to 0.4 mm. in size are present and many oöids, some of which are as much as 2 mm. in size. The oöids are composed of about 0.005 mm. sized chert grains, and the chert surrounding the oöids is near 0.04 mm. in size. A small amount of chalcedony is present in interstices between oöids.

50. Basal arenaceous limestone, R, Cherokee area, east of Rock Waterhole.

The calcite grain size averages about 0.005 mm. or less. Sand grains ranging up to 1 mm. in size are abundant and are composed almost entirely of quartz; only a few are chert.

51. Basal chert, R, 300 feet south of Cherokee Creek section.

The chert contains abundant sand grains up to 0.7 mm. in size which are well rounded and composed of quartz and some microcline. Oöids up to about 1 mm. in size are abundant and are composed of chert mostly of 0.003 to 0.01 mm. grain size, surrounded by chert of coarser grain and by some chalcedony. Chalcedony is present as fair sized areas and seems to compose some oöids. Some oöids are somewhat calcareous.

52. Sand in dolomitic limestone, 1022 feet in Cherokee Creek section.

The dolomite rhombs average about 0.2 mm. in size and are interspersed with areas of calcite. Sand grains predominantly of quartz are common, some of them being as much as 0.6 mm. in size.

53. Dolomite in limestone, 1045 feet in Cherokee Creek section.

The dolomite rhombs average about 0.3 mm. in size and are in a network surrounding large areas of 0.002 mm. grained calcite.

54. Chert, R, 1046.5 feet in Cherokee Creek section.

This section appears to be chiefly composed of calcitic pellets and pellet fragments enveloped partially by a chert or quartz mosaic in which the grains average about 0.1 mm. in size. A few fragments of fossils are present.

55. Dolomite in limestone, 1045 feet in Cherokee Creek section.

Irregular streaks of 0.3 mm. dolomite and somewhat larger rhombs of dolomite scattered through calcite make up about 10 per cent of slide. The calcite grain size is about 0.003 mm.

56. Chert, R, 38 feet below *Archaeoscyphia* bed on Kirk ranch.

A mixture of chert composed of about 0.003 mm. sized grains and calcite of about 0.01 mm. sized grains varying from almost pure chert to possibly a 50-50 mixture. A faint banding is perceptible when section is viewed as a whole. A few rhombs 0.15 mm. in size composed of a mosaic of calcite crystals are present. This suggests that dolomite crystals were removed and that calcite then filled the molds.

57. Chert, just below *Archaeoscyphia* bed, Cherokee Creek section, TF–91.

The chert is composed of layers of different grain size ranging between about 0.003 and 0.02 mm. Some calcite is sprinkled through some layers.

58. Chert, 1085 feet in Cherokee Creek section. section.

Essentially the same as section 57 except grain size variation appears to be less.

59. Limestone from the *Archaeoscyphia* bed, 1125 feet in Cherokee Creek section.

Calcite having an average grain size of about 0.001 to 0.002 mm. predominates with only a few areas of coarser grain being present.

60. Microgranular dolomite, R, 1124 feet in Cherokee section.

The dolomite averages about 0.05 mm. in grain size. A vein of calcite cuts the rock.

61. Dolomitic limestone, just below the *Archaeoscyphia* bed on Kirk ranch.

Dolomite rhombs up to 0.6 mm. in size are scattered through areas of about 0.005 mm. grain sized calcite.

62. Quartz rosettes in microgranular dolomite, //, just beneath *Archaeoscyphia* bed on Chappel-San Saba road.

One rosette is 4 by 8 mm. and a portion of another is about 6 mm. in diameter. The center of each rosette is filled by a large crystal of calcite, and the rosettes are surrounded by dolomite having a grain size averaging 0.05 mm. In a few places dolomite has invaded the centers of the rosettes. The rosette is composed of a quartz mosaic in which most of the grains are radially elongated. Shadowy outlines of inclusions in the quartz show growth stages of the rosettes.

63. Cannonball chert, R, *Archaeoscyphia* bed in southeastern Cherokee area.

The section is an intimate intermixture of pelleted chert and limestone in which some pellets are predominantly chert and others are predominantly limestone. The grain size of the chert is about 0.001 mm., and fossil fragments are common. The majority of the pellets average about 0.15 mm. in size.

64. Cannonball chert, R, *Archaeoscyphia* bed in southeastern Cherokee area.

About the same as section 63 except that many large pellets 3 mm. in size are made up of smaller pellets.

65. Spiculiferous chert, R, *Archaeoscyphia* bed, Cherokee area, TF–17.

A slightly curved spicule is present. The section is mostly an intermixture of irregular shaped areas of brown and gray chert having a variable grain size between about 0.005 and 0.02 mm. Some chalcedony and a few quartz mosaics with grains up to 0.2 mm. in size are present. Some zig-zag and branching fractures are filled with gray chert.

66. Top limestone, R, 1127 feet in Cherokee Creek section.

The calcite grains average about 0.005 mm. in size. A few dolomite rhombs are present, and fossil fragments are numerous.

67. *Archaeoscyphia,* longitudinal section, Cherokee area, State highway 16, TF–17.

The structure is readily visible with the eye or low magnification. Spicules are of light gray chert in part associated with a small amount of chalcedony. The interspicular area is filled with brown chert. The central cavity of the sponge contains chert in which there are many fossil fragments. The interspicular chert seems to range between about 0.005 and 0.02 mm. in grain size, whereas the spicules are coarser grained.

68. *Archaeoscyphia,* cross section, Cherokee area, State highway 16, TF–17.

Similar to section 67 except that considerable calcite is associated with the spicular portion of the sponge, and the spicular pattern is different.

PENNSYLVANIAN

Marble Falls limestone

69. Chert near base, R, Cherokee Creek section.

The section is crowded with microfossils. The chert grain size ranges between about 0.01 and 0.04 mm.

DESCRIPTION OF THIN SECTIONS FROM THE JOHNSON CITY AREA

CAMBRIAN

Wilberns formation

Point Peak shale member

1. Limestone ..... 4–15 PRU[18]

Calcite predominates, some of which is present as fossil fragments. The calcite crystals average about 0.1 to 0.2 mm. and range up to 1 mm. in size. No dolomite was recognized but other chips taken from this interval are somewhat dolomitic. Angular grains of quartz, microline, plagioclase, and biotite ranging between 0.02 and 0.08 mm. in size constitute about 10 per cent of the section. Limonite grains probably pseudomorphs after pyrite average 0.05 mm. in size. Glauconite grains averaging about 0.1 mm. range up to 0.4 mm. in size and are angular to subrounded in shape. Some 0.25 mm. spherical and some irregularly shaped areas of a clear light brown isotropic substance are present having an index of refraction slightly lower than that of Canada balsam and above 1.49. Sponge spicules are present.

Pedernales dolomite member

2. Dolomite 15–25

The dolomite crystals average 0.4 mm. and range up to 0.6 mm. in size. The impurities show a tendency to be concentrated between grains with some remaining in the central part of the dolomite crystals. The borders of the crystals are for the most part more clear than the centers. The excluded material is light brown, isotropic, has an index of refraction near that of Canada balsam, and by reflected light is yellowish to reddish brown. Pyrite crystals up to 0.3 mm. in size are partly altered to limonite. A few grains of glauconite and a few of quartz and feldspar average about 0.1 mm. in size.

3. Dolomite 25–38

The dolomite crystals average 0.06 mm. and range between about 0.02 and 0.09 mm. in size. Impurities located mostly at grain boundaries are opaque to transmitted light and are chalky white by reflected light. A few pyrite crystals are present which average 0.05 mm. in size.

4. Dolomite 38–53

The dolomite crystals average about 0.1 mm. and range up to 0.6 mm. in size and are components of oöids which range up to 1.1 mm. in size. The dolomite has an orientation (analagous to that of spherulites in igneous rocks) such that an indistinct extinction cross is produced in the oöids between cross-nicols. Cloudy, brownish gray limestone in areas averaging 0.2 to 1.0 mm. in size are situated between the oöids and some crystals as much as 0.01 mm. in size are present in it. Quartz particles are scarce and range up to 0.06 mm. in size.

5. Chert 101

Dolomite crystals make up about 10 to 20 per cent of the section and are scattered throughout as 0.2 mm. sized rhombs and irregular shaped pieces. The chert is very light brown, is composed of quartz crystals ranging from about 0.002 to 0.15 mm. in size, and is clouded by yellowish to reddish particles of limonite. Quartz mosaics are present with crystals up to 0.2 mm. in size.

6. Dolomite 137

The dolomite is vuggy and is made up of crystals averaging 0.6 mm. and ranging up to 1.5 mm. in size. Some caliche has been deposited on the walls of the vugs. Impurities as dust sized particles are scattered rather uniformly throughout, some of which are highly birefringent, suggesting that they may be calcite.

7. Chert 173

Dolomite crystals make up about 5 per cent of the section and are present as rhombs and clusters of rhombs, the individual crystals of which are about 0.15 to 0.25 mm. in size. The chert is very light brown and is in grains ranging from about 0.006 to 0.012 mm. in size. Dust sized particles included in the chert are highly birefringent. Quartz mosaics with crystals up to 0.2 mm. in size line cracks and vugs in the chert.

8. Dolomite 151–195

The dolomite crystals average about 0.5 mm. and range up to 1.0 mm. in size. Dust sized impurities are rather uniformly distributed and are in part highly birefringent.

9. Dolomite 205–210

[18]PRU = Pedernales River section (upstream segment). Footage is above base of section.

The dolomite crystals average 0.075 mm. and range up to 0.25 mm. in size and groups of different sizes are rather irregularly distributed. The section contains pebbles or pellets up to 8 mm. long composed of cloudy limestone containing dolomite crystals of smaller size than in the surrounding matrix. Some of these objects are composed of dolomite, one contains a pellet-like object 0.5 mm. long, and some contain detrital grains, probably quartz, up to about 0.075 mm. in size. Much of the impurities are along grain boundaries and by reflected light are pasty white and in part are stained yellowish to reddish brown. Highly birefringent inclusions are common in the dolomite.

ORDOVICIAN

Tanyard formation

Threadgill member

10. Dolomite 215

The dolomite crystals average 0.6 mm. and range up to 2.0 mm. in size. The impurities are distributed as clouds throughout the dolomite but vary widely in amount from area to area, and some crystals have the impurities zonally distributed. A rather rare interstitial material is brownish by transmitted light, light greenish gray by reflected light, birefringent, has an index of refraction higher than that of Canada balsam, and an interrupted extinction suggesting a somewhat fibrous habit.

11. Dolomite ..... 20–23TC[19]

The dolomite crystals average 0.75 mm. and range up to 2.5 mm. in size. Some mylonite zones cross the section. The impurities, some of which are highly birefringent, are concentrated in the central portion of the dolomite crystals and the borders of the crystals are clear. A small amount of interstitial material of the type described in section 10 is present.

12. Dolomite and limestone 20–23

The limestone is in areas one-half inch or more in size surrounded by a network of dolomite. The calcite areas are composed of pellets containing crystals 0.005 mm. or less in size surrounded by a network of clear calcite averaging 0.03 mm. and ranging up to 0.05 mm. or more in size. The dolomite crystals are up to 2 mm. in size and where in contact with the calcite areas are embayed by and form promontories into the calcite areas. The dolomite crystals contain a myriad of small calcite inclusions. Mylonite zones cross the section.

13. Limestone 20–23

The section is composed of irregular clouded areas averaging 0.2 mm. in size composed of grains 0.005 mm. or less in size surrounded by a network of calcite ranging mostly from 0.03 to 0.1 mm. in size with an occasional crystal as much as 0.7 mm. in size. With the hand lens the section appears to be a pellet limestone. A 0.2 mm. vein crosses the section and is composed of 0.1 mm. calcite crystals.

14. Chert 99–127

The chert is liberally sprinkled with small calcite particles. One calcite vein crosses the section. The chert is composed of grains 0.01 mm. in size surrounded by a network of mosaic quartz averaging 0.05 mm. in size and ranging up to 0.15 mm. in size. Chalcedony is common.

15. Limestone 99–127

This section is of a pellet limestone similar to the one described under 13 except that the pellets average about 0.1 mm. in size.

Staendebach member

16. Dolomite 229–230

The dolomite crystals average 0.25 mm. in size, have clear borders and cloudy centers. Some of the particles causing the cloudiness are highly birefringent. A small amount of interstitial chert is situated among the dolomite rhombs.

17. Chert ..... 106 PRD[20]

The section is composed of pellets up to 0.6 by 1.0 mm. in size and spheres 0.2 to 0.7 mm. in diameter of cloudy brown chert averaging 0.01 mm. in grain size, surrounded by a mosaic of clear quartz averaging 0.04 mm. in size and some dolomite. Some of the larger pellets contain small pellets, and some of the pellets contain approximately 50 per cent of highly birefringent material, probably calcite, as small inclusions. The dolomite rhombs in part penetrate pellets with the ghost outline of the pellet being visible across the rhombs.

18. Dolomite 106

The dolomite crystals average 0.3 mm. in size. Cloudy pellet-like areas, some of which are situated astride grain boundaries, suggest that the dolomite formed from a pellet limestone. Some of the particles forming the cloudy areas are highly birefringent.

19. Dolomite 150–165

The dolomite crystals average 0.3 mm. in size. Inclusions tend to be concentrated near the centers of rhombs, but in some rhombs they are zonally arranged. Some of the particles are highly birefringent. Mylonite zones cross the section.

20. Chert 165–211

The chert is composed mostly of particles 0.005 mm. or less in size, with quartz mosaics up to 0.06 mm. in size surrounding vugs and as isolated areas. Inclusions pasty white by reflected light are common. A few rhombic holes in the section are dolomolds.

21. Dolomite 165–211

The dolomite crystals average 0.2 mm. in size. Impurities are pasty white by reflected light and are arranged in a microdendritic manner in the dolomite. Highly birefringent particles are numerous. The central part of the dolomite rhombs are light brown and show absorption.

[19]TC = Towhead Creek section.

[20]PRD = Pedernales River section (downstream segment).

22. Chert and dolomite 165–211

The chert is composed of 0.15 mm., irregular, cloudy, gray areas, the grain size of which averages 0.005 mm. or less, surrounded by a mosaic of colorless quartz up to 0.1 mm. in size. Dolomite is present as rhombs up to 0.7 mm. in size and contains some highly birefringent particles. With the hand lens the cloudy areas have the appearance of pellets.

23. Dolomite 227–259

The dolomite crystals average 0.6 mm. in size. The dolomite is uniformly cloudy, and highly birefringent particles are scarce.

24. Dolomite 249–254

The dolomite crystals average 0.075 mm. in size and contain small inclusions which are in part highly birefringent. Interstitial material is pasty white by reflected light and opaque to transmitted light. A sufficient amount of this material is present to yield a dolomoldic residue.

25. Dolomite 259–264

The dolomite crystals average 0.35 mm. in size. Inclusions are fairly evenly distributed in some rhombs and in others are well zoned. The inclusions are in part highly birefringent.

26. Dolomite 321–326

The dolomite crystals average 0.75 mm. in size. Inclusions show some tendency toward being zoned but are mostly fairly evenly distributed throughout the rhombs except around vugs where the dolomite is clear. Very little of the cloudy material is highly birefringent.

27. Limestone 346–351

The limestone is composed of cloudy pellet-like bodies up to 0.4 mm. in size composed of crystals 0.005 mm. or less in size, surrounded by a network of clear calcite composed of crystals mostly under 0.01 mm. in size but with some as much as 0.6 mm. in size. A few dolomite rhombs crowded with calcite crystals are present which range up to 1.5 mm. in size. Stylolites are outlined by a brown material, which by reflected light is mostly pasty white with a few reddish brown spots. The stylolites swing around dolomite rhombs as if they were relatively insoluble.

28. Limestone and dolomite ..... 122–126 HBU[21]

The calcite is composed of grains mostly ranging between 0.003 and 0.005 mm. in size and a few which are larger. Dolomite rhombs range up to 1.5 mm. in size and are studded with calcite particles. Chert as rounded quartz mosaics and as fibrous chalcedony is rare. Fossil fragments are common.

Gorman formation

Dolomitic facies

29. Dolomite 141–146

This section is a breccia composed of fragments having a grain size ranging between 0.04 and 0.06 mm. in a matrix of cloudy very irregular dolomite ranging up to 0.7 mm. in size. Some of the fine grained fragments contain angular quartz (sand) grains up to 0.13 mm. in size. A few 0.3 mm. sized pieces of chert are present.

30. Dolomite 166–171

The dolomite crystals average about 0.6 mm. in size and range from uniformly cloudy in some portions of the section to dolomite rhombs with cloudy centers in other portions of the section. The cloudiness is caused mostly by highly birefringent inclusions. One bleached streak 0.05 mm. wide crosses the section going through rhombs without interrupting their optical properties. This suggested that the bleaching occurred before the formation of the dolomite rhombs.

31. Dolomite 276–283

The dolomite crystals average 0.1 mm. in size with some zones averaging about 0.05 mm. in size. Interstitial material present is mostly opaque to transmitted light and pasty white to orange by reflected light.

Calcitic facies

32. Limestone 418–423

The section is composed of calcite mostly as grains 0.003 mm. or less in size and clear bedding streaks and a few crosscutting streaks composed of 0.02 to 0.1 mm. sized crystals. Some network structure is visible and with the hand lens the rock is seen to be thin bedded with some beds composed of small pellets. Stylolites are abundant, some of which are outlined, using reflected light, by a thin zone of pasty white material and others by a thicker zone of reddish material.

33. Sandy dolomite 473–478

The dolomite crystals average 0.1 mm. in size. Annular cloudy areas are located mostly in the central parts of rhombs but occasionally transgress grain boundaries. The annular rings are very dark, the centers medium cloudy, and the outside areas are less cloudy to clear. With the hand lens the section appears to be oölitic. Detrital grains range up to 0.1 mm. in size and are mostly quartz, with some microcline and plagioclase.

34. Dolomite 488–493

The dolomite crystals average 0.15 mm. in diameter. Small highly birefringent inclusions cause a slight cloudiness in the dolomite. Very faintly crystalline, very light brown, interstitial chert is common.

35. Limestone 528–533

The limestone is composed of 0.1 mm. sized cloudy pellets having a grain size of about 0.002 mm. surrounded by a network of 0.01 mm. calcite. A few vein-like mosaics with crystals up to 0.6 mm. long are present. Stylolites are outlined by pasty white to yellowish material in reflected light.

Honeycut formation

36. Sandy dolomite 636–636.5

The dolomite crystals average 0.1 mm. in size and vary from clear to cloudy. The sand averages about 0.15 mm. in size and is angular to well rounded with some grains ranging up to 0.5 mm. in size. One grain of plagioclase was

[21]Honeycut Bend section (upstream segment).

recognized and the rest of the material is quartz. A few small areas of chert are present.

37. Limestone ..... 725–730 RH[22]

The limestone is very thin bedded and rather uniformly about 0.005 mm. grained. Stylolites are common and are mostly confined to bedding planes with only short up and down loops. Material, light brown by transmitted light, has accumulated up to 0.1 mm. thick along the stylolites.

38. Limestone and dolomite 745–750

Dolomite rhombs are scarce and range up to 0.3 mm. in size. The calcite is in cloudy pellet-like to very irregular areas having a grain size of 0.002 mm., surrounded by a network of clear calcite averaging 0.05 mm. in grain size with some grains as much as 0.5 mm. or more in size as irregular shaped areas and as portions of fossil fragments. Fossil fragments are numerous, stylolites are common, and small irregular areas of chert are present. Dolomite rhombs are in part dissolved along stylolites.

39. Dolomite 855–860

The dolomite crystals average 0.2 mm. in size, with two small areas in which the grain size is about 0.05 mm. Cloudiness varies from areas of uniformly clear dolomite to areas of uniformly cloudy dolomite with intermediate areas in which the borders of the dolomite are clear and the centers cloudy. The cloudiness seems to be largely caused by small highly birefringent inclusions. Some opaque interstitial material is present which is buff by reflected light. Bleached streaks up to 0.04 mm. in width are common.

40. Dolomite ..... 900–905 HBD[23]

The crystals of dolomite average 0.04 mm. in size. Cloudiness is scarce and that which is present seems to be caused mostly by highly birefringent inclusions.

41. Dolomite 945–950

The dolomite crystals average 0.08 mm. in size. The rock is very thinly bedded, the bedding being made visible by variation of cloudiness rather than by variation in grain size. Under the microscope these bands are indistinct with irregular layers of partly cloudy dolomite rhombs alternating with irregular layers of mostly cloudy dolomite rhombs A bleached streak crosses the bedding.

42. Dolomite 970–975

The dolomite crystals average 0.04 mm. in size in some areas and 0.08 mm. in size in others. The finer grained areas contain fossil fragments made up of coarser grained dolomite. The fine grained dolomite is somewhat more cloudy than the coarser grained dolomite. Much interstitial material present is pasty white by reflected light.

43. Limestone 1116–1121

A few 0.2 mm. sized dolomite rhombs are present containing much included calcite. The calcite is rather uniformly in about 0.004 mm. sized grains. Limonite particles 0.02 mm. in size are common, and one thin stylolite is present.

44. Dolomite 1146–1151

The dolomite crystals average about 0.1 mm. in size and are slightly cloudy mostly from included highly birefringent particles.

45. Limestone and dolomite 1176–1181

The calcite is uniform grained about 0.005 mm. in size and contains perfect rhombs of dolomite averaging 0.6 mm. in size. Cloudiness in the dolomite is mostly calcite in zones with the borders of the rhombs clear. Where groups of dolomite grains are in contact only the portion of the rhombs next to the calicite is clear.

46. Dolomite 1222–1225

The dolomite crystals average 0.2 mm. in size, and bedding is visible as zones of mostly cloudy dolomite alternating with zones of clear to cloudy centered dolomite. The cloudy areas are brownish in color and show absorption. Some interstitial material which is dark brown and cloudy may be chert.

47. Dolomite 1245–1250

The dolomite crystals average 0.13 mm. in size and are mostly cloudy with narrow clear borders. Only a small amount of the cloudiness is caused by highly birefringent particles.

48. Limestone 1252–1255

The limestone is rather uniformly 0.005 mm. grained. Some reddish buff limonite areas are present.

49. Chert 1265

The chert contains oöids averaging 0.4 mm. in diameter which have a concentric structure. The centers of some oöids are made up of birefringent particles 0.001 mm. in size and some layers of the oöids are quartz mosaics about 0.01 mm. in size. The particle size of the chert between oöids is about 0.005 mm. Light brown fibrous chalcedony is situated between some of the oöids. Synchronously extinguishing calcite areas as much as 2 mm. in size surround some oöids. Some oöids are composed of calcite.

50. Limestone 1280–1285

The section contains pellets and pebble-like masses up to 1.7 by 6 mm. in size composed of calcite having a grain size of about 0.005 mm. These objects are in a groundmass of calcite ranging in grain size from 0.01 to 1.7 mm. Stylolites are marked by a light brown isotropic material and are very irregular.

51. Limestone 1285–1290

This section contains in some areas 0.07 mm. sized pellets and in others faintly outlined pebble-like objects. The grain size of these objects averages 0.002 mm. or smaller, and they are situated in a groundmass having a crystal size near 0.01 mm. with an occasional isolated crystal being as much as 0.04 mm. in size. A few detrital grains of quartz measure up to 0.06 mm. in size. Stylolites are scarce and fossil fragments are present.

[22]RH = Rough Hollow section. Footage from base of Honeycut Bend section (upstream segment).

[23]Honeycut Bend section (downstream segment).

DEVONIAN

Stribling formation

52. Limestone 1295–1300

The limestone is composed of grains averaging 0.01 mm. or less in size liberally sprinkled with grains up to 0.02 mm. in size. The calcite is cloudy except for 0.02 mm. wide clear calcite streaks which are common. Fossil fragments are common but small.

53. Limestone 1300–1305

Limestone as in above section. One clear streak is terminated by a thin stylolite. Fossil fragments are rare.

MISSISSIPPIAN

Ives breccia

54. Limestone and chert 1305–1306.5

The limestone is composed of light brown calcite grains up to 2 mm. in size joined to other grains by irregular suture-like lines. Glauconite grains range up to 0.03 mm. in diameter and are in part replaced by calcite. Some brown isotropic areas 0.03 mm. in diameter are present, one of which is ovoid annular with a calcite crystal in the center. The chert is composed of about 0.003 mm. sized particles and contains rounded calcite areas up to about 0.2 mm. in size. Both the chert and the limestone contain small quartz grains up to about 0.02 mm. in size. The chert where in contact with calcite shows a feathery interpenetration zone up to 0.6 mm. wide, indicating replacement. To determine which is the replacing mineral, additional sections are needed.

PENNSYLVANIAN

Marble Falls limestone

Lower biohermal limestone member

55. Shale 1306.5–1308

Calcite is predominant with grains 0.006 to 0.03 mm. in size. Black, frayed to skeletal lignitic particles are common. Argillaceous material which is beige by reflected light is common between the calcite grains. Sponge spicules are present.

56. Limestone 1308–1315

The limestone is composed of a groundmass of calcite having a grain size of about 0.005 mm. in which are numerous Foraminifera, 3 mm. sized fragments of crinoidal columns, and other fossil fragments.

Spiculite member

57. Spiculite 1315–1320

This section is predominantly calcite 0.01 mm. in size containing very abundant sponge spicules many of which are replaced by calcite. The rest of the sponge spicules are of cryptocystalline silica. The section contains some material which appears to be lignitic and considerable interstitial material which may be clay.

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PLATE 17

View north 25 degrees west up Llano River from a hill south of White's Crossing, Bear Spring area, Mason County, Texas

White's Crossing is the low-water bridge in the middle ground. The wooded hill at the right is underlain by Carboniferous rocks, and the hills and bluffs beyond this are underlain by the Gorman formation. The original locality for Keokuk fossils in limestone at the base of the Barnett formation is at the right (east) side of the Crossing and just north of a fault. Study of Plate 5 will aid visualization of the geology in the area here pictured.

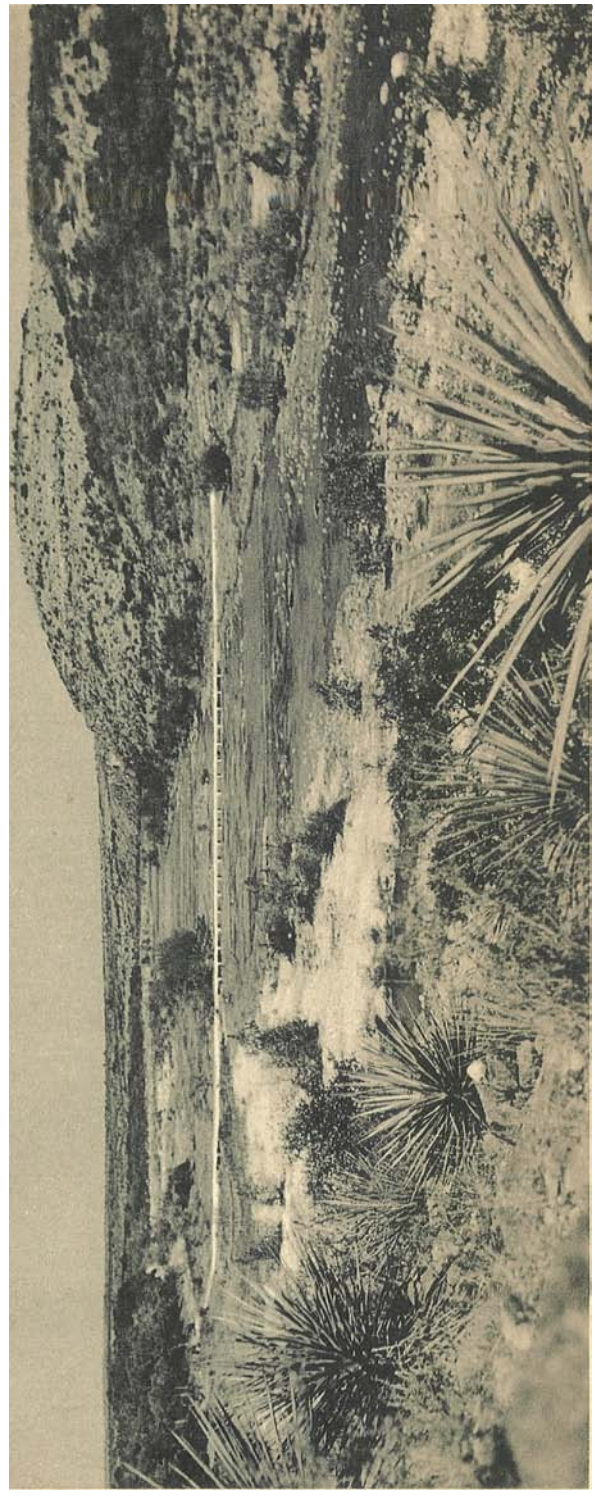

PLATE 18

Stromatolitic bioherm at the top of the Point Peak shale member of the Wilberns formation, Mason County, Texas

The bioherm pictured is about 50 feet thick and is one of a group of similar structures on the right (south) bank of Llano River opposite the mouth of Honey Creek and about 1 mile downstream from White's Crossing. The bioherm consists of massive sublithographic limestones. It is based on interbedded shale and limestone and overlain by granular limestone. It evidently functioned as a buttress during load-compression so that the beds beneath show compaction dips and the initial dips of those above and abutting the upper part of the bioherm have been accentuated by compaction by an amount comparable to the dips of the subjacent beds. The highest prominent shale break is marked with an X. The massive limestone bed, marked Y, through which the base of the bioherm protrudes passes below other bioherms observed east of here along the same bluff. The clustered objects under the bioherm and bed Y are the nests of cliff swallows. Figure A on Plate 19 is a more distant view of the same bioherm.

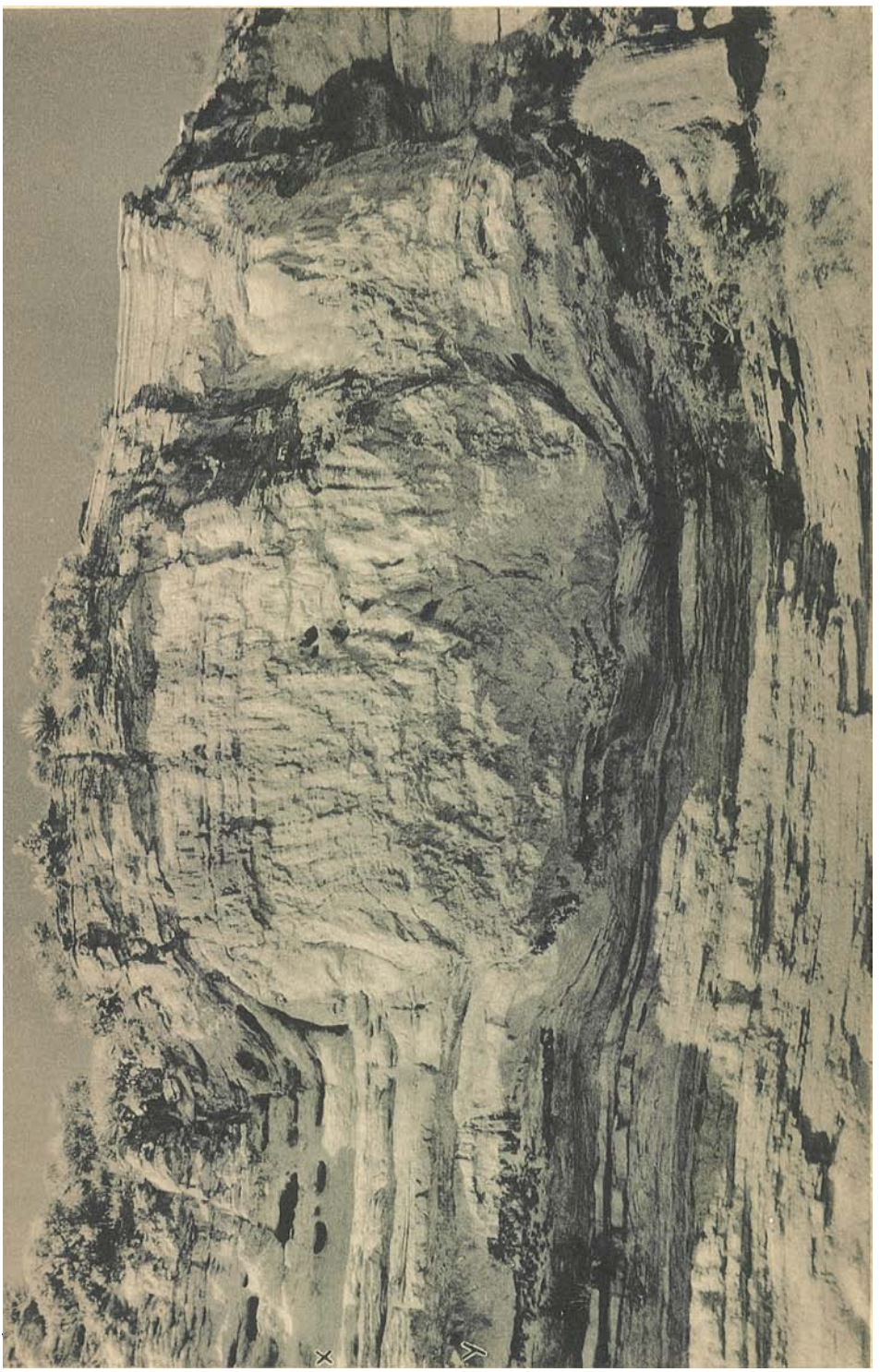

PLATE 19

Rocks of the Wilberns and Tanyard formations in Gillespie and Mason counties, Texas

FIGURE A. A stromatolitic bioherm at the top of the Point Peak shale member of the Wilberns formation, Mason County.

This figure is a more distant view of the same bioherm pictured on Plate 18, showing its larger relationships. The same intervals are marked X and Y in both photographs. Llano River washes the base of the bluff. The bioherm is about 50 feet thick.

FIGURE B. An exposure of the San Saba limestone member of the Wilberns formation along Threadgill Creek, Lange's Mill area, Gillespie County.

The bluff is about 60 feet high and shows limestones of the lower part of the member. It is just downstream from Lange's Mill on the left (northwest) bank of Threadgill Creek.

FIGURE C. Thinly bedded limestones of the Threadgill member of the Tanyard formation at the juncture of Threadgill and Mormon Creeks, Lange's Mill area, Gillespie County.

The figure (at x) is standing on a bed that contains silicified *Tetralobula* and *Finkelnburgia* and is about 50 feet above the base of the Tanyard formation. The view is southeast up Mormon Creek from the left (west) bank of Threadgill Creek. Compare this photograph with figure C of Plate 20, which shows essentially correlative limestones in the eastern part of the Llano region.

FIGURE D. The Cambrian-Ordovician contact in the Threadgill Creek section, Lange's Mill area, Gillespie County.

The contact is placed at the base of the heavy ledge at the man's head (at x) which is considered to mark the base of the Threadgill member of the Tanyard formation. That ledge contains the lowest *Ophileta* and *Lytospira* seen in this section, and *Plethometopus* occurs in abundance immediately below it. The rocks of the San Saba limestone member of the Wilberns formation below it contain abundant globular glauconite, and those above it are essentially nonglauconitic. Sedimentation appears to have been essentially continuous from Cambrian into Ordovician time at this place. This photograph should be compared with figures A and B of Plate 20, which show probably disconformable relationships at the same contact.

X
Y
A
X
C
B
X
D

PLATE 20

Rocks of the Tanyard and Wilberns formations in San Saba and Mason counties, Texas

FIGURE A. A probably disconformable contact between Cambrian and Ordovician rocks on Buffalo Creek, Cherokee area, San Saba County.

The locality pictured is on the right (west) bank of Buffalo Creek, about three-tenths of a mile downstream from Hog Cave Hole on the W. S. Porch ranch. Medium to coarse grained, vuggy, rough-weathering dolomite at the base of the Threadgill member of the Tanyard formation rests on the slightly truncated surface of fine to very fine grained, compact, smooth-weathering dolomite of the Pedernales dolomite member of the Wilberns formation. Some of the irregularity exhibited by this contact may be attributable to solution subsequent to formation of the rocks, but the irregularity is persistent and other evidence for disconformity is noted on page 194.

FIGURE B. A probably disconformable contact between Cambrian and Ordovician rocks on Buffalo Creek, Cherokee area, San Saba County.

A similar view to figure A taken a few hundred feet farther south. These photographs should be compared with figure D of Plate 19, which shows the Cambrian-Ordovician contact in an area where sedimentation appears to have been essentially continuous across the boundary.

FIGURE C. A quarry in limestones of the Threadgill member of the Tanyard formation in the Cherokee area, San Saba County.

The small quarry pictured is a short distance northeast of Flatrock Hole, on the north side of Buffalo Creek on the W. S. Porch ranch. The thickly bedded nature of some of the limestone is shown by comparison with the man standing in the pile of blocks near the center of the photograph. Compare this photograph with figure C on Plate 19, showing essentially correlative limestone in the western part of the Llano region.

FIGURE D. Trails and fossils on the surface of a limestone bed in the Threadgill member of the Tanyard formation, Bear Spring area, Mason County.

The bed pictured is 174 feet above the base of the Tanyard formation, on the right (south) bank of Llano River, in the Pete Hollow section. The trails show as discontinuous welts and were probably made by some buoyant benthonic organism that secreted an agglutinating substance as it progressed over the sea bottom, such as the specimens of *Lytospira gyrocera* (Roemer) shown in this figure (ends of hammer-head and handle) probably did in life. Bedding surfaces similarly marked are very common in the thinly bedded limestones of the Threadgill member of the Tanyard formation in the western part of the Llano uplift, and, probably because of their greater permeability, the trails and casts of the fossils are commonly selectively dolomitized.

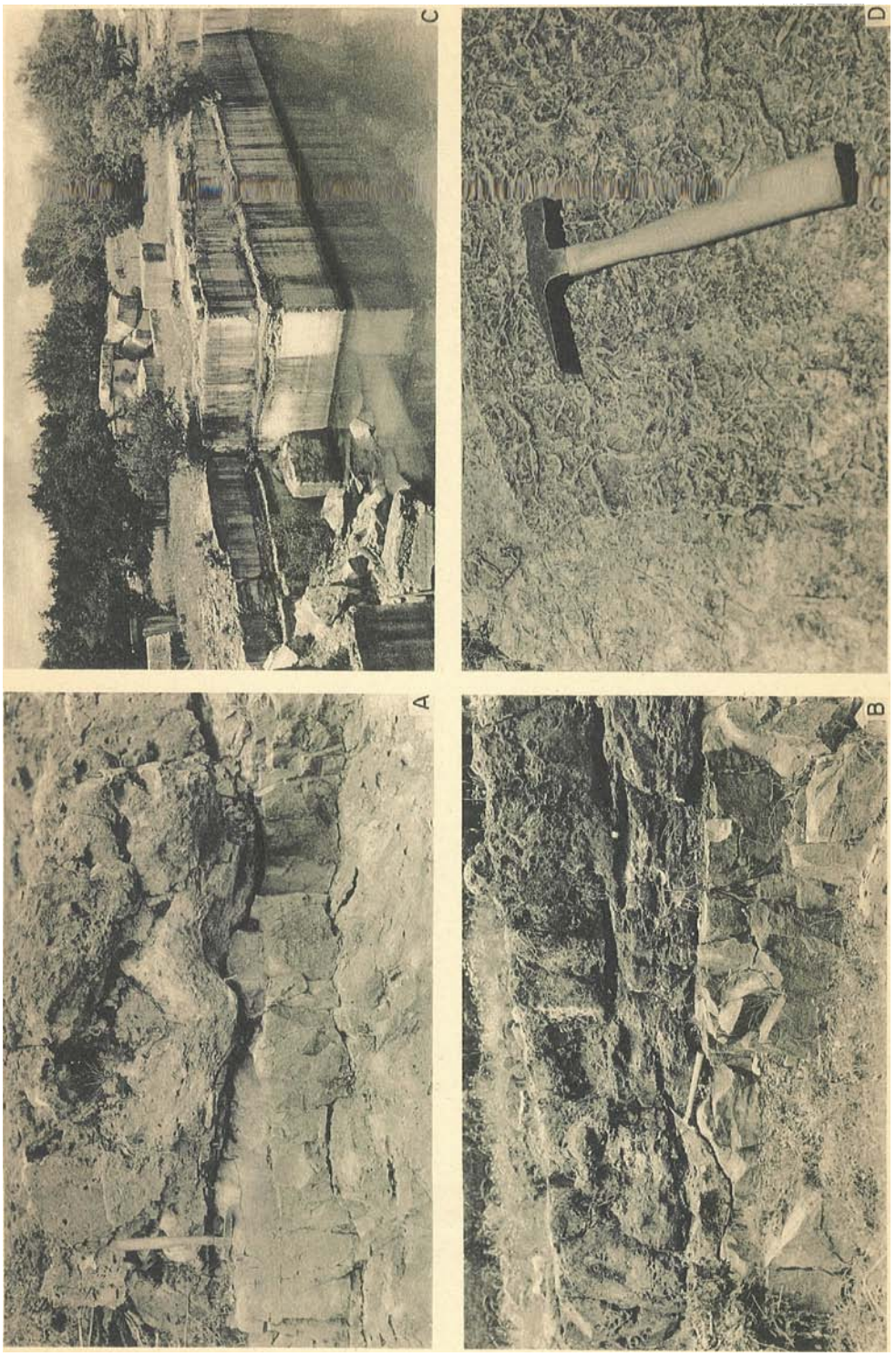
C
D
A
B

PLATE 21

Terrain and rocks of the Tanyard formation in San Saba and Burnet counties, Texas

FIGURE A. A panoramic view south 60 degrees west toward the Buffalo Hills from a hill about one-half mile north-northwest of Dee triangulation station, Cherokee area, San Saba County.

The bald hills in the foreground are those at the head of Red Ox Draw, and the similar hills in the distant center are the Buffalo Hills. Both are underlain by Tanyard rocks and indicate the characteristic topographic and vegetative expression of the dolomites of the Tanyard formation in areas of gentle dip.

FIGURE B. The Ellenburger Hills, southeastern San Saba County, viewed from the southwest.

The bald hills here pictured constitute the principal ridge of the Ellenburger Hills. The rocks dip gently to the left, and the photographer was standing on dolomites near the top of the Tanyard formation. The terrain is typical of the dolomites of the Tanyard in areas of gentle dip, and Tanyard fossils were collected at the top of the ridge at an elevation of about 1590 feet (TF–59).

FIGURE C. A chert mass in the Staendebach member of the Tanyard formation, Tanyard area, Burnet County, Texas.

The chert mass occupies the central part of the photograph and is weathered in relief. It is on the north side of a draw just north of the end of the Tanyard section. The mass is about 40 feet thick at the center; is about 60 feet wide in this view; is surrounded by dolomite; and is composed of massive, white-weathering, subchalcedonic to semiporcelaneous chert.

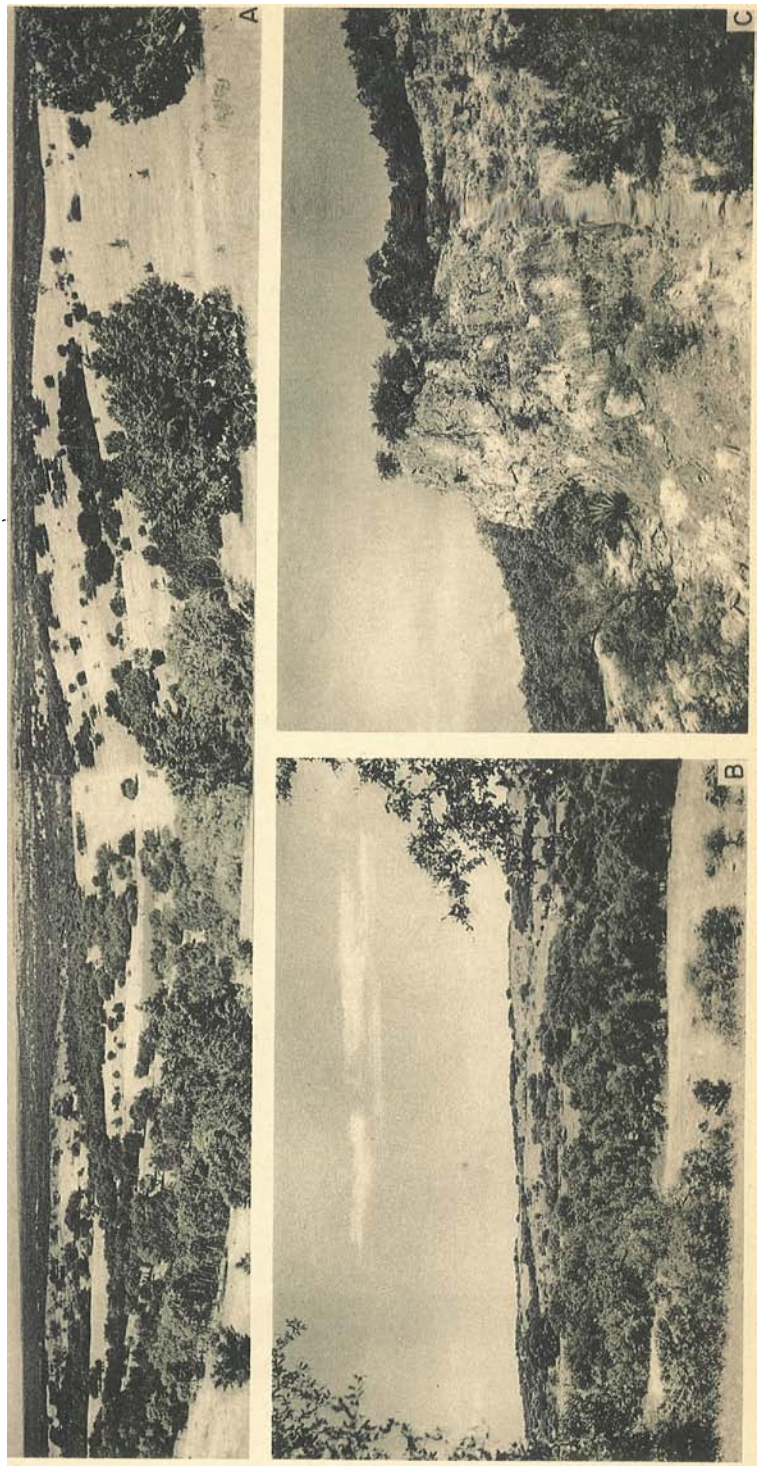
A
C
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PLATE 22

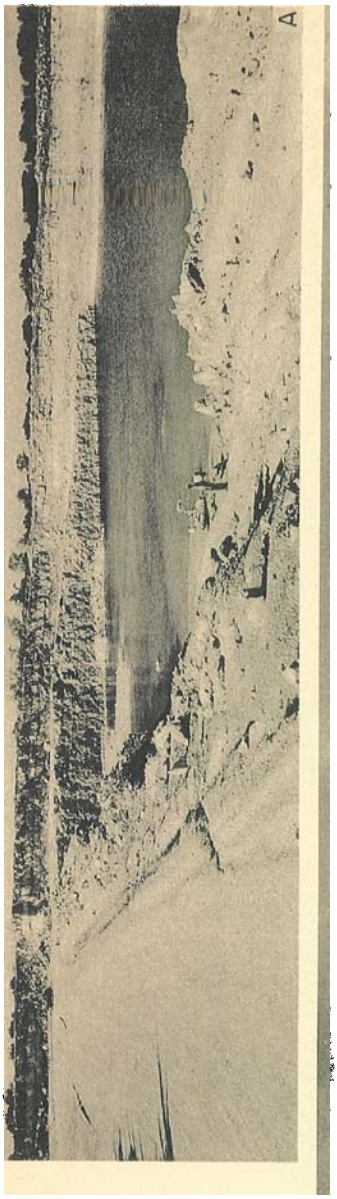
The aggregate quarry and plant of the Victoria Gravel Company, 6 miles south of Burnet, Burnet County, Texas

FIGURE A. A view northwest in the aggregate quarry.

Both quarry-benches are in cherty dolomites of the Staendebach member of the Tanyard formation. Figure F of Plate 23 shows a detail of the fresh aggregate rock at the rockfall by the lower wall in the center of the picture.

FIGURE B. The crushing and screening plant viewed from the west.

The crusher is at the southeastern corner of the aggregate quarry near where the view in figure A was taken. The quarry for magnesium ore, which is in chert-free dolomites at the top of the Threadgill member of the Tanyard formation, is situated a few hundred yards southwest of the point from which this picture was taken.


A

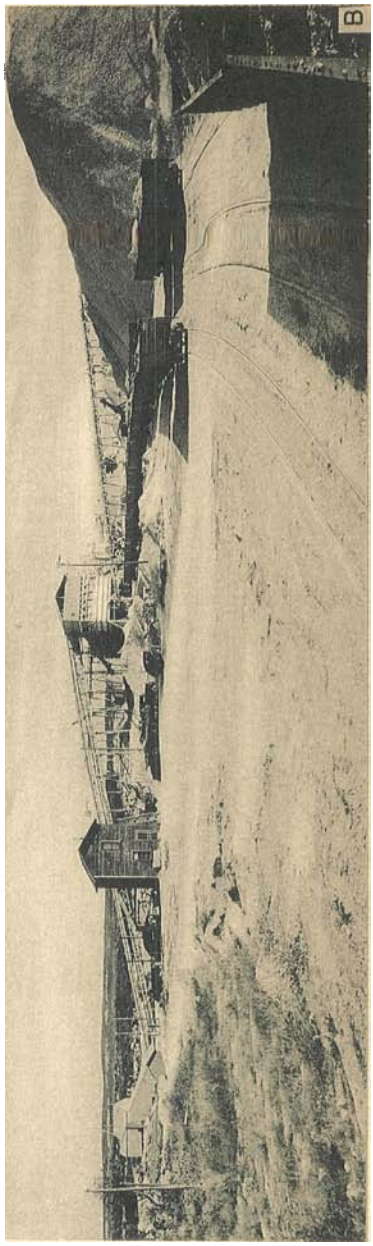

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PLATE 23

Types of chert in the Tanyard and Honeycut formations, San Saba and Burnet counties, Texas

FIGURES A–E, I. Chert of the Staendebach member of the Tanyard formation, Cherokee area, San Saba County.

(A) Ledges near the base of the member at the northeast end of Four-Mile Hill. Conspicuously drusy and dolomoldic incrustrations obscure the ledge rock and the eventual result of weathering consists of separate sponge-like, punky blocks that may contain a core of dolomite with much interstitial chert. Disintegration is at a more advanced stage in the distant ledges. Similar chert is not uncommon in the dolomitic facies of the Threadgill member of the Tanyard formation in the Cherokee area, but none is pictured.

(B) Residual chert near the base of the member at the northeast end of Four-Mile Hill (TF–51). Punky, sponge-like blocks of drusy and dolomoldic chert predominate, with scattered blocks of the white-weathering chalcedonic to porcelaneous chert more typical of the member. Fossils are commonly obtained from such punky cherts.

(C) White-weathering chert near the top of the dolomitic facies of the member east of State highway 16. Chalcedonic to porcelaneous chert, regardless of stratigraphic position, commonly weathers white and shiny, and such large masses as are here shown mark the Staendebach member of the Tanyard formation, and locally the Gorman formation, on the eastern side of the Llano uplift. On the western side such chert occurs typically near the Tanyard-Gorman contact, and more commonly above than below it.

(D) Vesicular, laminar chert weathering from sublithographic pellet limestone near the base of the calcitic facies of the member east of State highway 16 (B–52).

(E) Oölitic laminar chert near the top of the member six- to seven-tenths of a mile east of State highway 16 (TF–130). Bands of mostly oölitic chert or chertified pellet limestone are separated by layers of impressions of flat pebbles surrounded by the same material. Such chert characterizes the upper third of the Staendebach member through much of the north half of the Llano uplift. At the locality pictured it is associated with "*Rhabdoporella*"-cherts, consisting of the aggregated siliceous remains of countless dasycladacean algae.

(I) A chertified stromatolite in limestone of the member in a quarry east of State highway 16 on the H. C. Perry ranch.

FIGURE F. Chert of the Staendebach member of the Tanyard formation in the aggregate quarry of the Victoria Gravel Company, Burnet County. The thin layers and lenses of porcelaneous, white chert here pictured occur in very fine grained dolomite near the middle of the member. Figure A of Plate 22 shows the quarry in which this photograph was made.

FIGURES G, H. Chert of the Honeycut formation, Cherokee area, San Saba County.

(G) Chertified *Archaeoscyphia annulata* in sublithographic limestone of the *Ceratopea capuliformis* zone along State highway 16 (TF–17).

(H) Cannonball chert in sublithographic limestone of the *Ceraptoea capuliformis* zone west of State highway 16 (TF–15).

A
D
G
B
E
H
C
F
I

PLATE 24

Rocks of the Gorman formation in the Bear Spring area, Mason County, Texas

FIGURE A. A panoramic view east-northeast at the Rattlesnake Hill section.

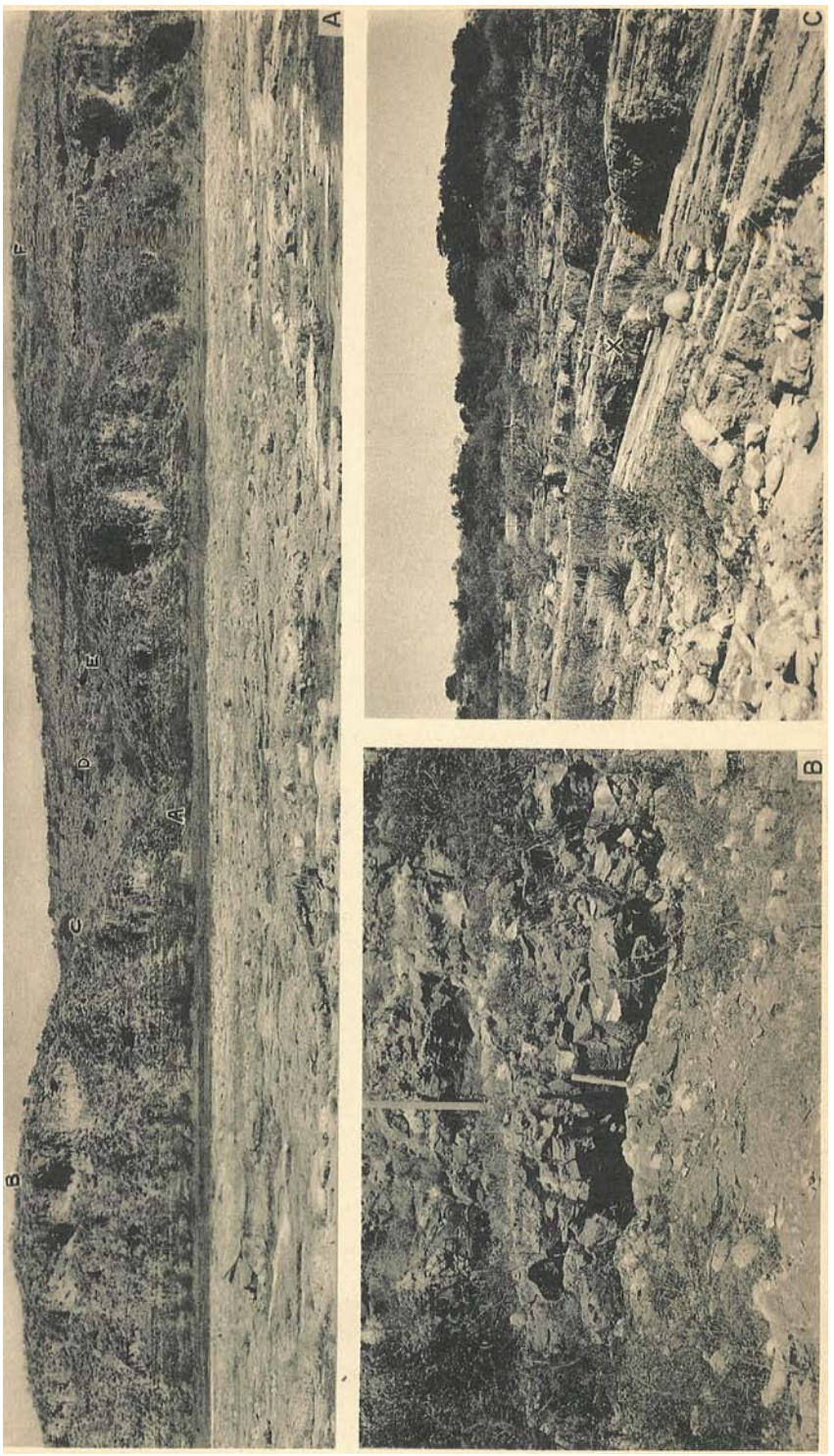
The upper 400 feet of the Gorman formation in the Rattlesnake Hill section is displayed in this panorama. A bed 58 feet above the base of the Gorman formation was traced along the base of the bluff at the left to the letter A, at the draw near the center of the view, and most of the dolomitic facies was measured up the accessible right (south) end of this bluff between A and B. A few feet of section was gained down-dip behind the bluff to just above the large clump of live oak above C, and from there the section shifts on the *Archaeoscyphia* bed of the Gorman formation above the clump at D to the draw at E. From E it ascends part-way up Rattlesnake Hill, makes a shift on the prominent ledge above the clump at F, and continues from F to a cap of Carboniferous at the top of the hill. The bluffs at the left and center show most of the dolomitic facies, and the heavy ledges that are so well defined along the hillside above E belong in the calcitic facies of the Gorman formation. Llano River flows to the right (south) at the base of the bluffs. Study of Plate 5 will aid visualization of the geology here pictured.

FIGURE B. The contact of the Tanyard and Gorman formations at the base of the Rattlesnake Hill section.

The locality is about one-half mile northwest up the left bank of Llano River from figure A. The contact is in dolomite and is marked by the head of the hammer. It is slightly irregular due to disconformity or to solution. The base of the Gorman formation is markedly arenaceous at this place, and scattered sand grains occur in the top few inches of rock assigned to the Tanyard formation.

FIGURE C. Limestone of the calcitic facies of the Gorman formation immediately east of White's Crossing.

To see how thickly bedded the limestones here pictured are with reference to those characteristic of the Tanyard formation in the western part of the Llano region, compare this photograph with figures C and D on Plate 19. A hammer (at X) near the center of the picture gives the scale.


A
B
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C
X

PLATE 25

Rocks of the Gorman formation in San Saba, Lampasas, and Mason counties, Texas

FIGURE A. Limestone of the calcitic facies of the Gorman formation in a bluff on the right (west) bank of Colorado River about one-fifth of a mile north of Gorman Falls, San Saba County.

The *Archaeoscyphia* zone of the Gorman formation and a bed containing *Syntrophinella* occur at the top of this 80-foot bluff. In the Bear Spring area of Mason County, beds equivalent to these are mostly dolomite.

FIGURE B. Stromatolites in limestone near the top of the Gorman formation in the bed of Honey Creek, Bear Spring area, Mason County.

Structures similar to these, though smaller, are being made by sediment-binding algae on the Bahama Banks at the present time (Hatch, Rastall, and Black, 1938, p. 166). The scale is given by the hammer (at X) in front of the bush at the right.

FIGURE C. Contact of the dolomitic (below) and calcitic (above) facies of the Gorman formation on the left (northeast) bank of Colorado River about one-fourth of a mile downstream from Gorman Falls and on the opposite bank of the river from it in Lampasas County.

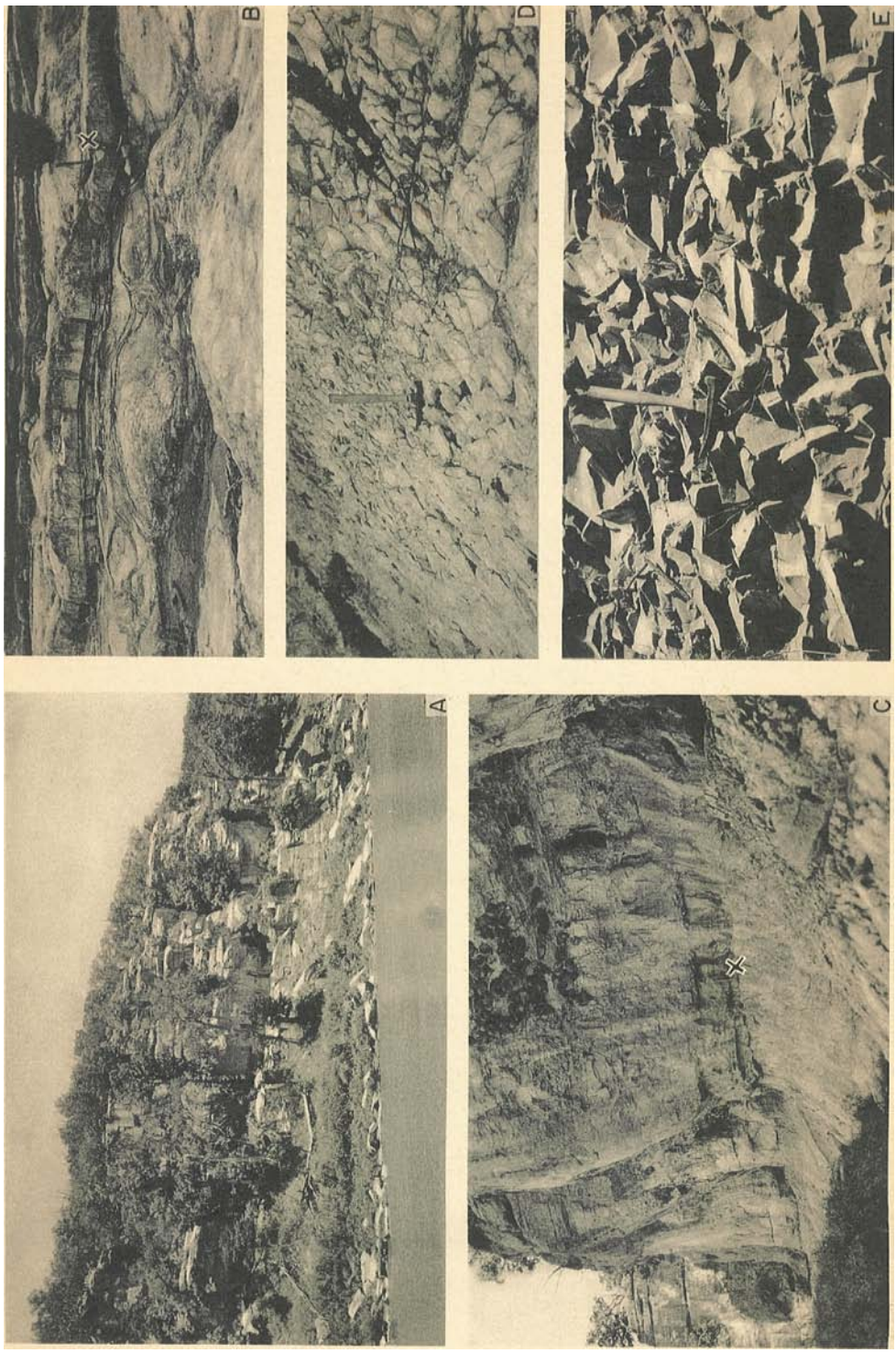
The contact, marked by the hammer (at X) immediately right of center, is abrupt and nongradational at this place. It is in the measured Gorman Falls section. The clustered objects on the overhanging limestone are the nests of cliff swallows.

FIGURE D. Detail of the dolomite in the lower part of figure C.

The smooth-surfaced sphenoidal blocks are characteristic of the weathered surfaces of microgranular to very fine grained dolomites. Note also how the bedding cuts across the seeming jumble of the blocks, apparently dipping slightly to the right in this photograph.

FIGURE E. Detail of sphenoidally weathering dolomite on the left (northeast) bank of Colorado River, about three-tenths of a mile downstream from Gorman Falls and on the opposite bank of the river from it in Lampasas County.

The locality is slightly downstream from that of figures C and D, and the rocks are a little lower in the Gorman Falls section.


B
D
E
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C

PLATE 26

Rocks of the Gorman and Honeycut formations in San Saba County, Texas

FIGURE A. The contact of the Gorman and Honeycut formations in the Gorman Falls section, at Tie Slide Canyon.

Two hammers to the right of the center of the picture mark the contact. The upper and least apparent hammer (at X) rests on the top ledge of the Gorman formation and leans against a dolomite ledge marking the base of the Honeycut formation. The lower and more apparent hammer (at Y) leans against the reticulate-weathering upper ledge of the Gorman formation. At this locality the upper ledge of the Gorman formation is marked by borings, the fillings of which include numerous sand grains and are selectively dolomitized. Probably because of uncommonly good groundwater circulation along this contact, many of the sand grains have pinkish ferruginous stains, a feature very unusual for sand grains in the Ellenburger rocks.

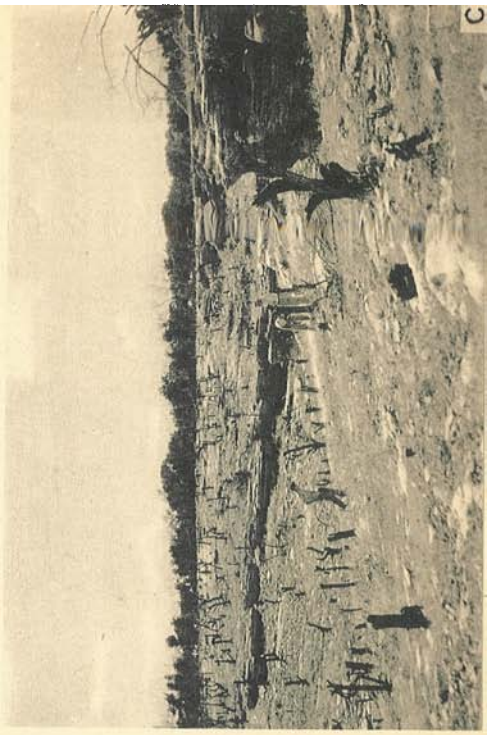
FIGURE B. The upper limestones of the Gorman formation at Goat Caves near the mouth of McAnelly Canyon in the Cherokee area.

The bluff is about 80 feet high and the contact of the Gorman and Honeycut formations is about 4 feet below its top. The 45- to 50-foot interval of heavy bedded, pure limestone that marks the top of the Gorman formation comprises the sheer and slightly undercut wall of the bluff, breaking to interbedded dolomite and limestone in the lower part. The Goat Caves are small openings in the limestone at the base of the undercut portion of the bluff.

FIGURE C. Strata of the Honeycut formation in the upper part of the Gorman Falls section, near locality 205T–1–17A.

The relatively thinly bedded, slabby-weathering exposures shown are fairly typical of the interbedded limestones and dolomites of the lower 300 feet of Honeycut strata.

A


C

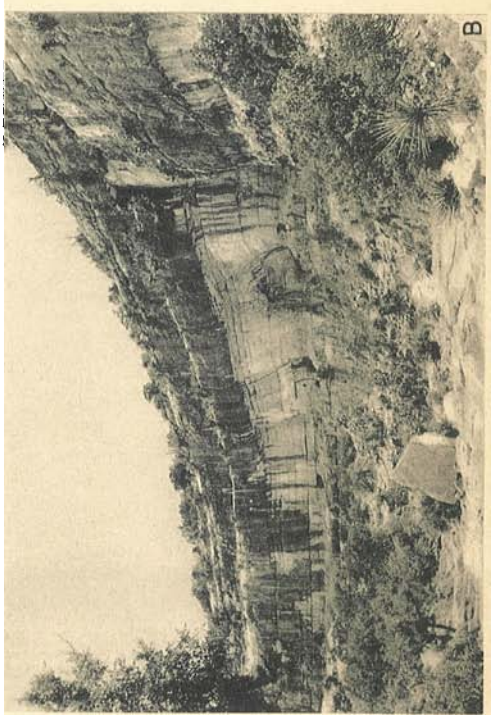

B

PLATE 27

Devonian rocks in Blanco and Burnet counties, Texas

FIGURE A. Type locality of the Stribling formation (16T–2–43M), Honeycut Bend of Pedernales River, Blanco County.

The figure at X stands on the top bed of the Stribling formation and a packsack at Y is on the top thick bed of limestone of the Honeycut formation of the Ellenburger group in its thickest section. The Stribling formation is 11 feet thick at this place.

FIGURE B. Detail of bedding in the Stribling formation at the type locality.

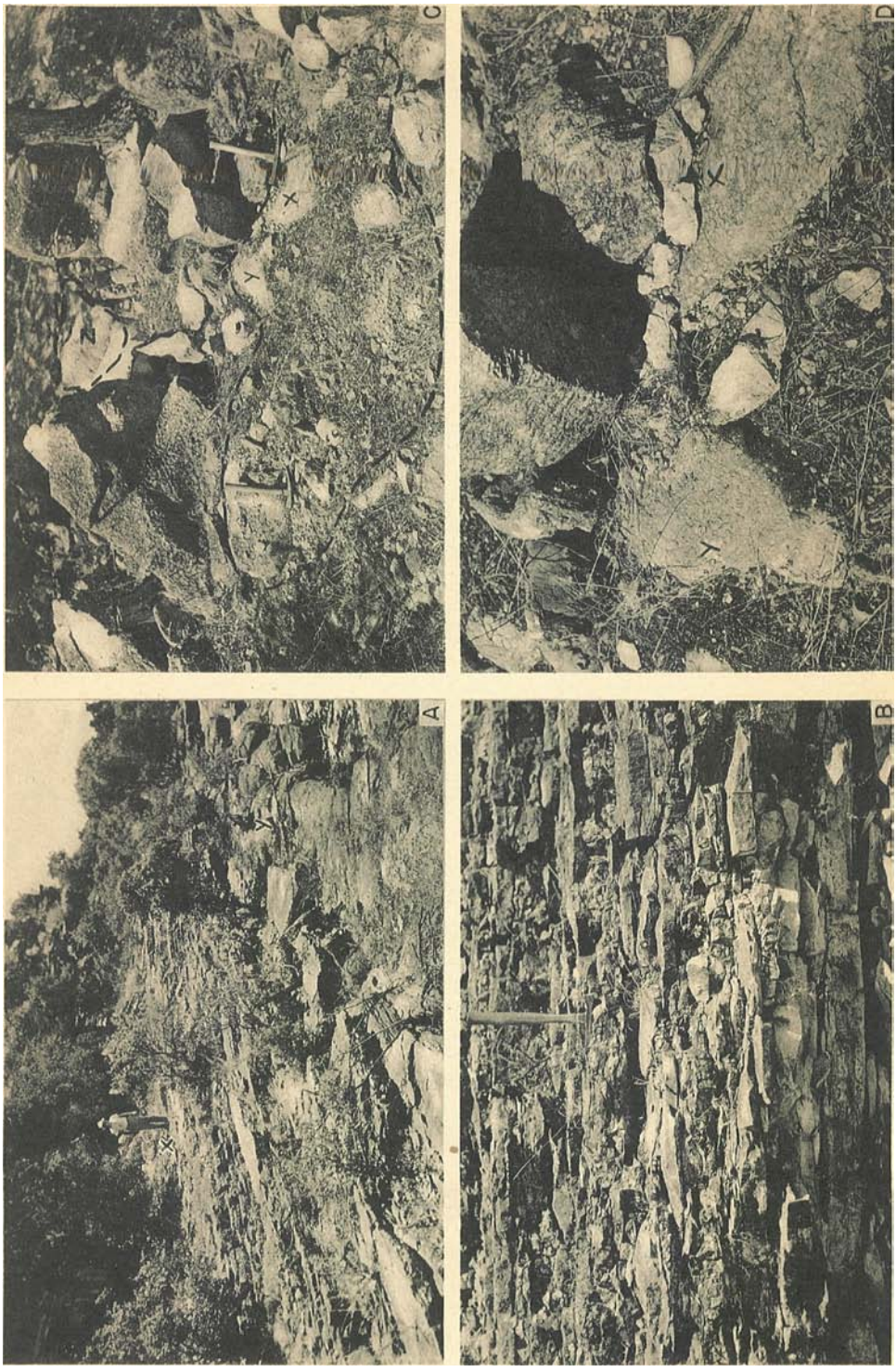
Approximately the middle 3.5 feet of the formation are shown in this photograph. The lenticular plates of limestone and chert and their shingle-like arrangement are characteristic.

FIGURE C. Type locality of the Pillar Bluff limestone (TF–273), Burnet County.

The broken line around X and Y outlines the discovery pocket and that around Z outlines a film of the Pillar Bluff limestone that is plastered against a ledge of the Honeycut formation. The photograph was taken from the top of a fence.

FIGURE D. Detail of the Pillar Bluff limestone at the type locality.

The letters X and Y mark the same blocks in figure D as in figure C.


C
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A
X
B

PLATE 28

Mississippian rocks in McCulloch, Blanco, and Mason counties, Texas

FIGURE A. An ancient structural sink filled with Chappel limestone on the left (north) bank of San Saba River at the east edge of McCulloch County.

The Chappel limestone occupies a collapsed area in the left two-thirds of the photograph, abutting limestone of the Gorman formation in the right third of the photograph. In this structural sink about 50 feet of dark pink fossiliferous Chappel limestone and an underlying thin coquina-like limestone of Glen Park age occur between strata of the Gorman formation below and the Barnett formation above. At the margins of the sink the Barnett formation rests directly on limestone of the Gorman formation. The Chappel limestone and the beds of Glen Park age evidently were let down into the limestones of the Gorman formation after their deposition but before the Barnett strata were deposited. Similar features are common where the Mississippian rocks have overlapped the calcitic facies of the Gorman formation. Such features are known as "structural sinks" because they display the structure but not necessarily the topographic expression of a sink.

FIGURE B. Chappel limestone and strata of pre-Chappel age at locality 16T–2–25B, 2 miles south-southwest of Cypress Mill, Blanco County.

The head of the hammer marks the base of the Chappel limestone, and the undulating surface at the lower edge of the photograph is the top of the Honeycut formation at this place. The intervening 5 inches of rock is a brown phosphatic rock containing pieces of fish bone and largely comprised of conodonts, but insoluble in acetic acid. In the conodont assemblage genera commonly regarded as Devonian predominate, but "Mississippian genera" occur. Large, angular fragments of chert occur in the lower part of this "bone bed," and it may grade laterally into the Ives breccia.

FIGURE C. Crinoidal limestone of the Barnett formation in disconformable contact with the Gorman formation on the left (northeast) bank of Honey Creek, Bear Spring area, Mason County.

Although this contact is not more noticeably disconformable than others of more dubious character (Pl. 24, fig. B), it marks a profound hiatus. Accentuation of the irregularity of this contact by differential solution is evident at some places. The massive character of some of the detrital limestones of the Barnett formation is well displayed here. Although this limestone weathers dark gray, it is white on a fresh surface.

FIGURE D. A view north across Llano River at the Carboniferous overlap in the vicinity of White's Crossing, Bear Spring area, Mason County.

Carboniferous strata underlie the area of thicker tree growth (mostly cedar), and their contact with the Ellenburger rocks is a little below the lower heavy band of vegetation. The contact of the Barnett formation and the Marble Falls limestone is in the lower part of this heavy band of vegetation. The rocks that dip steeply east on the far bank of the river include a large part of the Gorman formation and strike into a fault that offsets the Ellenburger-Carboniferous contact (*see* Pl. 5). Figures E and F on this plate were taken at the extreme left of this photograph, on the far side of the road.

FIGURE E. Contact of the Chappel limestone with limesands of Keokuk age at the base of the Barnett formation at White's Crossing, Bear Spring area, Mason County.

The hammer rests on the top surface of the dark colored, compact, sparingly crinoidal Chappel limestone. The next 10 feet of rocks above it are coarse, pink stained, crinoidal limesands containing abundant macrofossils of probable Keokuk age (TF–184). The actual contact of the rocks pictured was observed in the brush just to the left of the photograph.

FIGURE F. Detail of the limesands of Keokuk age pictured in figure E.

The rock is composed of large crinoid columnals and is stained light pink. It contains cobbles of similar material and, near the base, cobbles of compact limestone possibly derived from the Chappel limestone below. A fauna of brachiopods, gastropods, corals, crinoids, and blastoids from this locality (TF–184) is of probable Keokuk age. Similar fossils were found in some of the included cobbles. On the basis of grain-size alone, this particular rock would be a calcareous granule conglomerate, but it is really only part of a detrital bank of pelmatozoan fragments of variable size, and the word limesand more accurately expresses its nature over the Bear Spring area as a whole.

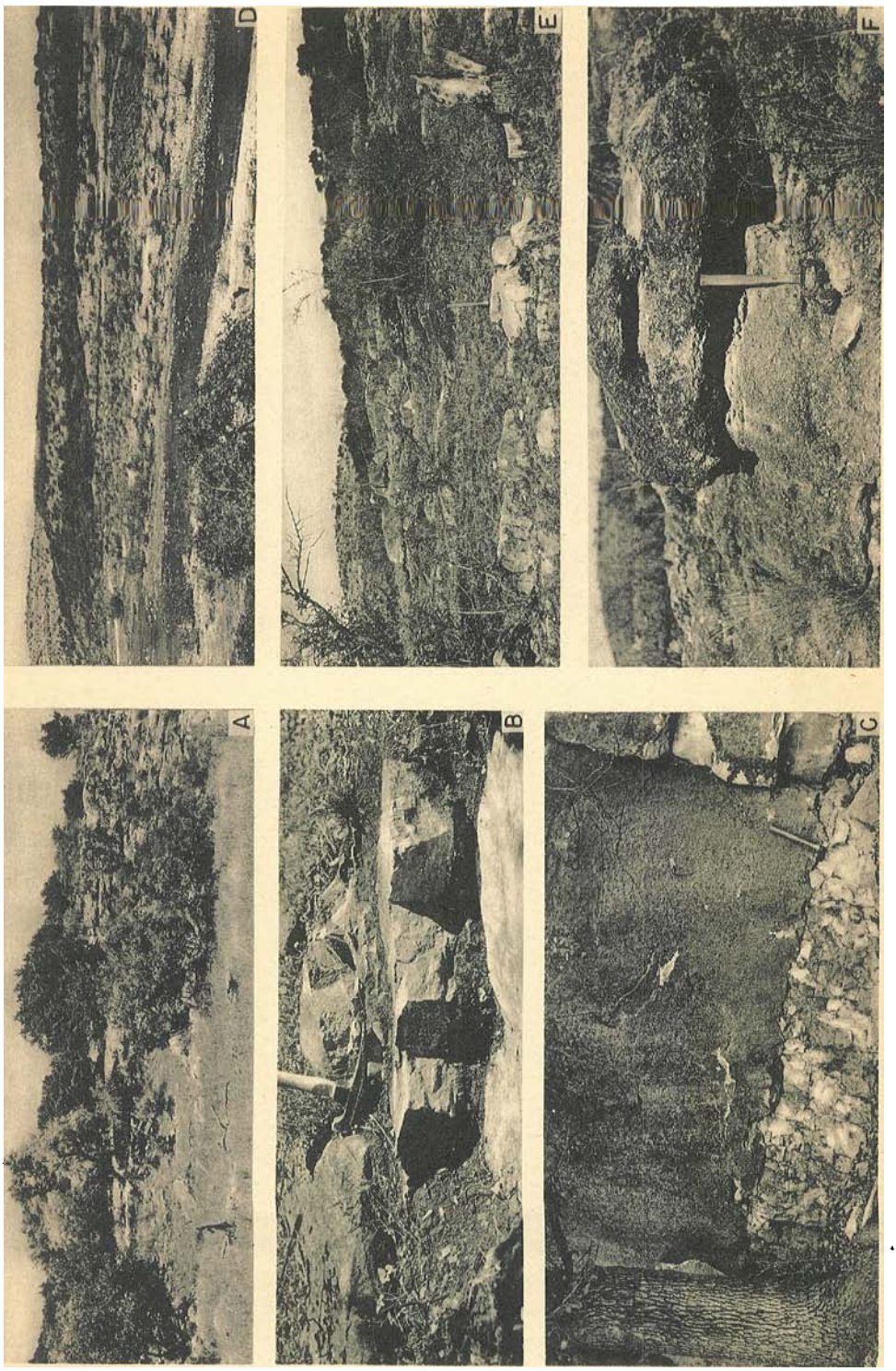
D
E
F
A
B
C

PLATE 29

Profile views of the Beach Mountain section, Culberson County, Texas

FIGURE A. A view west at the profile of the north end of Beach Mountain from State highway 84 about 9 miles by speedometer north of Van Horn.

FIGURE B. Profile of the upper part of the section viewed from the east.

FIGURE C. Profile of the lower part of the section viewed from the west.

The numbers on the profiles indicate feet of section above the base of the Bliss (?) sandstone (Lower Ordovician). The top of the Bliss (?) sandstone is at 125 feet, and tops of the units recognized in the El Paso formation (Lower Ordovician) are at the following points: Unit A, 377 feet; Subunit B1, 525 feet; Subunit B2a, 909 feet; Subunit B2b, 1190 feet; Unit C and El Paso-Montoya (Upper Ordovician) contact at 1240 feet. The contact of the Bliss (?) sandstone with the pre-Cambrian or Cambrian (?) Van Horn sandstone is under the slope-wash in the lower part of the profile shown in figure C. The letters U and D in figure C show the relative throw of a minor fault in a draw between the pinnacle at 911 feet and the upper part of the section, and the broken line indicates the draw. Dots indicate sandstone in the El Paso formation. Total relief in the profile is about 1000 feet.

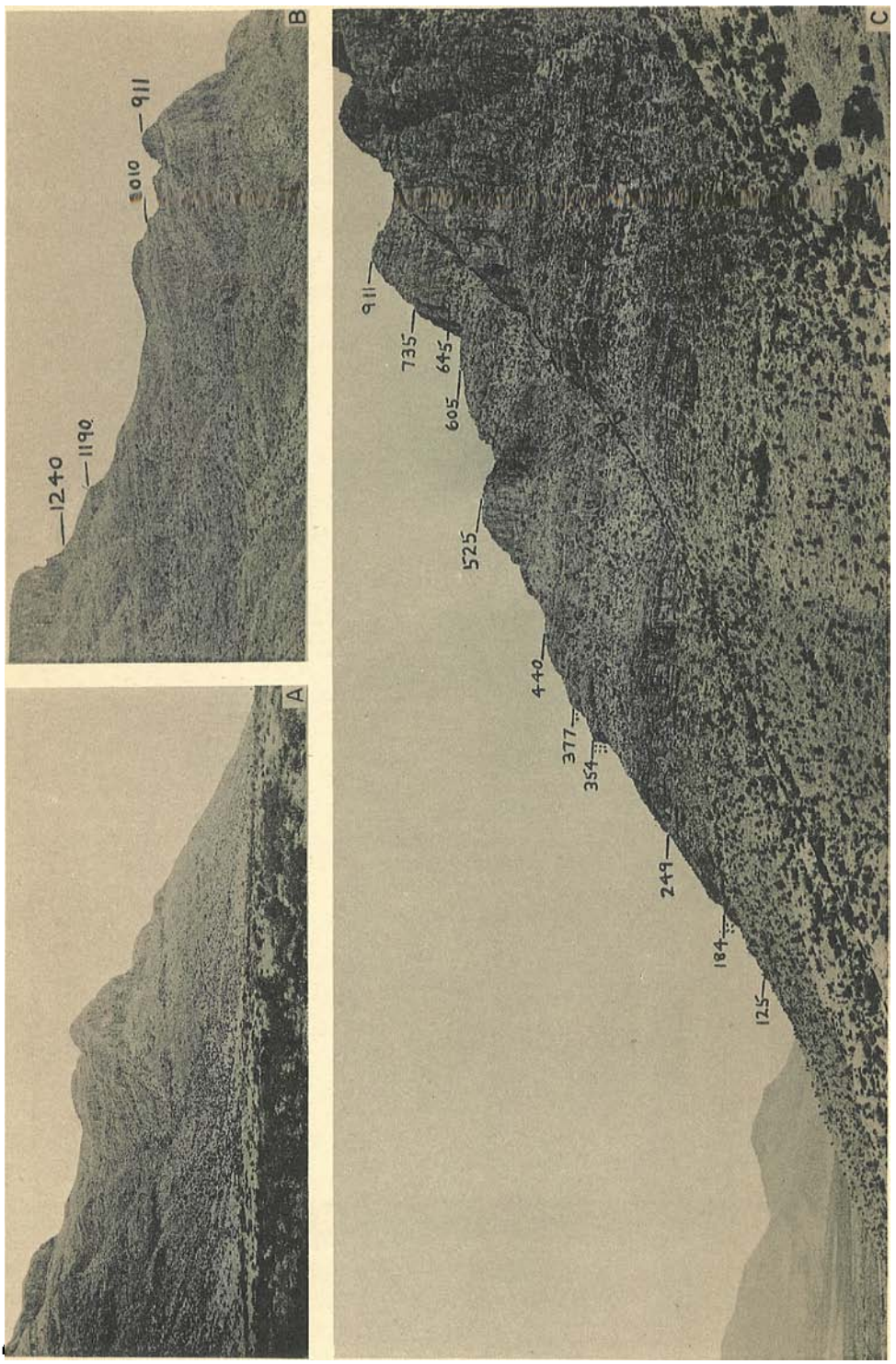
A
B
1240
1190
1010
911
C
911
735
645
605
525
440
377
354
249
184
125

PLATE 30

Lower Ordovician and Quaternary rocks in central Texas and central Colorado

FIGURE A. Upper massive limestones of the Gorman formation in Tie Slide Canyon, Gorman Falls section, San Saba County, Texas.

FIGURE B. Part of a travertine mass at Post Oak Falls near the head of Buchanan Lake (Colorado River), San Saba County, Texas.

Masses of Quaternary fresh-water limestone such as this are common in the areas mapped in central Texas, both along present-day streams and abandoned or intermittent stream courses. They occur typically at places where streams draining areas of carbonate rocks undergo or have undergone maximum aeration, and therefore feature scarps and bluffs such as the one pictured. Because many major faults in central Texas are marked by fault-line scarps, they are obscured by such travertine masses at many places. When this photograph was taken, Post Oak Creek was plunging from the highest point on the travertine mass, and an instance is known to the authors (Honey Creek falls in Llano County) where a stream actually flows for a short distance along a ridge of travertine and falls off both sides of it. Local building-up of stream courses is apparently a normal aspect of travertine formation. *See* also Plate 35, figure B.

FIGURE C. View west at the Missouri Gulch section of the Manitou formation, Manitou Park, Douglas County, Colorado.

Almost the full thickness of the approximately 100 feet of the Manitou formation at this locality is pictured. Its contact with the Sawatch (?) quartzite (Upper Cambrian?) is concealed somewhere in the immediate foreground, and the Williams Canyon limestone (Middle Ordovician?) comes in at the lip of the bluff.

FIGURE D. View east from Cave-of-the-Winds at the Williams Canyon section of the Manitou formation, just north of Manitou, El Paso County, Colorado.

The vertical lower bluff includes almost the entire 200 feet of the Manitou formation at its designated type section. The base of the bluff is only a few feet below the contact of the Manitou formation with the Sawatch (?) quartzite (Upper Cambrian?), and the Williams Canyon limestone (Middle Ordovician?) comes in at the first ledge on the bench above the main bluff. The prominent upper bluff is formed by the Madison limestone (Mississippian). The section described in Part III of this paper was measured at the right side of the photograph, at a reëntrant in the bluff.

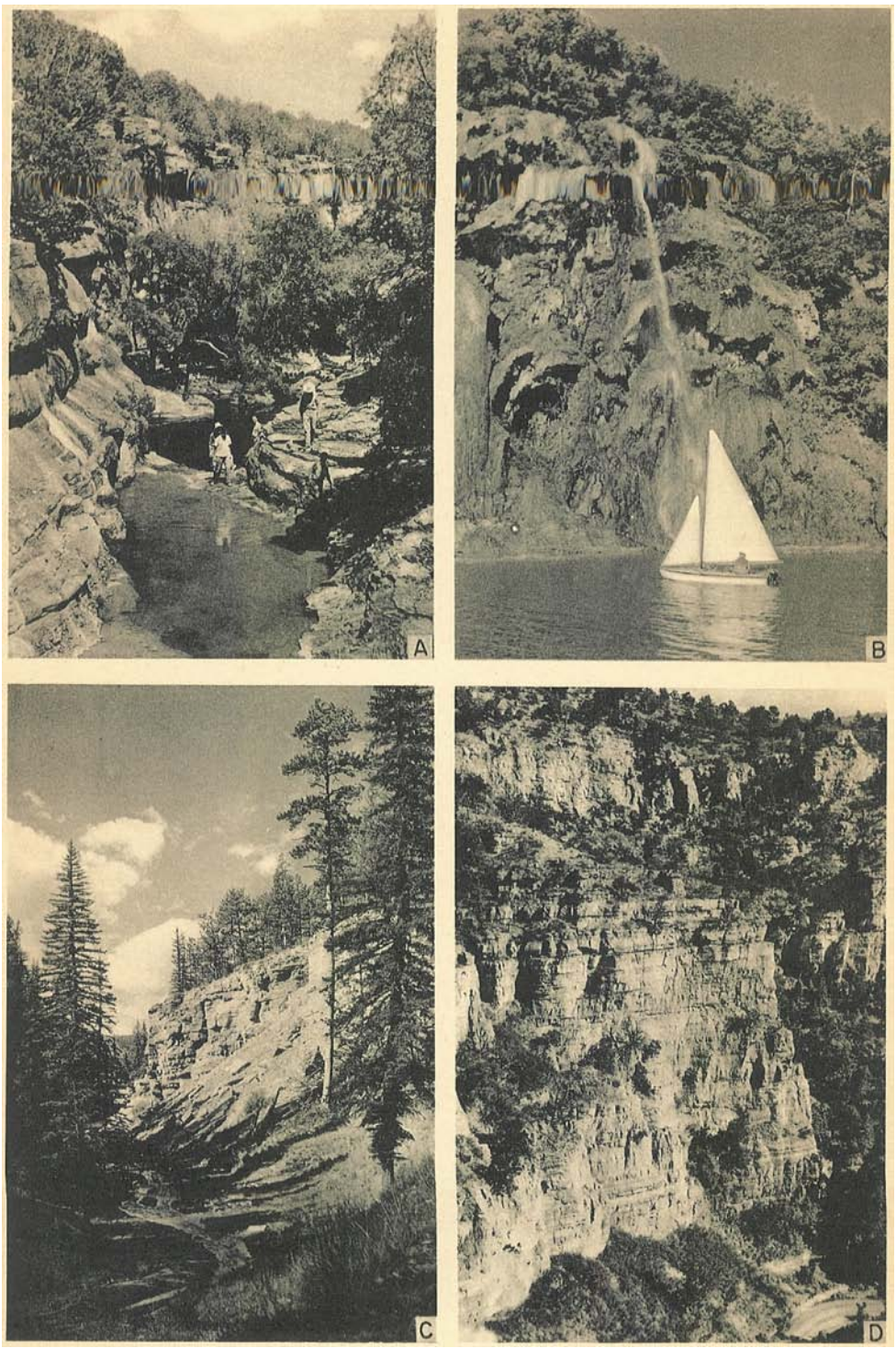
A
B
C
D

PLATE 31

Stereograms of the Tanyard formation and the Cambrian-Ordovician contact in the Cherokee area, San Saba County, Texas[24]

FIGURE A. The contact of the Threadgill, Ott(mg), and Staendebach, Ots(mg), members of the Tanyard formation in the Buffalo Hills.

Bald hills such as these and those shown by figure A on Plate 32 are typical of the Tanyard formation where it is in the dolomitic facies in areas of gentle dips. The dip at this place was determined as 1.5° north, by means of an alidade and plane-table. Only dolomite crops out in the area pictured, but the seepage in the draw at the east edge of the photograph probably results from the nearness of a dolomite-limestone contact. Live oak grows in clumps on the hills, with cedar in the valley of Buffalo Creek. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

FIGURE B. The Cambrian-Ordovician contact and laterally intergrading limestone and dolomite in the Threadgill member of the Tanyard formation at Four-Mile Hill.

ewp indicates the Pedernales dolomite member of the Wilberns formation, Ott(mg) the dolomitic facies of the Threadgill member of the Tanyard formation, and Ott(ca) the calcitic facies of the Threadgill member. It is typical of the Cambrian-Ordovician contact where it is in dolomite in areas of gentle dips to occur at the upper edge of a flat such as the one pictured, just where the ground begins to rise. The reader will notice that the areas underlain by limestone tend to be lighter in color and are marked by better defined ledges than the surrounding areas of dolomite. The scattered large clumps of trees are live oak; the closer, scrubbier growth is cedar. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

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[24]Note the combined north arrow and scale on all stereograms (Plates 31 through 37). All of the aerial photographs illustrated are at the approximate standard scale of 1/20,000, and the north arrow on each stereogram is one-half mile long at that scale. For full benefit these stereopairs should be observed stereoscopically.

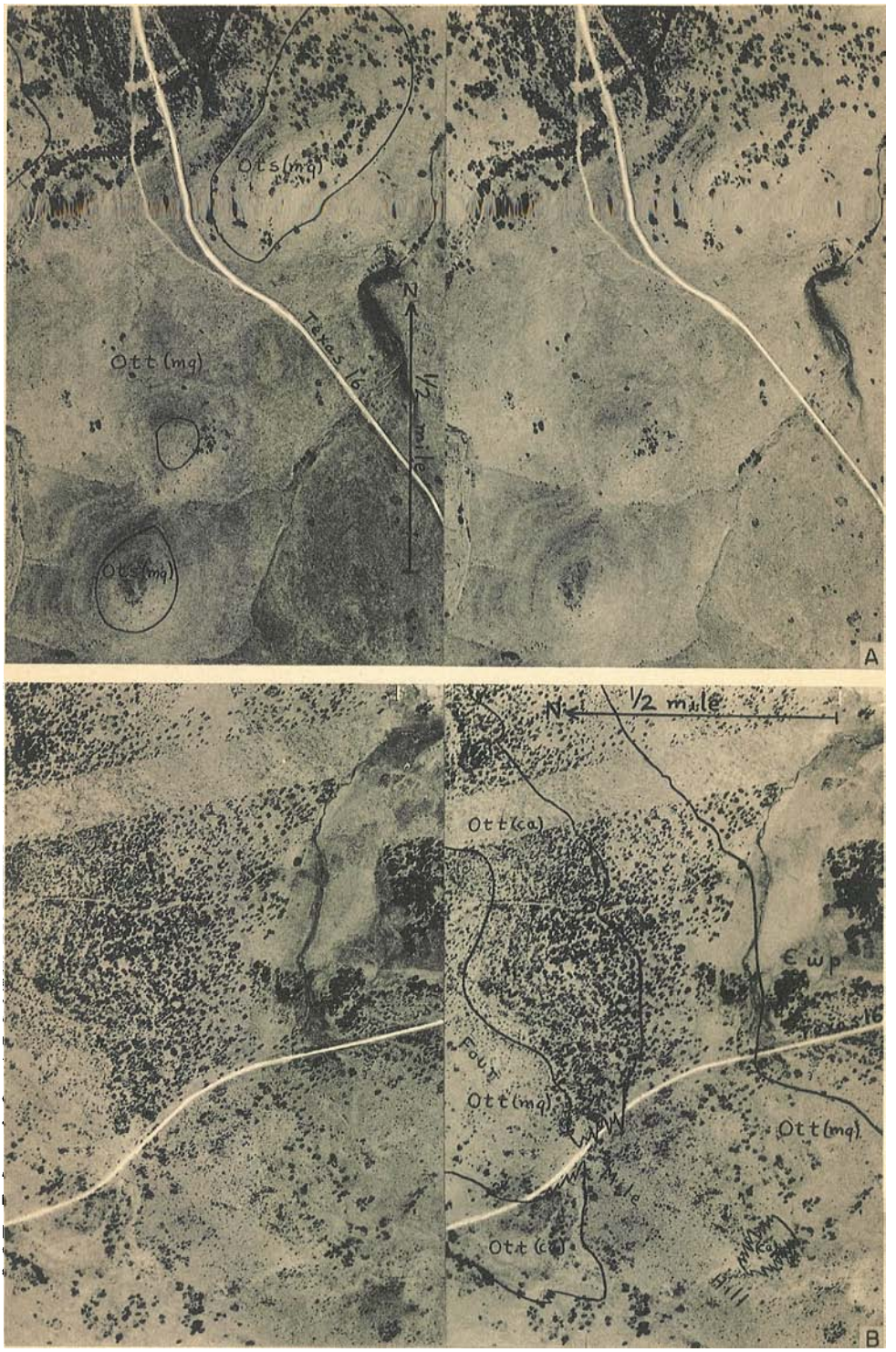

Ots (mq)
Ott (mq)
Ots (mq)
N
1/2 mile
Texas 16
A
N
1/2 mile
Ott (ca)
Ewp
Fault
Ott (mq)
Ott (mq)
Ott (ca)
B

PLATE 32

Stereograms of the Tanyard formation and the Cambrian-Ordovician contact in the Cherokee area, San Saba County, Texas

FIGURE A. The contact of the Threadgill, Ott(mg), and Staendebach, Ots(mg) + Ots(ca), members of the Tanyard formation near Dee Triangulation Station.

This stereogram and that of figure A on Plate 31 show variations of the bald or sparsely wooded hills that characterize the dolomites of the Tanyard formation in areas of gentle dip. The larger scattered clumps consist of live oaks, but the thickly clustered trees are mostly cedar. A thin cap of limestone, Ots(ca), at the top of the principal hill has not affected the normal expression of the dolomites. The dip at the east edge of this stereogram was determined as 2.5° north by means of an alidade and plane-table. The geologic contacts on this stereogram were mapped by R. L. Heller. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

FIGURE B. The Cambrian-Ordovician contact and laterally intergrading limestone and dolomite in the Threadgill member of the Tanyard formation between Dee Triangulation Station and Pole Hill.

ewp indicates the Pedernales dolomite member of the Wilberns formation, Ott(mg) marks the dolomitic facies of the Threadgill member of the Tanyard formation, and Ott(ca), indicates the calcitic facies of the Threadgill member. This stereogram and that of figure B on Plate 31 show variations in the photographic expression of the same contacts. The dip here is about 2° or 3° north. The geologic contacts on this stereogram were mapped by R. L. Heller. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

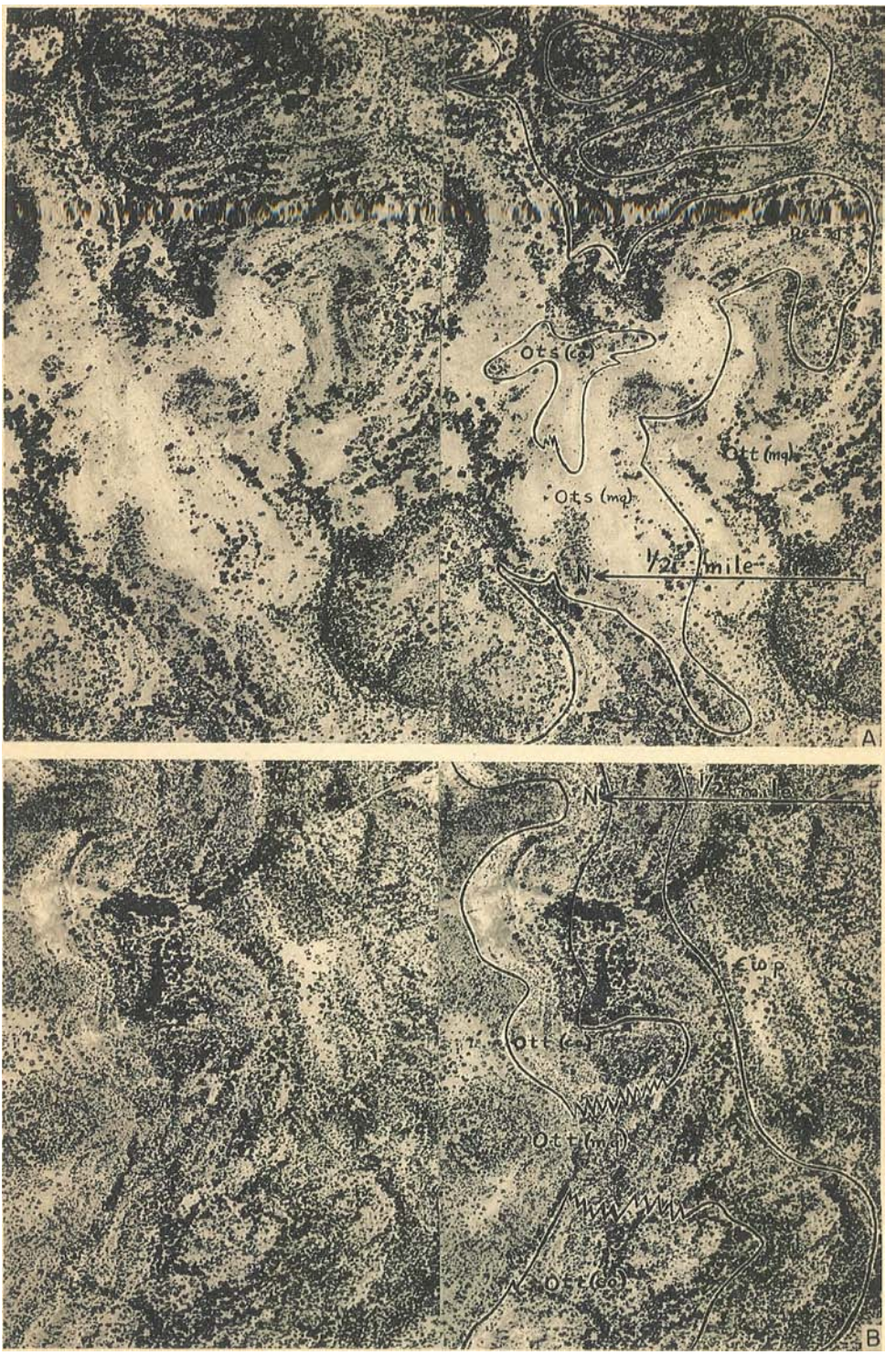

Ots (ca)
Ott (mq)
Ots (mq)
N
1/2 mile
A
N
1/2 mile
Ott (ca)
Ott (mq)
Ott (ca)
B

PLATE 33

Stereograms of the Tanyard-Gorman contact in the Cherokee area, San Saba County, and of pre-Gorman strata in the Moore Hollow area, Llano County, Texas

FIGURE A. The contact of the Tanyard and Gorman formations near Rattlesnake Pond, at the center of the Cherokee area, San Saba County.

The subdued and bald or sparsely wooded topography that characterizes the dolomitic facies of the Gorman formation, Og(mg), in areas of low dip stands in marked contrast to the more irregular, more thickly wooded, and "ledgier" topography of the calcitic facies of the Staendebach member of the Tanyard formation, Ots(ca). The uppermost beds of the Staendebach member are dolomite in this vicinity, hence the "break" in terrain does not quite coincide with the formational boundary. Note the pimple-mounds that are so conspicuous on the Gorman formation in this stereogram. In central Texas such features are characteristic of very gentle and poorly drained topography, and, where abundant, they are almost invariably underlain by microgranular to very fine grained dolomite of the Gorman formation or the Pedernales dolomite member of the Wilberns formation. Sinks, of which Rattlesnake Pond is one and the depression at the left center of the stereogram is another, are common in the lower part of the Gorman formation where it overlaps the calcitic facies of the Staendebach member of the Tanyard formation. In the stereogram, a growth of cedar, in which are scattered larger clumps of live oak, features the limestones of the Staendebach, whereas the trees that grow on the Gorman formation consist of scattered clumps of live oak and mesquite. The dip is very gently north. The geologic contact on this stereogram was mapped by R. L. Heller. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

FIGURE B. Geologic contacts and terrain of all Paleozoic strata below the Staendebach member of the Tanyard formation in the Moore Hollow area, Riley Mountains, Llano County, Texas.

Thirteen geological contacts in an area of relatively steep dips are shown in this stereogram, normal dip ranging from 5° to 20° and averaging 12° to 15°. Foreshortening of the stratigraphic sequence, and emphasis on topographic control of the vegetation, has obscured the contacts in the carbonate sequence above the Point Peak shale member of the Wilberns formation. The margins of the biostrome or zone of coalesced bioherms at the top of the Point Peak (wrongly shown at base of San Saba limestone member on Plate 10) and all lower contacts are well displayed, however. Symbols are as follows: in the pre-Cambrian, ps indicates the Packsaddle schist; in the Upper Cambrian Riley formation, erh is the Hickory sandstone member, erc the Cap Mountain limestone member, and erl the Lion Mountain sandstone member; in the Upper Cambrian Wilberns formation, eww is the Welge sandstone member, ewm the Morgan Creek limestone member, ewpp the Point Peak shale member, ews the San Saba limestone member, and ewp the Pedernales dolomite member; in the Lower Ordovician Tanyard formation, Ott(mg) is the dolomitic facies and Ott(ca) the calcitic facies of the Threadgill member, Ots(mg) the dolomitic facies of the Staendebach member. The obvious contacts are indicated for only part of their length. For a large-scale planimetric map of this vicinity see Plate 10. *Photographs from Soil Conservation Service, U.S.D.A.*

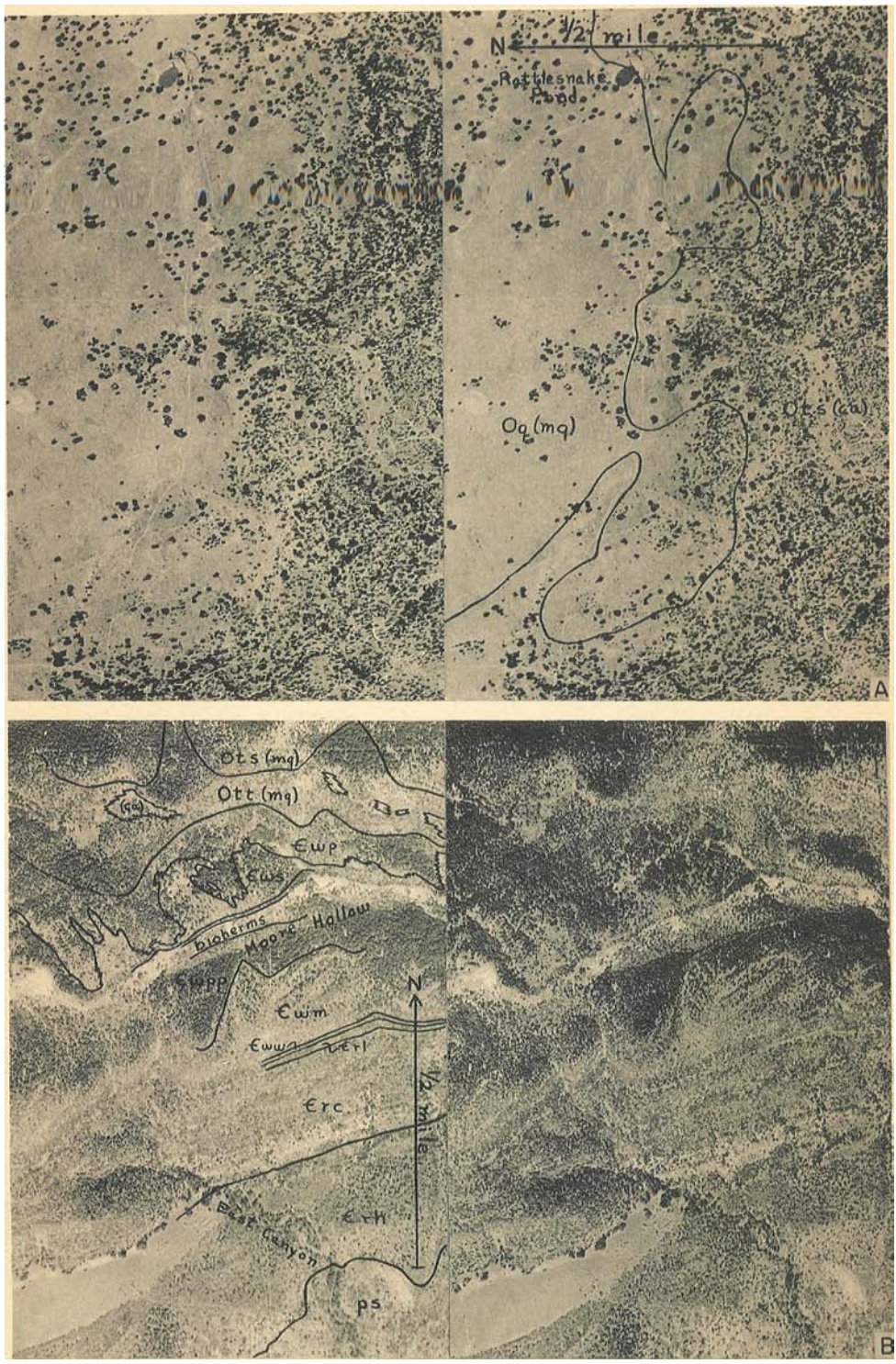

N
½ mile
Rattlesnake Pond
Oq (mq)
Ots (qa)
A
Ots (mq)
Ott (mq)
(qa)
Oa
Ewp
Ews
bioherms
Moore Hollow
Ewpp
Ewm
Ewu
Ewl
Erc
Erh
East Canyon
ps
N
½ mile
B

PLATE 34

Stereograms of the Gorman-Honeycut contact and of *en echelon* faulting in the Cherokee area, San Saba County, Texas

FIGURE A. *En echelon* faulting in the Simpson Creek fault zone near McAnelly Spring.*

The northwesterly fault of the *en echelon* pair has an observable stratigraphic throw of about 200 feet three-fourths of a mile southwest of McAnelly Spring. In the space of this stereogram its throw is transferred to the southeasterly fault of the "scissors." The southeasterly fault clearly does not offset the bench along the contact of the Gorman and Honeycut formations, and tracing of other beds proves that it has decreased to zero throw well northeast of this bench. "Scissors-faulting" of this sort is not at all uncommon in central Texas, and it is actually possible to measure sections around the ends of such features, reversing the direction of traverse to continue stratigraphically upward in the section. Symbols are as follows: Og(ca) indicates the calcitic facies of the Gorman formation; Oh, the Honeycut formation; Cm, strata of Mississippian age; Cp, strata of Pennsylvanian age; U and D, the relative throw along the faults shown. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

FIGURE B. The contact of the Gorman, Og(ca), and Honeycut, Oh, formations near Rock Waterhole of Barnett Draw.

The bench at the Gorman-Honeycut contact is so strikingly displayed in this stereogram that the contact is lined just far enough to guide the eye to the exact placement of the contact. The reader will observe the break from the rough, thickly wooded and poorly grassed, vegetationally banded (*see* Pl. 35, fig. B) terrain of the heavy bedded limestones of the upper part of the Gorman formation to the more even, less thickly wooded and better grassed terrain of the alternating limestone and dolomite in the lower part of the Honeycut formation. The dip is about 2° to 3° north. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

*The northwest (lower left) fault of the *en echelon* pair continues to the southwest (lower right) corner of the stereopair, but the white guide-lines were inadvertently omitted for its westerly end.

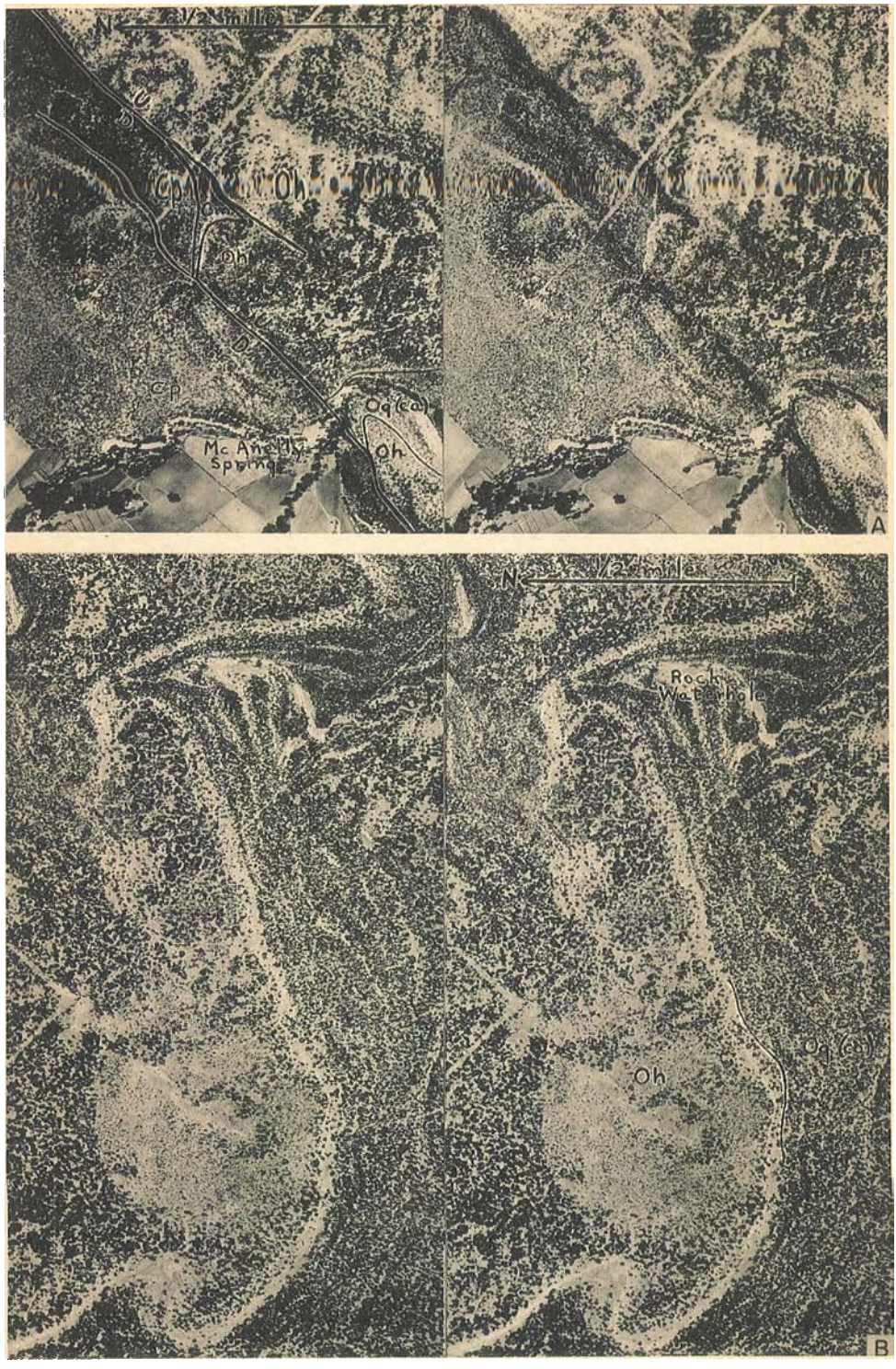

N
½ mile
Oh
Cp
Oq(ca)
Oh
A
N
½ mile
Rock
Oq(ca)
Oh
B

PLATE 35

Stereograms of the Gorman and Honeycut formations and the Carboniferous overlap in San Saba and Lampasas counties, Texas

FIGURE A. The Carboniferous overlap and the Elm Branch fault along Simpson Creek valley in the Cherokee area, San Saba County.

Og(mg) indicates the dolomitic facies of the Gorman formation; Oh, the Honeycut formation; Cm, strata of Mississippian age; and Cp, the Pennsylvanian Marble Falls limestone (undivided). The mesquite-covered bench that marks the overlap of the Mississippian Barnett formation on the Ellenburger strata through much of the Llano uplift is well displayed. Although younger Mississippian or Devonian strata occur locally along this zone of overlap they do not ordinarily affect its expression. The highly glauconitic and conglomeratic zone at the base of the Marble Falls limestone is well displayed in the shale pit on State highway 16. Placement of the Barnett-Marble Falls contact west of Simpson Creek is made inexact by the poor exposures in the thick band of vegetation wherein it falls. The dip is mostly gentle and to the north. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

FIGURE B. Stereogram of the Gorman and Honeycut formations in the Gorman Falls area, San Saba and Lampasas counties.

The upper 383 feet of the type section of the Gorman formation, Og; the entire thickness of 325 feet of the Honeycut formation, Oh; the Mississippian, Cm; some Marble Falls limestone, Cp; and travertine, Qt, are pictured. The contrast between the Honeycut formation and the Gorman formation is well shown, with the thinner alternations in the Honeycut formation at this place (*see* Pl. 34, fig. B) producing vegetational banding and bench topography in contrast to the more massive, more heavily wooded Gorman formation on which vegetational banding and topographic benches are less distinct. The Gorman Falls section follows the inverted V's, with dotted lines indicating offsets. The bottom 37 feet of the section is not shown. It extends about 800 feet south of the boundary of the stereogram along the east bank of Colorado River. The dip is gently to the north-northwest. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

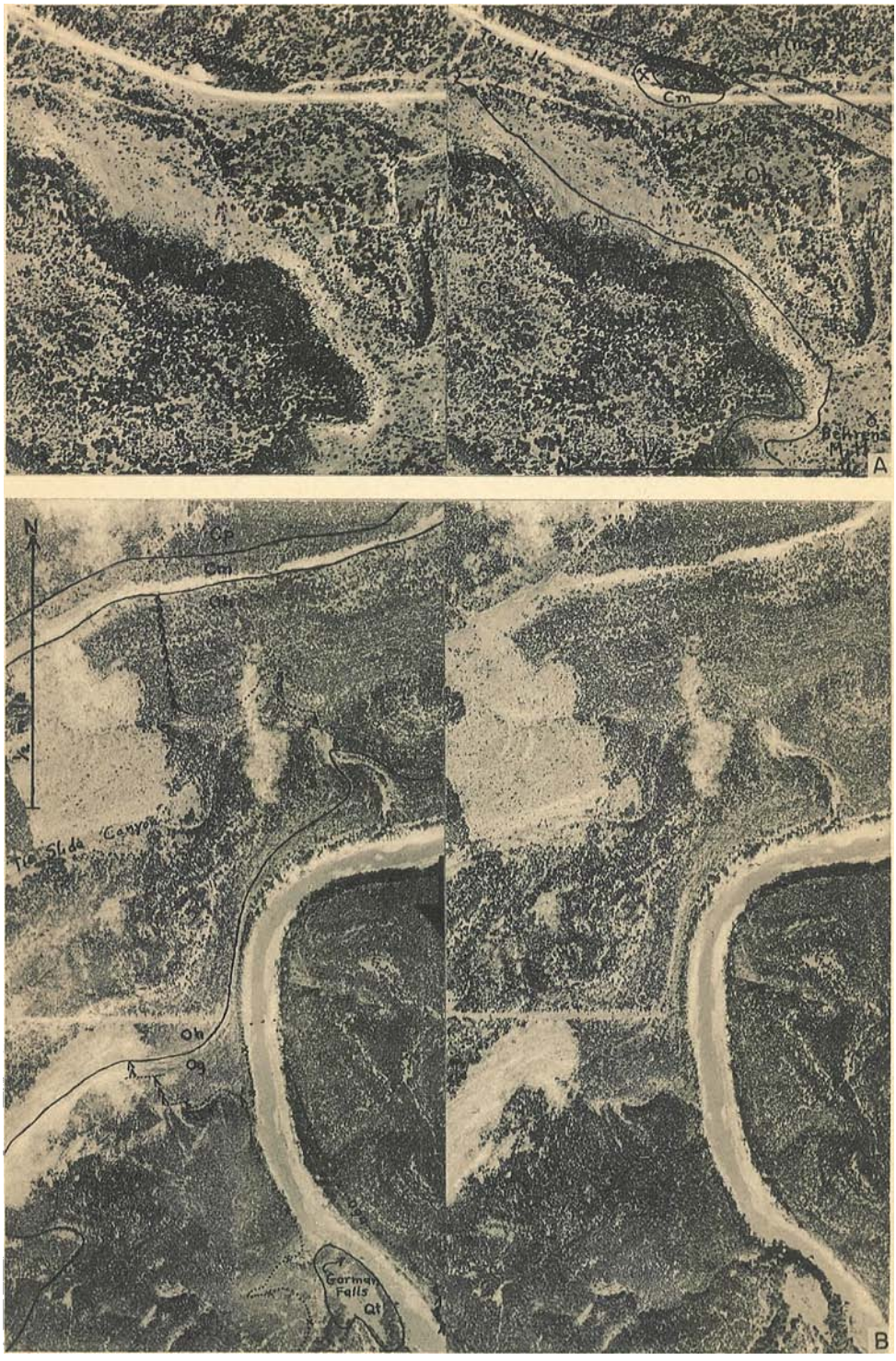

Cm
Ch
Behrens
A
N
Cp
Cm
Ch
Canyon
Ch
Op
Gorman
Falls
Qt
B

PLATE 36

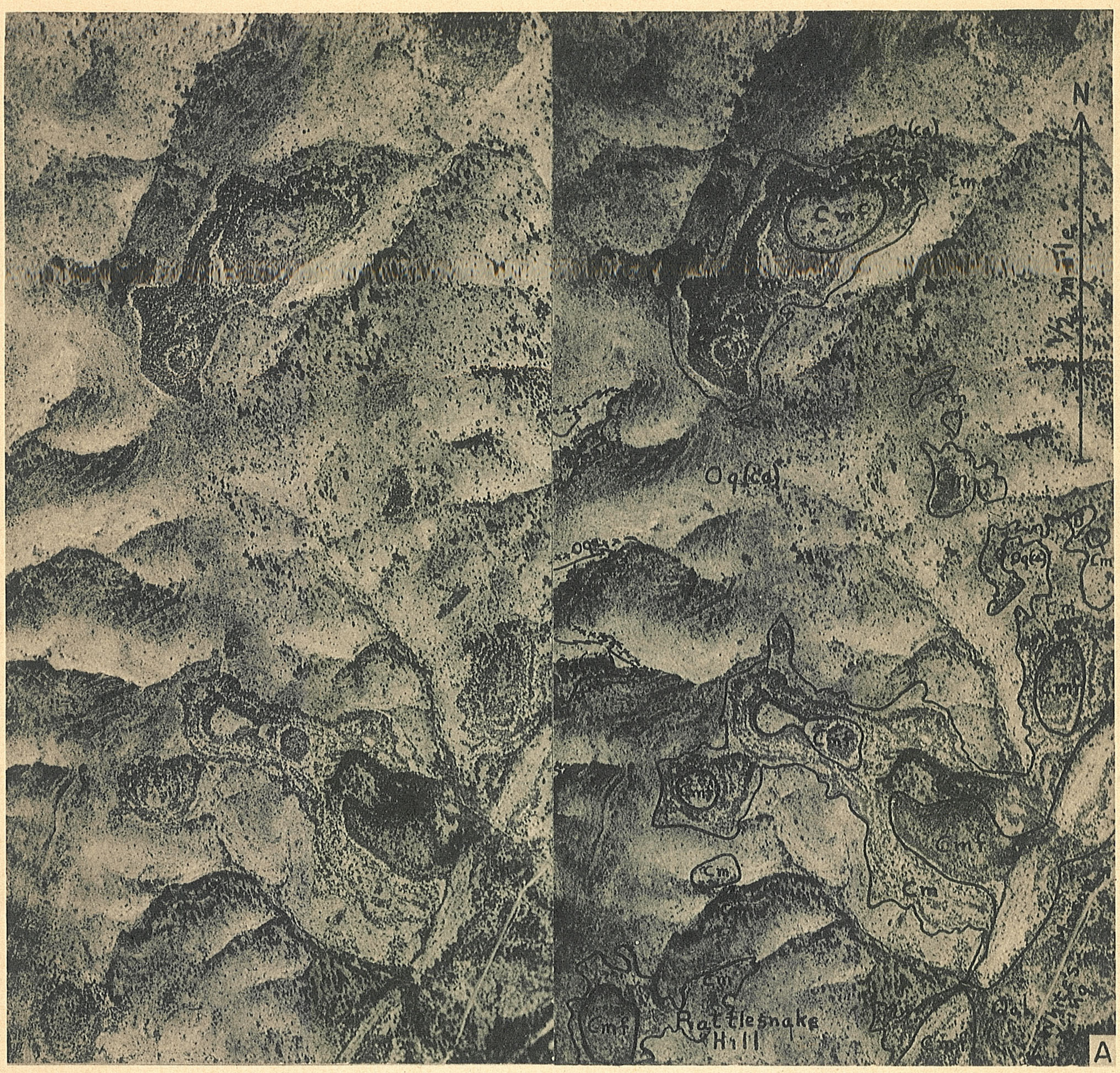
Stereograms of the Cambrian-Ordovician boundary and the Carboniferous overlap in the Bear Spring area, Mason County, Texas

FIGURE A. The Carboniferous overlap north and east from Rattlesnake Hill.

Og(mg), at the left margin, indicates the dolomitic facies of the Gorman formation; Oga, the *Archaeoscyphia* zone of the Gorman formation; Og(ca), the calcitic facies of the Gorman formation; D, at the center of the right margin, the Devonian; Cm, the Barnett formation, the Chappel limestone, and, at three places, the Ives breccia of Mississippian age; Cmf, the Marble Falls limestone; Qal, alluvium, mostly concealing the Smithwick shale. The hill marked simply C, for Carboniferous, at the northeast corner of the stereogram was not mapped. The dip varies, averaging gently east but being steep in collapsed areas and along the unfaulted northwest side of the Honey Creek syncline. Most of the pods and lobes of Mississippian deposits are collapsed into the limestones of the Gorman formation, to what extent those observing stereoptically can readily see. Even some of the larger areas of Carboniferous rocks tend to show synclinal structure that is doubtless attributable to solution below. For a large-scale planimetric map of this vicinity see Plate 5, keeping in mind that greater detail can be shown at the larger scale and that adjustments for topographic distortion were made on the map. The pattern for the first isolated cap of Marble Falls limestone north of Rattlesnake Hill was inadvertently omitted from Plate 5. *Photographs from Soil Conservation Service, U.S.D.A.*

FIGURE B. The Cambrian-Ordovician contact near the juncture of Bluff Creek and Llano River.

Ew indicates the Wilberns formation (mostly the San Saba limestone member); S, the 7-foot sandstone 28 to 35 feet below the Cambrian-Ordovician contact; Ott(ca), the calcitic facies of the Threadgill member of the Tanyard formation; and the letters D and U show the relative throw on minor faults. The line of inverted V's on the left member of the stereogram marks the position of the Bluff Creek section. A narrow band of thickly clustered black persimmon and occasional scrub oaks marks the 7-foot sandstone, as may be seen on the unmarked photograph. The Cambrian-Ordovician contact bears a fairly constant relationship to the 7-foot sandstone and is therefore marked along only part of its trace. The average dip is gently east. This stereogram, which shows the Cambrian-Ordovician contact in thinly bedded limestone, should be contrasted with those on Plates 31 and 32, which show the same contact in dolomite. *Photographs from Soil Conservation Service, U.S.D.A.*


N
½ mile
Ogl(ca)
Cm
Cmf
Rattlesnake Hill
A

N
½ mile
Ott(ca)
S
BLUFF CK
LLANO R
B

PLATE 37

Stereotriplet of the Cherokee Creek section, Cherokee area, San Saba County, Texas

ewp indicates the Pedernales dolomite member of the Wilberns formation; ew, undifferentiated Wilberns strata; Ott(mg), the dolomitic facies of the Threadgill member of the Tanyard formation; Ots(mg), the dolomitic facies and Ots(ca) the calcitic facies of the Staendebach member of the Tanyard formation; Og(mg), the dolomitic facies, Og(ca) the calcitic facies, and Oga the *Archaeoscyphia* zone of the Gorman formation; Oh, the Honeycut formation and Oha the *Archaeoscyphia-Ceratopea capuliformis* zone; Cm, the Ives breccia, Chappel limestone, and Barnett formation of Mississippian age; and Cp, the Pennsylvanian Marble Falls limestone. U and D show the relative throw on faults, and the numbers 7 and 8 along the road mark cattle guards. Inverted V's indicate the line of the Cherokee Creek section, with the actual trace of offsets in the section shown by dashed lines, dotted lines (for sand), and a line of small circles (oölite bed). Except for the segment of section (116 feet stratigraphically) between the X-bed and the Threadgill-Staendebach contact, the entire Cherokee Creek section is shown, and the missing part of the measured section can be seen above the X-bed at its west end. The dip along the line of section ranges from 4° to 15°, but averages between 6° and 12°. For detail, see Plates 2 and 7. *Photographs from Field Service Branch, P.M.A.-U.S.D.A.*

PLATE 38

Fossils from the Wilberns and Tanyard formations

Fossils from the Wilberns formation,[25] *figures 21–50*

FIGURES 21–22. *Elvinia roemeri* (Shumard)

21. Plaster cast (x1) of pygidium figured by Roemer (1852, Pl. 11, figs. 3a–b) and by Bridge (1936, Pl. 69, fig. 8). Immediately below *Eoorthis* zone in Morgan Creek limestone member. Probably from Flatrock Crossing of San Saba River, 0.5 mile northeast of Camp San Saba, McCulloch County (*fide* Bridge, 1936). U.S.N.M.–95485.
22. Cranidium (x1) figured by Bridge (1936, Pl. 69, fig. 15). Immediately below *Eoorthis* zone of Morgan Creek limestone member. Top of west peak of Packsaddle Mountain, southeastern Llano County. This specimen was designated holotype of his *E. texana* by Resser (1938, p. 30). U.S.N.M.–93013.

FIGURES 23–24. *Elvinia shumardi* Resser

Holotype cranidium (x1) figured by Walcott (1925, Pl. 17, figs. 9–10) and by Bridge (1936, Pl. 69, fig. 9), and paratype pygidium (x1). Immediately below *Eoorthis* zone of Morgan Creek limestone member. Near Morgan Creek, about 8 miles northwest of Burnet, Burnet County. U.S.N.M.–70259.

FIGURES 25–26. *Pterocephalia sanctisabae* Roemer

25. Pygidium (x1) figured by Bridge (1936, Pl. 68, fig. 17). Immediately below *Eoorthis* zone of Morgan Creek limestone member. Near Morgan Creek, Burnet County. U.S.N.M.–93010.
26. Plaster-cast (x1) of syntype cranidium figured by Roemer (1852, Pl. 11, figs. 1a–b) and by Bridge (1936, Pl. 68, fig. 7). Same stratigraphic position and locality as specimen represented by figure 21. U.S.N.M.–95486.

FIGURES 27–29. *Plectotrophia alata* (Walcott)

Interior and exterior (x2) of a ventral valve and exterior (x2) of a dorsal valve figured by Ulrich and Cooper (1938, Pl. 40, figs. 1–3). *Plectotrophia* zone in Point Peak shale member, along road 8 miles southwest of Naruna, Burnet County. Photographs by courtesy of Dr. G. A. Cooper. U.S.N.M.–91334.

FIGURES 30–38. *Plectotrophia bridgei* Ulrich and Cooper.

30, 34. Lateral and dorsal views (x2) of exterior of a large dorsal valve.
31. Anterior view (x2) of exterior of a ventral valve.
32. Ventral view (x2) of interior of a small dorsal valve.
33, 37. Anteroventral views (x2) of interiors of two dorsal valves.
35–36. Interior and exterior (x2) of a ventral valve.
38. Lateral view (x2) of exterior of a ventral valve.

All specimens from the *Plectotrophia* zone in the Point Peak shale member, south slope of Point Peak, Llano County. Photographs by courtesy of Dr. G. A. Cooper of syntypes illustrated by Ulrich and Cooper (1938, Pl. 40). U.S.N.M.–91335.

FIGURES 39–41. *Huenella texana* (Walcott)

39. Anterior view (x2) of the holotype ventral valve.
40–41. Partially exfoliated ventral and dorsal valves (x2).

All specimens probably from within 50 feet above or in the *Eoorthis* zone of the Morgan Creek limestone member, Packsaddle Mountain, Llano County. They are from Walcott's type lot (Walcott, 1912, Pl. 103). U.S.N.M.–52494.

FIGURES 45–48. *Eoorthis texana* (Walcott)

Posterior, anterior, ventral, and dorsal views (x1) of four whole specimens from the Morgan Creek limestone member at Flatrock Crossing of San Saba River, 0.5 mile northeast of Camp San Saba, McCulloch County. Bridge loc. 96.

FIGURES 42–43. *Scaevogyra elevata* Whitfield

42. Lateral view (x1) of a specimen from the Pedernales dolomite member, 1.2 miles airline N. 63° W. from mouth of Jim John Creek on east side of draw, southeastern San Saba County. Bridge loc. 23.
43. Lateral view (x1) of a specimen figured by Dake and Bridge (1932, Pl. 12, fig. 2). Pedernales dolomite member, west bank of Colorado River, 0.75 mile northeast of mouth of Fall Creek, southeastern San Saba County. U.S.N.M.–86945.

FIGURES 44, 49–50. *Scaevogyra sweezeyi* Whitfield

44, 50. Umbilical and lateral views (x1) of two specimens from same stratigraphic position and locality as specimen represented by figure 42.
49. Apical view (x1) of a specimen figured by Dake and Bridge (1932, Pl. 12, fig. 1). Same stratigraphic position and locality as specimen represented by figure 43.

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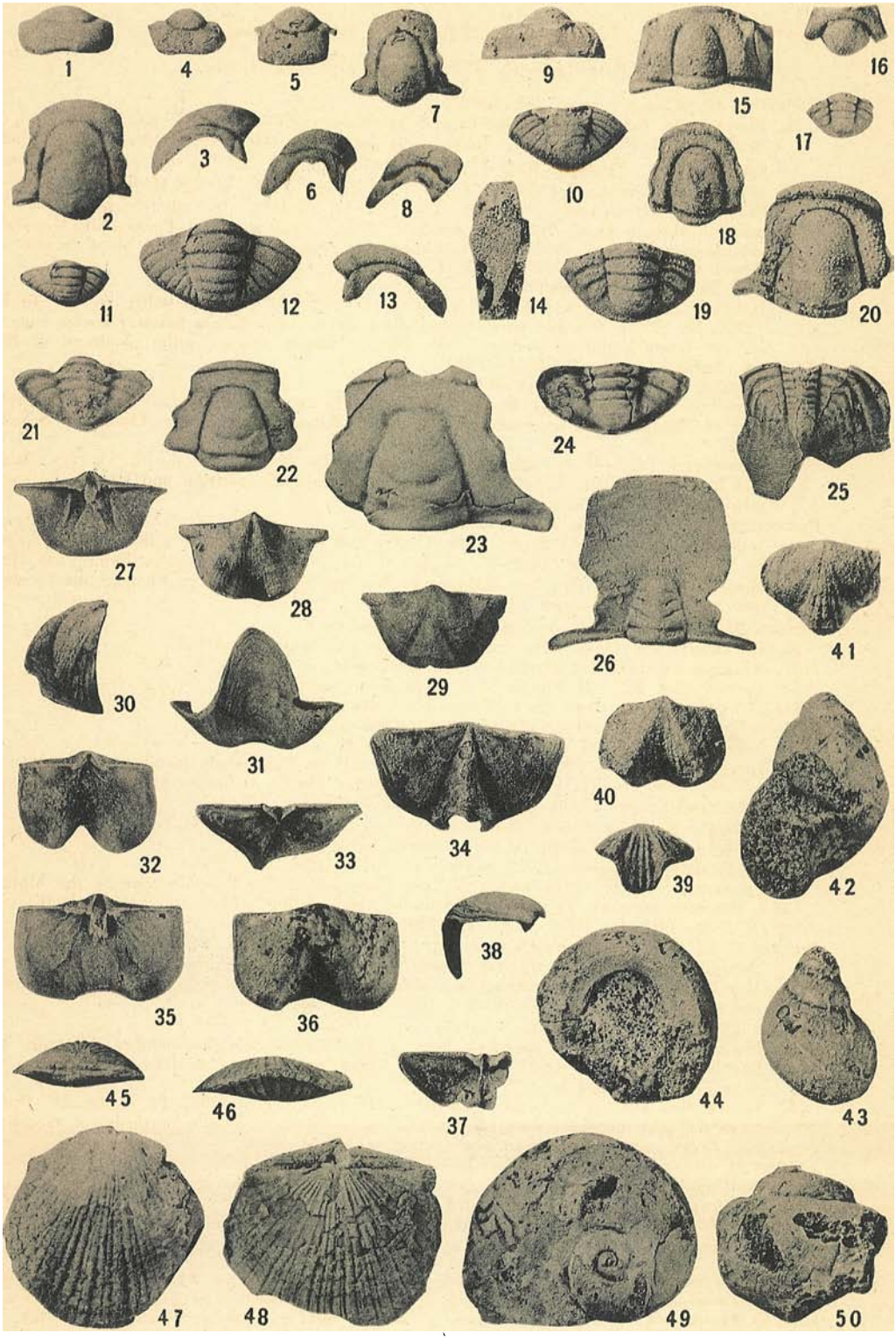
[25]Illustrations and descriptions of the several species of *Billingsella* from the Wilberns formation are being prepared for separate publication by Dr. W. C. Bell. Specimens of *Billingsella* from the Wilberns formation are illustrated by Walcott, 1912, Pl. 85. Additional figures of Cambrian fossils are given by Sellards, 1932, Pls. 2–3.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Trilobites from the Tanyard formation, figures 1–20

FIGURES 1–3, 10. *Paraplethopeltis depressa* Bridge and Cloud
Anterior, lateral and dorsal views (xl) of holotype cranidium and dorsal view (x2) of a pygidium from locality TF–37, about 7.13 miles airline S. 2° E. from intersection of highways at San Saba, Cherokee area. Upper 100 feet of Staendebach member.

FIGURES 4–9, 11–13. *Paraplethopeltis obesa* Bridge and Cloud
4, 9. Anterior view (xl) of a paratype cranidium and posterior view (x2) of a pygidium from Bridge's locality 66A, 1.5 miles by speedometer west from the ranch headquarters of Mack Yates, Sr., in southeastern San Saba County.
5–7. Anterior, lateral, and dorsal views (xl) of holotype cranidium from locality TF–111, about 8.47 miles airline S. 40° E. from intersection of highways at San Saba, Cherokee area.
8, 13. Lateral views (xl) of two paratype cranidia from boulders in terrace gravel at locality TF–149, about 8.69 miles airline S. 44° E. from intersection of highways at San Saba, Cherokee area.
11–12. Paratype pygidium (xl, x2) from locality TF–149, about 0.5 mile southeast from the headquarters of the J. F. Barnes ranch in southeastern San Saba County.
All specimens from upper 100 feet of Staendebach member.

FIGURE 14. *Paraplethopeltis*?
Free cheek (xl) from locality 16T–6–15A, 2 miles airline west-northwest from center of Johnson City, Johnson City area. Near top of Staendebach member.

FIGURE 15. *Hystricurus* sp.
Cranidium (x2) from locality TF–131, near top of Staendebach member, 6.03 miles airline S. 8° W. from intersection of highways at San Saba, Cherokee area.

FIGURE 16. *Hystricurus* (?) sp.
Anterior view (x2) of cranidium from locality TF–40, top of Staendebach member, 6.97 miles airline S. 6° E. from intersection of highways at San Saba, Cherokee area.

FIGURE 18. *Hystricurus* (?) sp.
Cranidium (x2) from locality TF–375, about 6 feet below top of Staendebach member in Moore Hollow section, Moore Hollow area.

FIGURES 17, 19–20. *Hystricurus* aff. *H. missouriensis* Ulrich
Pygidium (xl, x2) and cranidium (x2) from locality 16T–5–13D, about 6.5 miles airline northwest of Round Mountain, Blanco County.

In the explanations for Plates 38–44, for all brachiopod valves *dorsal* should read *brachial* and *ventral* should read *pedicle* (Cloud, P. E., Jr., Notes on recent brachiopods: Amer. Jour. Sci., vol. 246, pp. 241, 247, 1948).

PLATE 39

Fossils from the Tanyard formation

FIGURES 1–5. *Tetralobula texana* Ulrich and Cooper
1–2. Exterior (x2) and interior (x3) of a ventral valve.
3–4. Exterior and interior (x3) of a small dorsal valve.
5. Spondylium of a ventral valve (x4).
All specimens from 4250 feet west-southwest of ford at Blockhouse ranch, south (right) bank of San Saba River, northwestern Mason County. Probably from about 50 feet above base of Threadgill member. Photographs by courtesy of Dr. G. A. Cooper. U.S.N.M.–92874, syntypes.

FIGURES 6–10. *Finkelnburgia* aff. *F. bellatula* Ulrich and Cooper[25a]
6, 10. Exterior (x2, x1) of a dorsal valve.
7. Interior (x2) of a dorsal valve.
8–9. Exterior and interior (x2) of two ventral valves.
All specimens from locality TF–409, about 20 feet above base of Threadgill member, 0.63 mile airline N. 40° W. from center of highway bridge over San Saba River, Bald Ridge area.

FIGURES 11–13. *Ophileta* cf. *O. complanata* Vanuxem
11–12. Lateral and apical views (x1) of two specimens from locality TF–29, near middle of calcitic facies of Staendebach member, 4.62 miles airline N. 37.5° E. from benchmark 1523 at Cherokee, Cherokee area.
13. Umbilical view (x1) of a specimen "tentatively referred to the species" and figured by Knight (1941, pp. 217, 425, Pl. 18, figs. 2b–e). Bridge's locality 36, top of Threadgill member, 5.2 miles airline N. 15° W. from benchmark 1523 at Cherokee, Cherokee area.

FIGURE 14. *Ophileta* aff. *O. supraplana* Ulrich and Bridge
Apical view (x1) of a specimen from locality TF–67, about 12.8 miles by speedometer south-southwest from San Saba and just west of a county road, in the valley of Wallace Creek, San Saba County.

FIGURE 15. *Ophileta* sp.
Umbilical view (x1) of a specimen from locality TF–40a, top of Staendebach member, 6.97 miles airline S. 70° E. from intersection of highways at San Saba, Cherokee area.

FIGURES 16–17. *Ribeiria* aff. *R. calcifera* Billings
Lateral and anterior views (x1) of a specimen from Bridge's locality 66A, upper part of Staendebach member, about 1.5 miles by speedometer west from the ranch headquarters of Mack Yates, Sr., southeastern San Saba County.

FIGURES 18–19. *Ribeiria* sp.
Lateral and anterior views (x1) of a specimen from locality 16T–1–45A, upper part of Staendebach member, 3.25 miles airline east-southeast of Round Mountain, Blanco County.

FIGURES 20–22. *Ectenoceras* spp.
20–21. Ventral and lateral views (x1) of two specimens from locality TF–35, calcitic facies of the Staendebach member, 7.52 miles airline S. 0.5° E from intersection of highways at San Saba, Cherokee area.
22. Lateral view (x1) of a specimen from locality TF–29, near middle of calcitic facies of Staendebach member, 4.62 miles airline N. 37.5° E. from benchmark 1523 at Cherokee, Cherokee area.

FIGURE 23. *Levisoceras* sp.
Lateral view (x1) of a specimen from locality TF–41a, middle third of Threadgill member, 3.72 miles airline N. 16.5° W. from benchmark 1523 at Cherokee, Cherokee area.

FIGURE 24. *Clarkoceras cuneatum* Ulrich, Foerste, and Miller
Ventral view (x1) of a specimen from locality 16T–2–59A, 38 feet below top of Staendebach member in downstream Pedernales River section, Johnson City area.

FIGURE 25. *Clarkoceras* cf. *C. calvini* Ulrich, Foerste, and Miller
Lateral view (x1) of a specimen from locality 16T–6–15A, near top of Steandebach member, 2 miles airline west-northwest from center of Johnson City, Johnson City area.

FIGURES 26–27. *Burenoceras* sp.
Apical and lateral views (x1) of specimens from locality TF–110, middle of Staendebach member, 7.71 miles airline N. 29° E. from benchmark 1523 at Cherokee, Cherokee area.

FIGURES 28–29. *Caseoceras* spp.
28. Lateral view (x1) of a specimen from locality TF–134, about 100 feet below top of Threadgill member, 4.5 miles airline N. 17.5° W. from benchmark 1523 at Cherokee, Cherokee area.
29. Lateral view (x1) of a specimen from locality TF–130, near top of Staendebach member, 6.59 miles airline S. 7° W. from intersection of highways at San Saba, Cherokee area.

[25a]This new species of brachiopod is being described by Cloud (in press) as *Finkelnburgia helleri*.

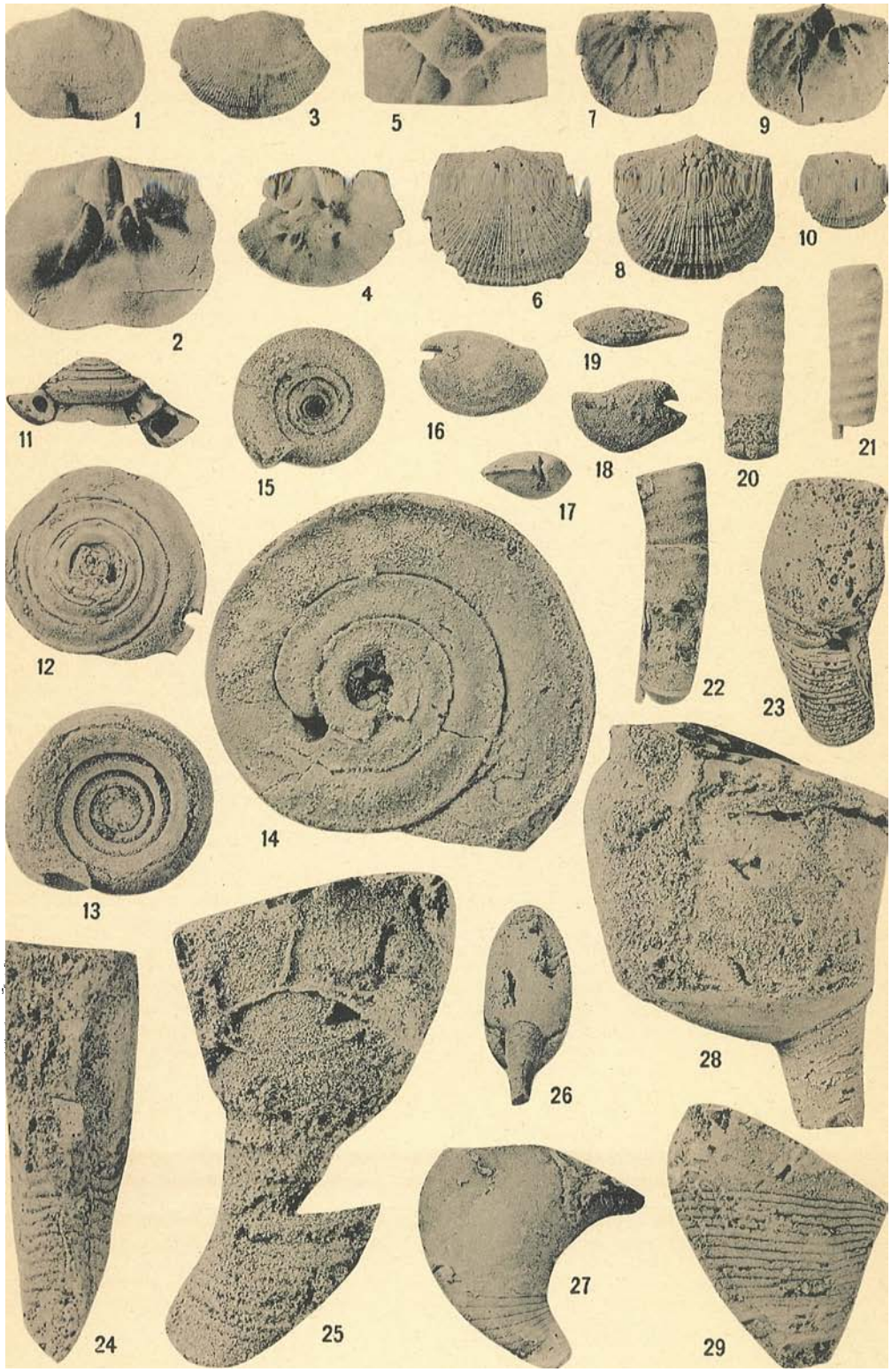
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PLATE 40

Gastropods from the Tanyard formation
(Fig. 14 is x2; all others are x1)

FIGURES 1–2. *Sinuopea cingulata* Ulrich and Bridge
Apical and lateral views of a specimen from Bridge's locality 36, top of Threadgill member, 5.2 miles airline N. 15° W. from benchmark 1523 at Cherokee, Cherokee area.

FIGURES 3–4. *Sinuopea vera* Ulrich and Bridge
Apical and lateral views of a specimen from locality TF–37, calcitic facies of Staendebach member, 7.13 miles airline S. 2° E. from intersection of highways at San Saba, Cherokee area.

FIGURES 5–6. *Sinuopea umbilicata* Ulrich and Bridge
Lateral and apical views of a specimen from locality TF–41a, middle third of Threadgill member, 3.72 miles N. 16.5° W. from benchmark 1523 at Cherokee, Cherokee area.

FIGURE 7. *Sinuopea* aff. *S. umbilicata* Ulrich and Bridge
Lateral view of a specimen from same locality and stratigraphic position as specimen represented by figures 1–2.

FIGURE 8. *Sinuopea* sp.
Lateral view of a high-spired specimen from locality TF–3, probably from the Threadgill member, about 2 miles north of Point Peak on the east side of the old Everett ranch road, northeastern Llano County.

FIGURE 9. *Ozarkina typica* Ulrich and Bridge
Apical view of a specimen from locality 27T–7–56A, upper part of Staendebach member, 4200 feet east-northeast of Tanyard Spring, Tanyard area.

FIGURES 10–13. *Ozarkina* aff. *O. complanata* Ulrich and Bridge
10–11. Apical view and lateral view of transverse median section of specimens from locality TF–35, calcitic facies of Staendebach member of Tanyard formation, 7.52 miles airline S. ½° E. from intersection of highways at San Saba, Cherokee area.
12–13. Apertural and apical views of a specimen from locality TF–397, about 6 to 10 feet below top of Staendebach member in Bald Ridge section, Bald Ridge area.

FIGURE 14. *Gasconadia* cf. *G. putilla* Sardeson
Lateral view (x2) of an internal mold showing the impression of the characteristic flaring aperture at the lower left. Locality TF–110, middle of Staendebach member, 7.71 miles airline N. 29° E. from benchmark 1523 at Cherokee, Cherokee area.

FIGURES 15–20. *Helicotoma uniangulata* (Hall) of authors
15. Apical view of a small specimen from locality TF–27, lower part of Staendebach member, immediately southwest of aggregate quarry of Victoria Gravel Company, north of Sudduth, Burnet County.
16. Transverse section of whorl of a large specimen, showing typical whorl profile slightly impressed by next whorl inside. Locality 16T–1–50C, about 3.25 miles airline north of Round Mountain, Blanco County.
17. Transverse section of whorl of a specimen of average size showing typical whorl profile. Locality TF–116, about 30 feet above base of Staendebach member, 5.18 miles airline N. 4° W. from benchmark 1523 at Cherokee, Cherokee area.
18. Umbilical view of a fragmentary specimen of average size from Bridge's locality 28, near top of Staendebach member, 1.2 miles airline S. 30° E. from south end of Long Waterhole on J. F. Barnes ranch, west end of Ellenburger Hills, southeastern San Saba County.
19–20. Apertural and apical views of a typical well-preserved specimen from same locality and stratigraphic position as specimen represented by figure 18.

FIGURE 21. *Proplina* sp.
Lateral view of a specimen from locality TF–44, about 140 to 170 feet above base of Threadgill member, 4.1 miles airline N. 35.5° E. from benchmark 1523 at Cherokee, Cherokee area.

FIGURES 22–23. *Schizopea typica* (Ulrich and Bridge)
22. Apical view of a specimen from locality 16T–5–13D, about 6.5 miles airline northwest of Round Mountain, Llano County.
23. Apical view of a specimen from same locality and stratigraphic position as specimen represented by figures 1–2.

FIGURES 24–26. *Schizopea grandis* (Ulrich and Bridge)
24. Umbilical view of a specimen from locality TF–62, lower part of Staendebach member, 4.32 miles airline N. 36° E. from benchmark 1523 at Cherokee, Cherokee area.
25. Lateral view of a specimen from locality TF–88, dolomitic facies of Threadgill member, 4.0 miles airline N. 46° E. from benchmark 1523 at Cherokee, Cherokee area.
26. Apical view of a specimen from locality 16T–2–57A, Staendebach member, 2.75 miles airline north-northeast from center of Johnson City, Johnson City area.

FIGURE 27. *Lytospira gyrocera* (Roemer)
Three specimens and fragments of others on a piece of rock from Bridge's locality 135, Threadgill member, south (right) bank of San Saba River, 0.5 to 0.6 mile east of crossing of Hext-Brady road, northwestern Mason County. The lower and best preserved specimen is in correct orientation for an apical view.

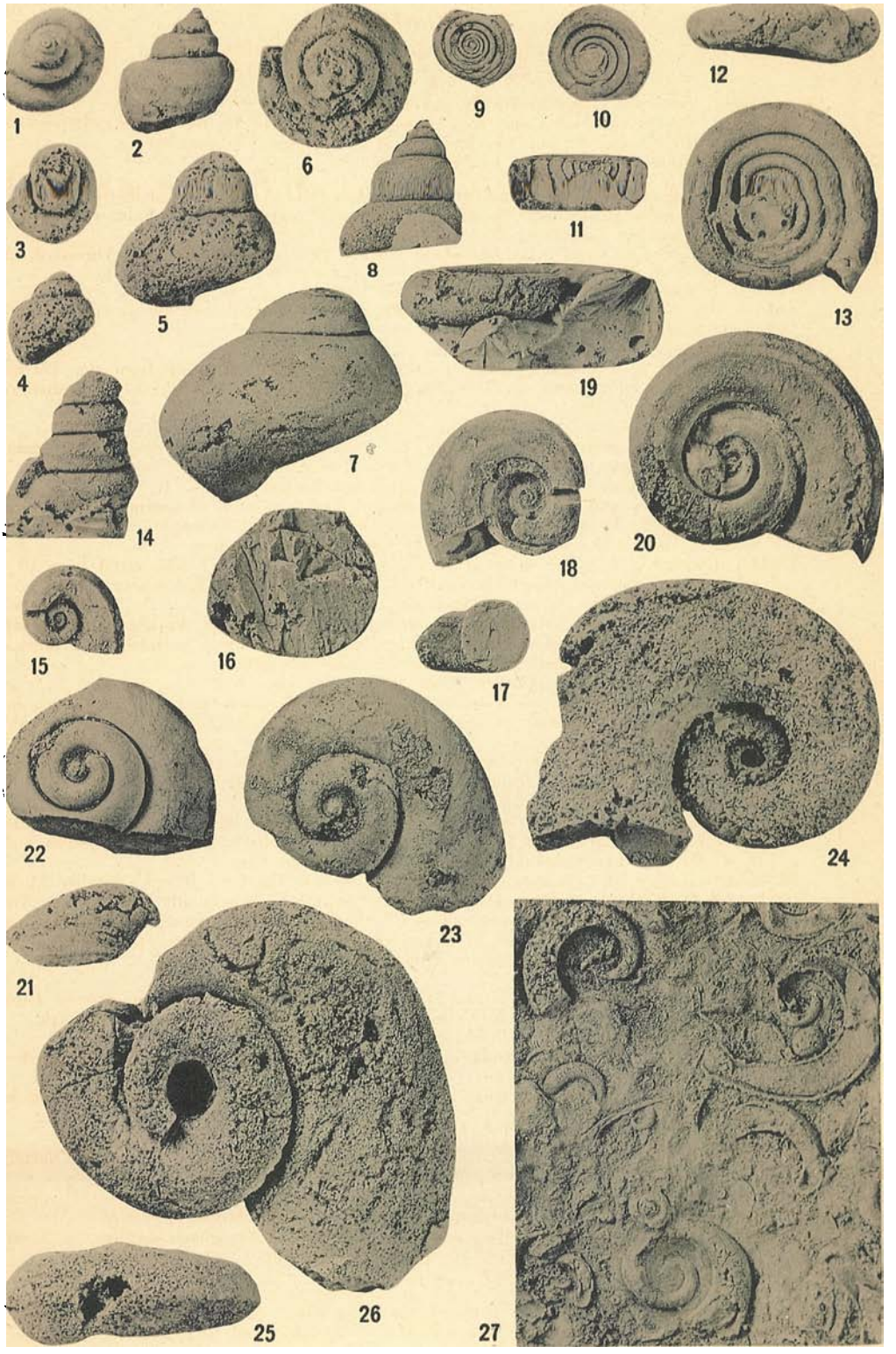
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PLATE 41

Fossils from the Gorman formation

FIGURES 1–5. *Syntrophina campbelli* (Walcott)

1. Impression of a ventral interior (x2) from locality TF–170, about 90 to 110 feet above base of formation, 3800 feet airline S. 25° W. from Bear Spring, Bear Spring area.
2, 4–5. Impressions of ventral interior and two dorsal interiors (all x2) from Bridge's locality 50, about 40 feet above base of formation, 6.87 miles airline S. 11.5° W. from intersection of highways at San Saba, Cherokee area.
3. Impression of a dorsal interior from locality TF–171, about 70 to 90 feet above base of formation, 6100 to 6200 feet airline S. 40° W. from Bear Spring, Bear Spring area.

FIGURES 6–10. *Diaphelasma pennsylvanicum* Ulrich and Cooper

6–7, 9–10. Ventral interior (x1), anteroventral view (x2) of dorsal interior, anterodorsal view (x1) of ventral interior, and dorsal interior (x1) of four specimens. Locality 16T–2–42E, 46 feet below top of formation in upstream Honeycut Bend section, Johnson City area.

8. Dorsal view (x2) of a complete specimen from locality TF–251, about 60 feet below top of formation, 2400 feet N. 65° W. from Gorman Falls, Gorman Falls area.

FIGURES 11–16. *Diaphelasma oklahomense* Ulrich and Cooper

11–12, 15–16. Anterior and posterior views (x1) of complete and nearly complete specimens, anteroventral view (x2) of dorsal interior, and anterodorsal view (x2) of ventral interior. Locality 16T–2–41A, 86 feet below top of formation as traced south into upstream Honeycut Bend section, Johnson City area.

13–14. Two dorsal exteriors (x2) from locality 16T–2–42C, 86 feet below top of formation in upstream Honeycut Bend section, Johnson City area.

FIGURES 17–20. *Syntrophinella* aff. *S. typica* Ulrich and Cooper[25b]

17–19. Dorsal exterior, ventral interior, and ventral exterior (all x2) of three specimens. Locality 205T–1–20A, above zone of *Archaeoscyphia*, 9500 feet south of Gorman Falls, 2400 feet northwest of Clark Spring and 300 feet northwest of a sharp bend in Clark Branch of Spicewood Creek, San Saba County.

20. Dorsal exterior (x2) of a specimen from locality TF–250, just above zone of *Archaeoscyphia*, 220 feet below top of formation in Gorman Falls section, Gorman Falls area.

FIGURE 21. Patelliform gastropod aff. *Proplina*

Lateral view (x1) of a specimen from locality TF–133, basal 5 feet of formation, 5.93 miles airline S. 9° W. from intersection of highways at San Saba, Cherokee area.

FIGURES 22–23. *Proplina* sp.

Dorsal and lateral views (x1) of a specimen from locality TF–125, upper part of formation, 3.16 miles airline S. 22° E. from intersection of highways at San Saba, Cherokee area.

FIGURE 24. *Plethospira* sp.

Lateral view (x1) of a specimen from TF–124, upper part of formation, 3.33 miles airline S. 26.5° E. from intersection of highways at San Saba, Cherokee area.

FIGURES 25–27. *"Euconia"* sp.

Two lateral views and an apical view (all x1) of three specimens from same locality as specimen represented by figure 24.

FIGURES 28–31. *Rhombella umbilicata* (Ulrich and Bridge)

28–30. Lateral and umbilical views (x1) of two specimens and whorl profile (x1) of a third specimen from locality TF–179, basal beds of formation, 5000 feet S. 55° W. from Bear Spring, Bear Spring area.

31. Lateral view (x1) of a specimen from TF–121, base of formation, 5.84 miles airline S. 1° E. from intersection of highways at San Saba, Cherokee area.

FIGURES 32–33. *Hystricurus* sp.

Cranidium and pygidium (both x2) from locality TF–143, *Archaeoscyphia* zone, 7.58 miles airline S. 53.5° E. from intersection of highways at San Saba, Cherokee area.

FIGURE 34. *Lecanospira* sp.

Apical view (x1) of a specimen from locality 16T–2–31B, about 30 feet below top of formation, 7.45 miles N. 58° E. from juncture of highways at Johnson City, Johnson City area.

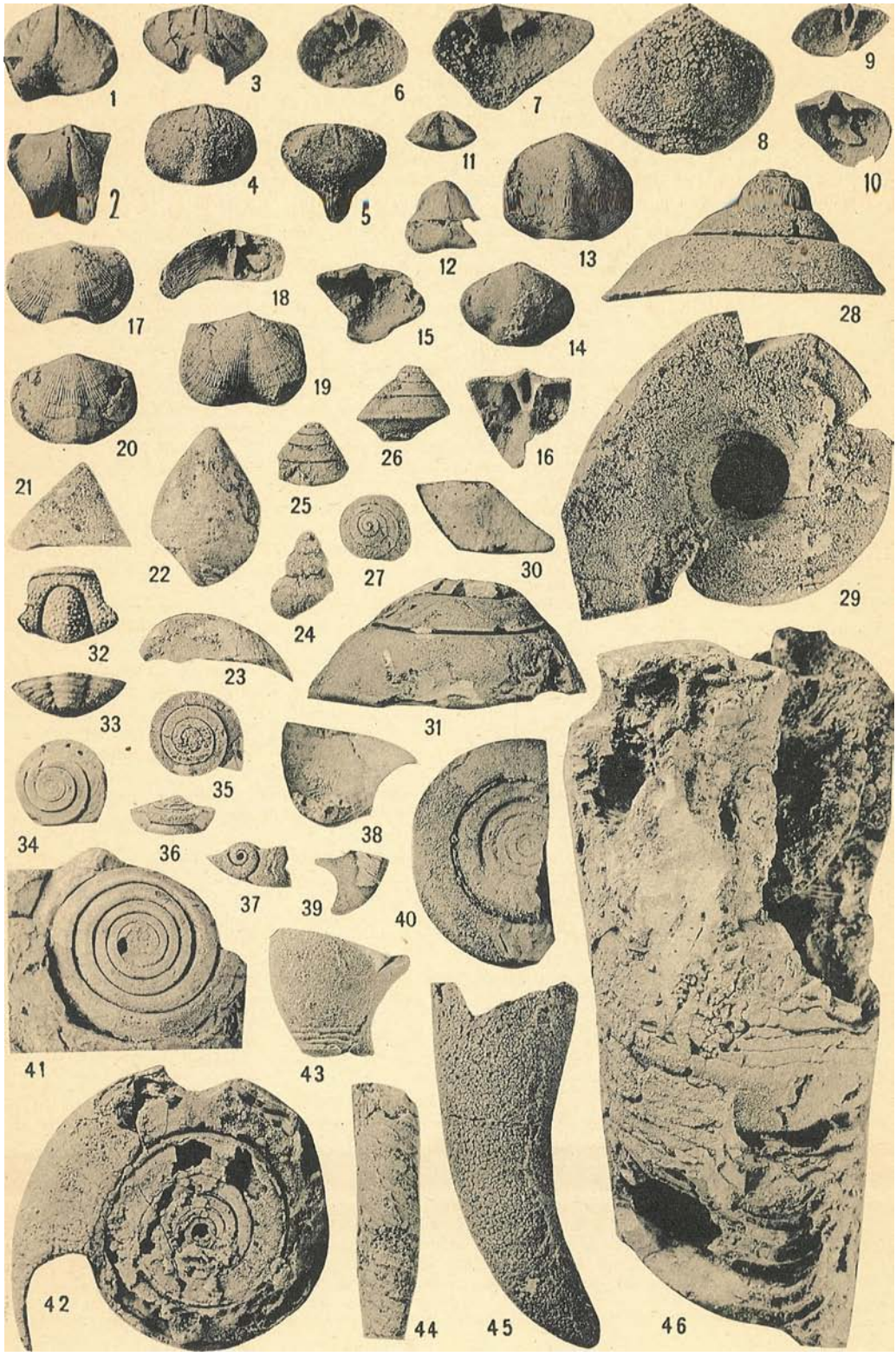
FIGURES 40–42. *Lecanospira sanctisabae* (Roemer)

40. Basal view (x1) of a fragmentary specimen from locality TF–90, about 200 to 210 feet above base of formation as projected northwest into Cherokee Creek section, Cherokee area.

41. External impression (x1) of the hyperstrophic spire. Specimen from locality TF–293, from float found 398 feet above base of formation in Rattlesnake Hill section, Bear Spring area.

42. Basal view (x1) of a silicified shell which shows the aperture. Locality 16T–2–42C, 86 feet below top of formation in upstream Honeycut Bend section, Johnson City area.

[25b]This new species of brachiopod is being described by Cloud (in press) as *Syntrophinalla warreni.*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FIGURES 35–36. *Ophileta* sp.
Apical view (x1) of a nearly complete specimen and lateral view (x1) of a partially sectioned specimen showing whorl profile. Locality TF–276, lower part of formation, 2.1 miles airline southeast from Gorman Falls at the southwest edge of the Colorado River floodplain, Gorman Falls area.

FIGURE 37. *Chepultapecia* sp.
Apical view (x1) of a specimen from locality TF–133, base of formation, 5.93 miles airline S. 9° W. from intersection of highways at San Saba, Cherokee area. This genus ranges into slightly higher beds as well as into the Tanyard formation below.

FIGURES 38–39. *Burenoceras* sp.
Lateral views (x2, x1) of a chert mold and of a plasticene replica of the exterior from same locality as specimens represented by figures 32–33.

FIGURE 43. *Burenoceras* (?) sp.
Lateral view (x1) of a specimen from same locality as specimen represented by figure 31.

FIGURE 44. *Mcqueenoceras* (?) or *Clitendoceras* (?) sp.
A siphuncle (x1) from same locality as specimens represented by figures 32–33.

FIGURE 45. *Piloceras* aff. *P. hornei* Ulrich, Foerste, and Miller
Lateral view (x1) of a siphuncle from same locality as specimen represented by figure 40.

FIGURE 46. *Clitendoceras* (?) sp.
Lateral view of a specimen from same locality as specimens represented by figures 32–33.

PLATE 42

Fossils from the Honeycut formation

FIGURES 1–8. *Xenelasma syntrophioides* Ulrich and Cooper

1–2, 6. Dorsal view (x1) and ventral view (x2) of a complete specimen, and internal view (x2) of a dorsal valve. From locality TF–140, the specimens actually having been taken from the top surface of the uppermost bed of the Gorman formation, 3.54 miles airline S. 9.5° W. from intersection of highways at San Saba, Cherokee area.

3–4. Dorsal and anterodorsal views (x2) of a ventral interior from locality TF–127, the specimens actually having been taken from the top surface of the uppermost bed of the Gorman formation, 4.26 miles airline S. 55° E. from intersection of highways at San Saba, Cherokee area.

5. Anterior view (x2) of a robust specimen from locality TF–378, about 10 feet above base of Honeycut formation, in Warren Springs section, Warren Springs area.

7–8. Impressions of ventral and dorsal interiors (x2) from locality TF–238, lower beds of Honeycut formation, about 9 miles airline S. 40° E. from the courthouse at Llano and 100 feet south of Honey Creek, Riley Mountains, Llano County.

FIGURE 9. *Finkelnburgia cullisoni* Ulrich and Cooper

Incomplete ventral interior (x1) from locality 27T–9–44D, 297 feet above base of formation, 2 miles west of Longhorn Cavern, Backbone Mountain area.

FIGURES 10–15. *Rananasus conicus* Cullison

10–13. Lateral and anterior views (x2) and dorsal views (x1, x2) of a cranidium from locality TF–22, *Ceratopea capuliformis* zone, 2.66 miles airline S. 36.5° E. from intersection of highways at San Saba, Cherokee area.

14–15. Posterior and dorsal views (x2) of a pygidium from locality TF–81a, just below *Ceratopea capuliformis* zone, 4.2 miles airline N. 57.5° E. from benchmark 1523 at Cherokee, Cherokee area.

FIGURES 16–18. *Rananasus* aff. *R. brevicephalus* Cullison

Anterior view (x2) and dorsal views (x2, x1) of a cranidium from locality TF–147, about 60 feet above base of formation, 7.2 miles airline S. 58° E. from intersection of highways at San Saba, Cherokee area.

FIGURE 19. *Jeffersonia* cf. *J. missouriensis* Cullison*

Pygidium (x1) from locality 16T–2–31A, about 150 feet above base of formation, 7.95 miles N. 62° E. from juncture of highways at Johnson City, Johnson City area.

FIGURE 20. *Jeffersonia granosa* Cullison

Pygidium (x1) from locality TF–242, *Ceratopea capuliformis* zone, 2.3 miles N. 1° W. from the headquarters of the J. F. Barnes ranch in southeastern San Saba County.

FIGURE 21. *Jeffersonia* sp.

Cranidium from locality TF–91, just below *Ceratopea capuliformis* zone, 5.23 miles airline N. 43° E. from benchmark 1523 at Cherokee, southeast block of Cherokee area.

FIGURES 22–23. *Jeffersonia* cf. *J. producta* Cullison

Chert cast and plasticene replica (both x1) of two incomplete cranidia suggesting this species. Same locality as specimen represented by figure 19.

FIGURE 24. *Bolbocephalus* aff. *B. jeffersonensis* Cullison

Pygidium (x1) from locality TF–22a, *Ceratopea capuliformis* zone, 2.7 miles airline S. 36° E. from intersection of highways at San Saba, Cherokee area.

FIGURE 25. *Bolbocephalus* cf. *B. jeffersonensis* Cullison

Pygidium (x1) from locality TF–102, about 70 feet above base of formation in Cherokee Creek section, Cherokee area.

FIGURES 26–27, 30, 34. *Mcqueenoceras* spp.

26. Siphuncle (x1) from locality 257, *Ceratopea robusta* zone, 5800 feet airline N. 47° W. from Gorman Falls, Gorman Falls area.

27. Siphuncle (x1) from locality TF–269, about 466 feet above base of formation, near bottom of Honeycut Bend, downstream Honeycut Bend section, Johnson City area.

30. Siphuncle (x1) from locality TF–15, *Ceratopea capuliformis* zone, 5.92 miles airline S. 15.5° W. from intersection of highways at San Saba, Cherokee area.

34. Incomplete specimen (x1) from locality TF–254, about 70 feet above base of formation, 5200 feet airline N. 51° W. from Gorman Falls, Gorman Falls area.

FIGURE 28. *Allopiloceras* sp.

Lateral view (x1) of a siphuncle from locality TF–246, zone of *Ceratopea* sp. 5, north bank of Pillar Bluff Creek, 5500 feet airline due south from a point 6.17 miles by speedometer west-southwest from the courthouse at Lampasas, northern Burnet County.

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*This report interprets *Jeffersonia* in the broad sense of Cullison (1944). The name might well have been written in quotation marks throughout, for the fossils included under it need restudy and perhaps subdivision and reassignment. Reuben Ross (letter to Cloud, Dec. 1947) points out that *Elutherocentrus* Clark 1935 (Jour. Paleont., p. 243) is also involved in the question.

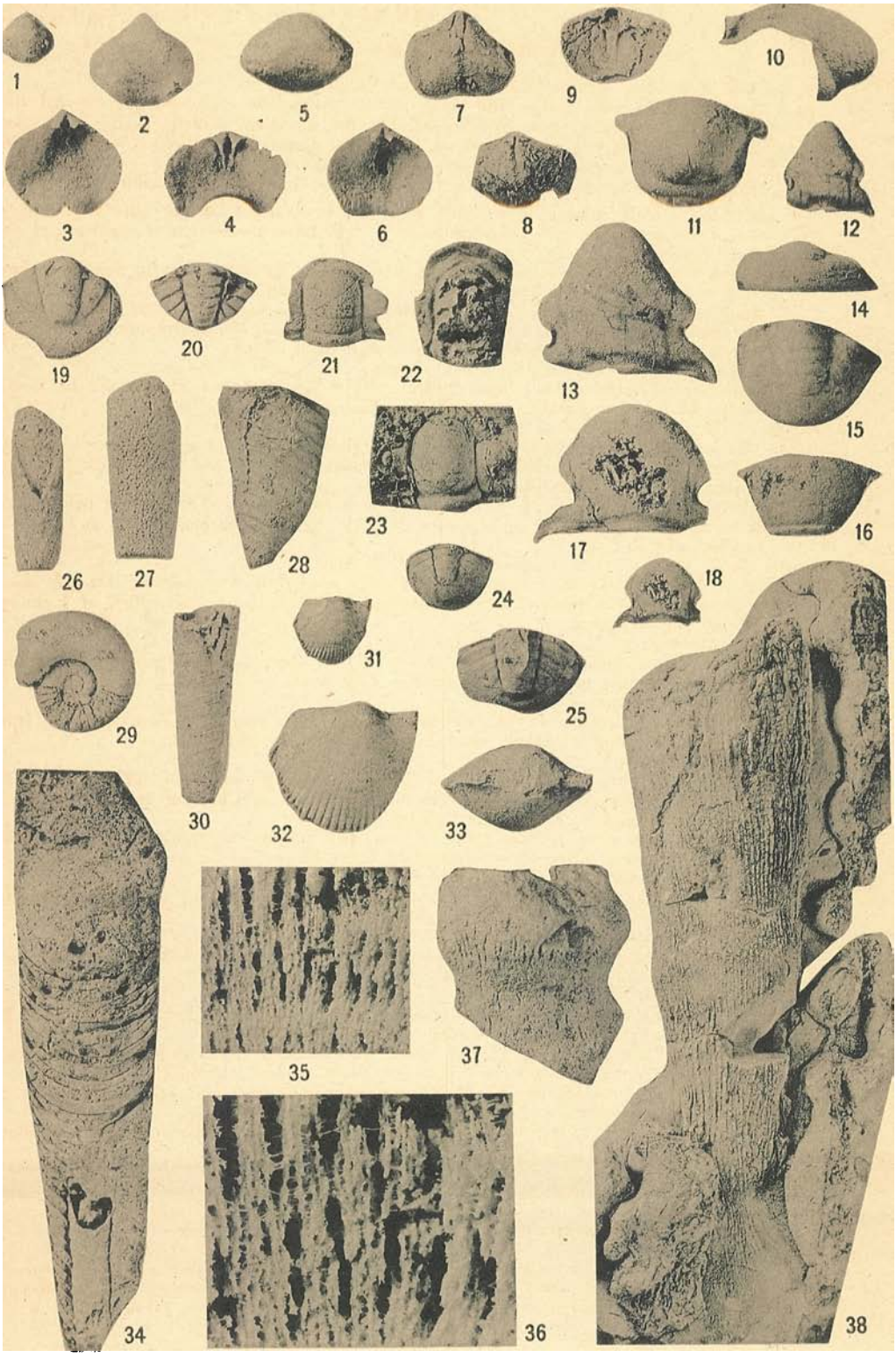
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FIGURE 29. *Moreauoceras milleri* Cullison
Lateral view (x1) of a specimen from locality TF–244, *Ceratopea capuliformis* zone, along a pasture road about 2.8 miles airline N. 1° W. from headquarters of J. F. Barnes ranch, northwest of Ellenburger Hills, southeastern San Saba County.

FIGURES 31–33. *Eopteria* aff. *E. typica* Billings
Lateral views (x1, x2) and top view (x2) of a specimen from locality TF–243, *Ceratopea capuliformis* zone, about 2.5 miles airline N. 1° W. from headquarters of J. F. Barnes ranch, northwest of Ellenburger Hills, southeastern San Saba County.

FIGURES 35–38. *Archaeoscyphia annulata* Cullison
35–37. Lateral views (x3, x6) of inner wall and similar view (x1) of outer wall of two fragments from locality 27T–9–45E, 197 feet above base of formation, 2.5 miles airline west-southwest of Longhorn Cavern, Backbone Mountain area.
38. Lateral view (x7/12) of a specimen in which the wall is calcitic, with a core of chert representing the paragastral cavity and the exterior of the undulating wall mirrored by a sheath of chert. Locality 16T–2–42A, about 330 feet above base of formation, 5 miles airline east of Johnson City within the loop of Honeycut Bend, Johnson City area.

PLATE 43

Fossils from the Honeycut formation
(Figs. 2–4, 26–28, 31–32 are x2; remainder are x1)

FIGURES 1–4. *Ceratopea* sp. [126]
Figures 1–3 are views (x1, x2) of the same specimen in two orientations; figure 4 (x2) is a second specimen in a different orientation. Locality TF–265, about 30 to 50 feet above base of formation, valley of Slickrock Creek, 1.83 miles airline south from a point about 7 miles by speedometer west-southwest of Marble Falls, southeastern corner of Llano County.

FIGURES 5–10. *Ceratopea capuliformis capuliformis* Oder (sp. 2)
5. View (x1) of a specimen from locality TF–282, thought to be about 180 feet above base of formation, 3.2 miles airline north from Long Waterhole on the J. F. Barnes ranch, southeastern San Saba County.
6, 9, 10. Three views (x1) of a specimen from locality 205T–1–17A, 218 feet above base of Honeycut formation, in Gorman Falls section.
7, 8. Two views (x1) of a *small* specimen from locality TF–15, thought to be about 140 feet above base of formation, 5.92 miles airline S. 15.5° W. from intersection of highways at San Saba, Cherokee area.

FIGURES 11–13. *Ceratopea capuliformis robusta* Oder (sp. 3)
11, 12. Two views (x1) of a specimen from locality TF–257, about 242 feet above base of formation, 5800 feet N. 47° W. from Gorman Falls, Gorman Falls area.
13. View (x1) of a specimen from locality TF–215, thought to be about 220 feet above base of formation, about 9 miles airline S. 40° E. from the courthouse at Llano, valley of Honey Creek in the Riley Mountains, Llano County.

FIGURES 14–17. *Ceratopea* sp. 4.
14. View (x1) of a specimen from locality TF–258, about 260 feet above base of formation, 5900 feet airline N. 47° W. from Gorman Falls, Gorman Falls area.
15. View (x1) of a specimen from locality TF–280, thought to be about 200 to 220 feet above base of formation, 3600 feet airline N. 62° W. from stock-guard at juncture of Cherokee-Chappel road with San Saba-Chappel road, southeastern San Saba County.
16, 17. Two views (x1) of a specimen from locality TF–239, thought to be about 180 to 210 feet above base of formation, 8.5 miles airline S. 17° W. from Naruna and 3.8 miles airline S. 25° E. from the Goodrich ranch headquarters, Burnet County.

FIGURES 18–21. *Ceratopea* sp. 5.
18. View (x1) of a specimen from locality 27T–10–4A, position in formation not estimated, 3.25 miles south of Marble Falls along west side of U.S. highway 281, Burnet County.
19, 21. Two views (x1) of a specimen from locality 16T–2–51C, 282 feet above base of formation on projection southwest into Rough Hollow section, Johnson City area.
20. View (x1) of a specimen from same locality as specimen represented by figure 15.

FIGURES 22–24. *Ceratopea keithi subconica* Oder (sp. 6)
22, 23. Two views (x1) of a specimen from locality 16T–2–33E, about 550 to 600 feet above base of formation, 3500 feet airline north of the mouth of Miller Creek, Johnson City area.
24. View (x1) of a specimen from locality TF–269, about 466 feet above base of formation, near bottom of Honeycut Bend, downstream Honeycut Bend section, Johnson City area.

FIGURE 25. *"Ophileta"* sp.
Apical view (x1) of a specimen from locality TF–244, *Ceratopea capuliformis* zone, along a pasture road about 2.8 miles airline N. 1° W. from headquarters of J. F. Barnes ranch, northwest of Ellenburger Hills, southeastern San Saba County.

FIGURES 26–30. *Orospira* spp.
26–28. Apical view (x2) and apical and umbilical views (x2) of specimens from locality TF–142, thought to be about 40 to 60 feet above base of formation, 3.05 miles S. 4.5° E. from intersection of highways at San Saba, Cherokee area.
29–30. Views (x1) of plasticene replicas of the umbilical surface and part of the upper surface of a large, ornate species. Locality TF–5, thought to be about 200 to 225 feet above base of formation, about 1.3 miles by speedometer southeast from Cherokee-Chappel road on south side of road to ranch headquarters of Mack Yates, Sr., southeastern San Saba County.

FIGURE 31. *Orospira depressa* Cullison
Apical view (x2) of a specimen from locality TF–19, lower beds of formation, 3.70 miles airline S. 10.5° W. from intersection of highways at San Saba, Cherokee area.

FIGURE 32. *"Euconia"* sp.
Lateral view (x2) of a specimen from same locality as specimens represented by figures 26–28.

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[126]The figures of *Ceratopea* here given are oriented as though they were of capulid gastropods. For proper orientation of *Ceratopea*, see Ulrich and Bridge *in* Shimer and Shrock (1944, Pl. 181, figs. 5–16).

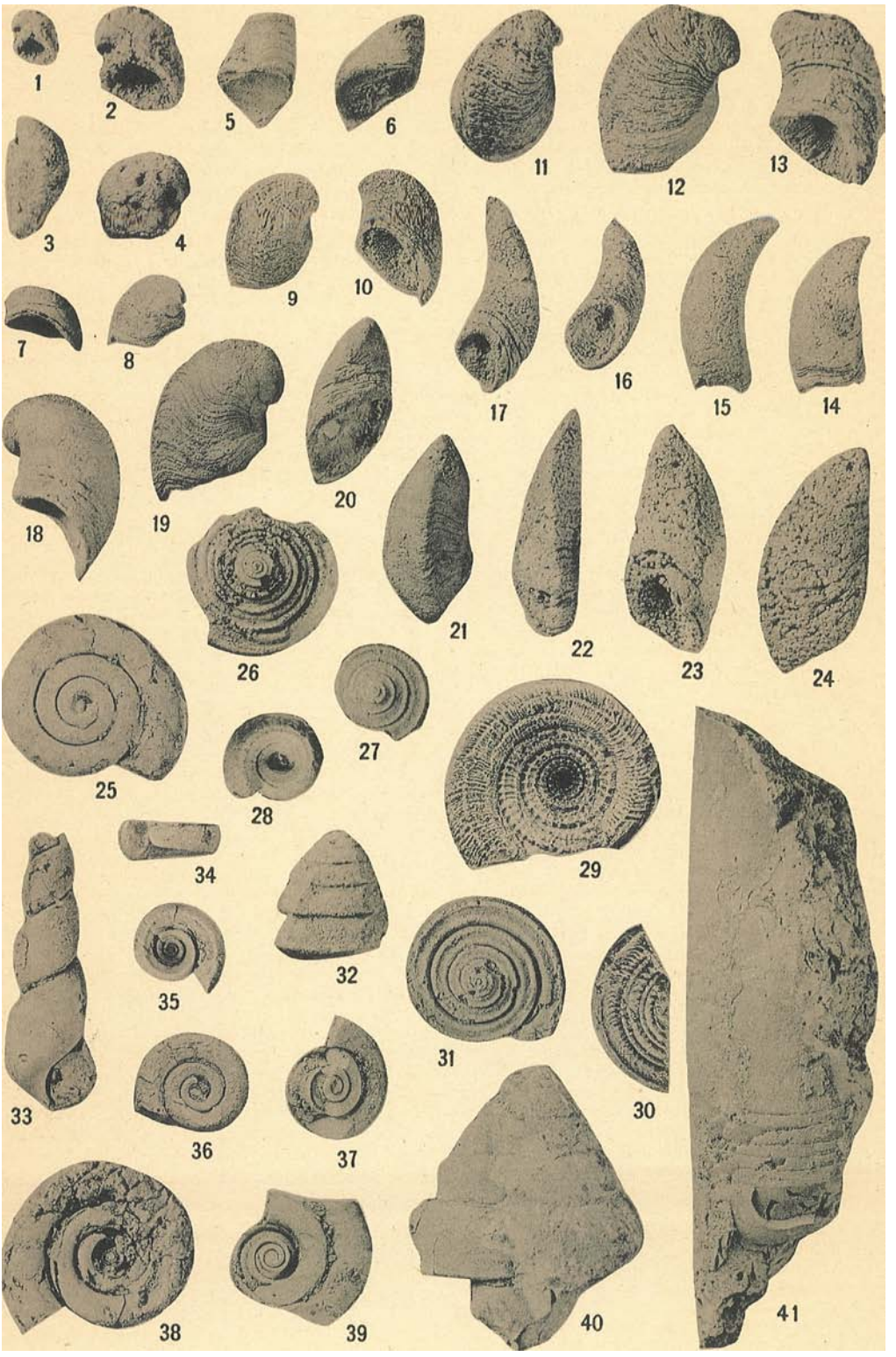
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FIGURE 33. *Hormotoma* sp.
Lateral view (x1) of a specimen from same locality as specimen represented by figure 5.

FIGURES 34–39. *Barnesella lecanospiroides* Bridge and Cloud
Lateral, apical, basal, oblique lateral, and two basal views (all x1) of specimens, some fragmentary, showing various features of this widely occurring hyperstrophic (pseudosinistral) shell. Although general appearances suggest *Lecanospira*, the whorl profile and probably the aperture is macluritiform. Same locality as specimen represented by figure 25. Figure 38 is of the holotype; the other figures are of paratypes.

FIGURE 40. *Euconia* aff. *E. etna* (Billings)
Lateral view (x1) of a specimen from locality 205T–1–17A, 218 feet above base of formation in Gorman Falls section, Gorman Falls area.

FIGURE 41. *Cotteroceras ?* sp. (or laterally compressed *Cyptendoceras)*
Lateral view (x1) of a specimen from same locality as that represented by figure 5.

PLATE 44

Fossils from beds above the Ellenburger group

(Fig. 34 is x3; figs. 33, 35–40 are x2; remainder are x1)

Fossils from Devonian rocks (Stribling formation), figures 1–11

FIGURES 1–6. *Leptocoelia* aff. *L. flabellites* (Conrad)
Ventral, dorsal, ventral interior, dorsal interior, anterior, and lateral views (all x1) of four specimens from locality 16T–2–43N, Honeycut Hollow, 4.5 miles airline east of Johnson City, Johnson City area (figs. 1, 2, and 6 are of a single specimen).

FIGURES 7–9. *Eodevonaria arcuata* (Hall)
Figures 7–8 are lateral and ventral views of a specimen from between 118 to 133 inches above base of formation; figure 9 is a ventral view of a specimen from between 11.5 to 25 inches above base of formation in type section of Stribling formation. Locality 16T–2–43M, bottom of Honeycut Hollow, 5 miles airline east of Johnson City, Johnson City area.

FIGURES 10–11. *Schuchertella* cf. *S. woolworthana* (Hall)
Ventral and dorsal views of a specimen from between 80 to 87 inches above base of formation at same locality as specimens represented by figures 7–9.

Fossils from Mississippian rocks, figures 12–42

FIGURES 12–16. *Sedenticellula* aff. *S. hamburgensis* (Weller)
Anterior, ventral, two dorsal, and ventral views (all x1) of three specimens from locality 16T–2–27A_{1a}, stratum thought to be correlative with Glen Park limestone, about 3800 feet northeast of Elm Pool, Johnson City area (figs. 12 and 14 of a single specimen; figs. 15 and 16 of a single specimen).

FIGURES 17–21. *Shumardella obsolens* Weller
Ventral, two dorsal, lateral, and anterior views (all x1) of five specimens from locality TF–406, Chappel limestone, about 2900 feet N. 39° W. from the peak of Bald Ridge and the windmill called High Lonesome, Bald Ridge area.

FIGURES 22–23, 26. *Plicatifera* aff. *P. calhounensis* (Moore)
22–23. Ventral views (x1) of a specimen from locality TF–392, Chappel limestone, about 1.76 miles N. 60° E. from the mouth of Lost Creek on the north (left) bank of San Saba River, southeastern McCulloch County.
26. Ventral view (x1) of an incomplete large specimen from Chappel limestone at same locality as specimens represented by figures 17–21.

FIGURES 24–25, 27. *Brachythyris chouteauensis* Weller
Lateral and ventral views (x1) of two specimens from Chappel limestone at same locality as specimens represented by figures 17–21 (figs. 24–25 of same specimen).

FIGURES 28–32. *Leiorhynchus carboniferum* Girty
Ventral, lateral, two dorsal, and ventral views (all x1) of five specimens from about 75 to 83 feet above base of Barnett formation. Locality TF–422, about 5000 feet N. 54° W. from the crossing over Honey Creek of the county road from Mason to White's Crossing, Bear Spring area.

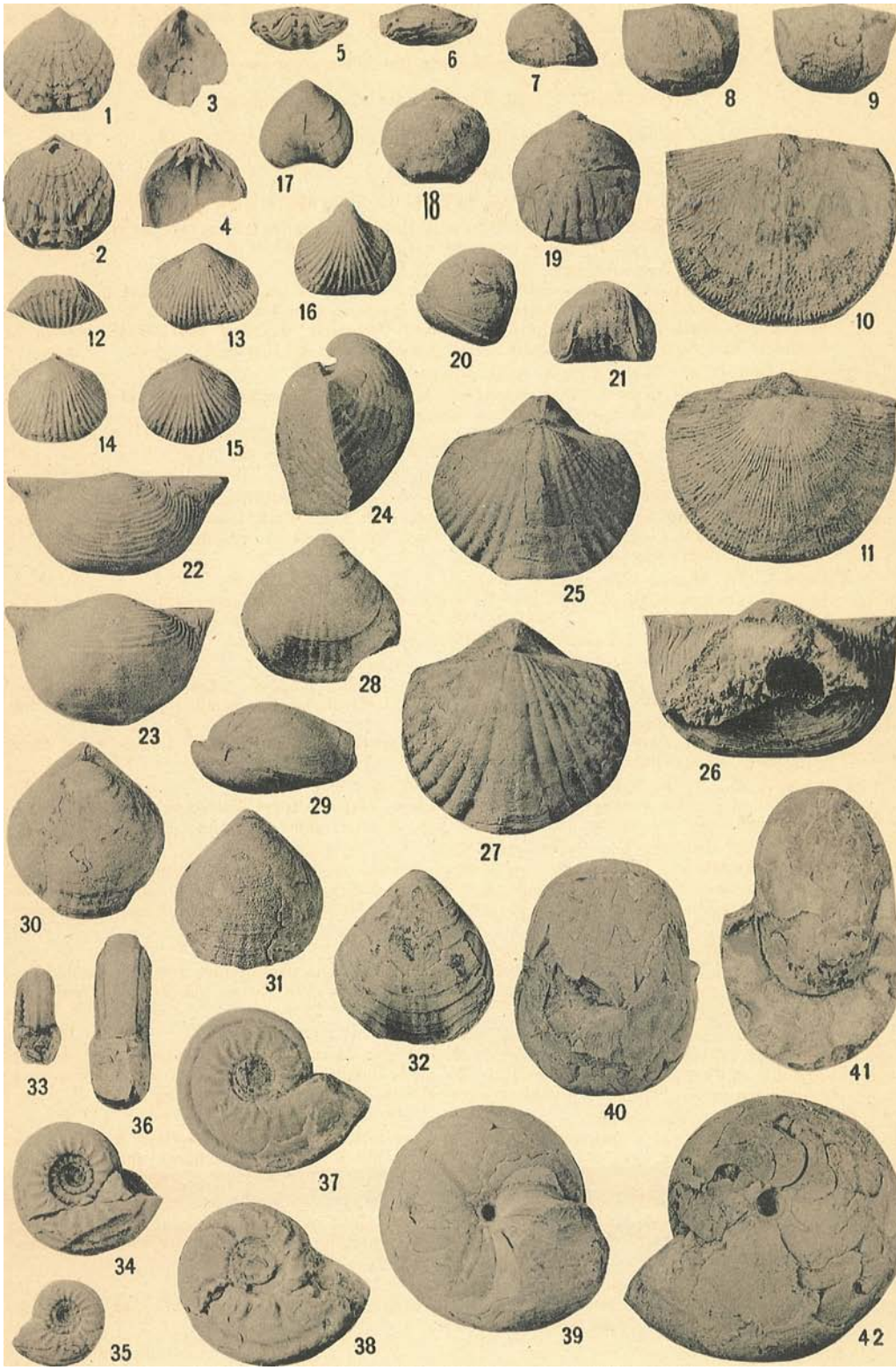
FIGURES 33–35. *Eumorphoceras bisulcatum* Girty
Three views (x2, x3, x2) of an immature specimen from same stratigraphic position and locality as specimens represented by figures 28–32. *Goniolobocera*s (?; *see* pp. 55–56) and *Goniatites* occur in the same beds.

FIGURES 36–37. *Eumorphoceras* aff. *E. bisulcatum* Girty
Two views (x2) of a specimen from about 36 feet above base and 14 feet below top of Barnett formation at Plummer and Scott's locality 205–T–24, about 2.61 miles S. 35° E. from intersection of highways at San Saba, Cherokee area (west of locality TF–22, not marked on map).

FIGURE 38. *Eumorphoceras* sp.
Lateral view (x2) of a specimen from a loose concretion thought to be derived from a ledge about 8 feet above base of Barnett formation, same locality as specimens represented by figures 36–37.

FIGURES 39–40. *Goniatites cumminsi* (Hyatt)
Two views (x2) of a specimen from same stratigraphic position and locality as specimen represented by figures 36–38. Note cancellate ornamentation of shell substance to right of umbilicus in figure 39.

FIGURES 41–42. *Goniatites* cf. *G. cumminsi* (Hyatt)
Two views (x1) of a specimen from same stratigraphic position and locality as specimens represented by figures 28–32 and 33–37.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Index map of central Texas showing location of areas where the formations of the Ellenburger group have been mapped.

EXPLANATION

- Qal — Alluvium
- Qt — Travertine
- Qtg — Terrace gravel

QUATERNARY

Pennsylvanian / Mississippian

- Cp — Strawn formation, Smithwick shale, and Marble Falls limestone (unrestricted) *(Sandstone, siltstone, shale, and cherty limestone)*

UNCONFORMITY

- Cm — Barnett formation, Chappel limestone, and Ives breccia *(Gray shale, crinoidal gray limestone, and chert breccia)*

CARBONIFEROUS

UNCONFORMITY

Lower Ordovician / Ellenburger group

- Oh — Honeycut formation *(Showing principal Archaeoscyphia bed, Oha. Thinly to thickly bedded, cherty limestone and dolomite; dolomite predominantly fine grained to microgranular)*
- Og(ca), Oga, Og(mg) — Gorman formation *(Showing calcitic, Og(ca), and dolomitic, Og(mg), facies, and principal Archaeoscyphia bed, Oga. Thickly to thinly bedded, cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)*

Tanyard formation

- Ot(ca), Ot(mg) — Staendebach member *(Showing calcitic, Ot(ca), and dolomitic Ot(mg), facies. Thickly to thinly bedded, cherty limestone and dolomite; dolomite predominantly fine to medium grained)*
- Ot(mg), Ot(ca) — Threadgill member *(Showing dolomitic, Ot(mg), and calcitic, Ot(ca), facies. Thickly to thinly bedded, sparingly cherty dolomite and limestone; dolomite predominantly medium to coarse grained)*

ORDOVICIAN

DISCONFORMITY

Upper Cambrian / Wilberns formation

- €wp — Pedernales dolomite member *(Thickly to thinly bedded, sparingly cherty, predominantly fine to very fine grained)*
- €ws — San Saba limestone member *(Granular to sublithographic, moderately glauconitic, gray)*
- €p, €w — Point Peak shale, Morgan Creek limestone, and Welge sandstone members *(Showing Plectotrophia bed, €p, in Point Peak shale. Green shale; gray to pink, glauconitic limestone; and brown, sparingly glauconitic sandstone)*

CAMBRIAN

Known, concealed, and inferred fault *(U, upthrown side; D, downthrown side)*

Observed and inferred contact

Laterally gradational contact *(Diagrammatic)*

Collapse contact

Strike and dip of beds

Horizontal beds

Vertical beds

Prevailing dip of beds

+ TF-22 — Locality of fossil collection

F — Fossils noted but not collected

Line of described section, showing offset *(S, undescribed supplementary section)*

Carlos Ashley — Fence, showing identical contiguous ownership

Windmill

Corrals, or pens

T — Tank *(Earth-dammed pond for water storage)*

Base from U.S. Department of Agriculture, Agricultural Adjustment Administration, aerial photographs flown by Kargl Aerial Surveys, Ltd., 1938.

Geology by P. E. Cloud, Jr., and R. L. Heller 1943–1944

GEOLOGIC MAP OF THE CHEROKEE AREA, SAN SABA COUNTY, TEXAS

Scale

1 ½ 0 1 Mile

5000 2000 0 5000 Feet

GEOLOGIC MAP OF THE JOHNSON CITY AREA, BLANCO COUNTY, TEXAS

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by Virgil E. Barnes and Lincoln E. Warren 1942–1944

Scale

1 ½ 0 1 Mile

5000 2000 0 5000 Feet

EXPLANATION

QUATERNARY

Qal — Alluvium

Qtg — Terrace gravel

CRETACEOUS

Lower Cretaceous

Comanche series

Trinity Peak formation of Hill 1901

Kgr — Glen Rose limestone
(Alternating beds of limestone, marl, and clay)

Ktph — Hensell sand member
(Red and gray, with conglomerate at base)

DISCONFORMITY

Ktpcc — Cow Creek limestone member
(Massive, cliff-forming, fossil coquina)

Ktps — Sycamore sand member
(Poorly sorted, with conglomerate abundant)

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian

Marble Falls limestone (unrestricted)

Cmf(u) — Upper massive limestone
(Gray to black, in part cherty, with minor black shale)

Cmf(sp) — Calcareous spiculite
(Fissile, dark gray to black)

UNCONFORMITY

Cmf(l) — Lower biohermal limestone
(Dark gray, with irregular black shale lenses)

UNCONFORMITY

Mississippian

Cb — Barnett formation
(Yellow weathering shale)

UNCONFORMITY

Cc — Chappel limestone
(Crinoidal, medium gray)

DISCONFORMITY

Ci — Ives breccia
(Fragmental chert, in part with calcareous matrix)

DEVONIAN

Lower or Middle Devonian

UNCONFORMITY

Ds — Stribling formation
(Limestone and chert)

Lower Devonian (?)

UNCONFORMITY

Dp — Pillar Bluff (?) limestone
(Fillings in upper surface of Honeycut formation)

ORDOVICIAN

Lower Ordovician

Ellenburger group

UNCONFORMITY

Ohc / Oh / Oha — Honeycut formation
(Showing Ceratopea, Ohc, and Archaeoscyphia, Oha, beds. Thinly to thickly bedded cherty limestone and dolomite; dolomite microgranular to medium grained)

Ogd / Og / Oga — Gorman formation
(Locally showing principal Diaphelasma, Ogd, and Archaeoscyphia, Oga, beds. Thickly to thinly bedded cherty limestone and dolomite above Ogs, and dolomite below Ogs; dolomite predominantly microgranular to fine grained)

Lower Ordovician

Ellenburger group

Tanyard formation

Ot(ca) / Ot(mg) — Staendebach member
(Showing calcitic, Ot(ca), and dolomitic Ot(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)

Oh(mg) / Oh(ca) — Threadgill member
(Showing dolomitic, Oh(mg), and calcitic, Oh(ca), facies. Thickly to thinly bedded dolomite and limestone; dolomite predominantly coarse to medium grained)

CAMBRIAN

Upper Cambrian

DISCONFORMITY

Willbarns formation

Cwp — Pedernales dolomite member
(Fine to coarse grained, thickly to thinly bedded, cherty)

Cwm — Morgan Creek limestone member
(Granular, glauconitic, pink at base)

Cww — Welge sandstone member
(Sparingly glauconitic, brown)

DISCONFORMITY

Riley formation

Cri — Lion Mountain sandstone member
(Highly glauconitic, with limestone lenses)

Crc — Cap Mountain limestone member
(Granular glauconitic, gray to brown; grades to calcareous sandstone at base)

Crh — Hickory sandstone member
(Noncalcareous, nonglauconitic)

Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

Strike and dip of beds

Horizontal beds

Prevailing dip of beds

2-49C — Locality of fossil collection

F — Fossils noted but not collected

Line of described section, showing offset

Fence, showing identical contiguous ownership

Windmill

Tank
(Earth-dammed pond for water storage)

10°

N

GEOLOGIC MAP OF THE BALD RIDGE AREA, McCULLOCH COUNTY, TEXAS

EXPLANATION

- **QUATERNARY**
  - Qal — Alluvium *(Locally includes colluvium, travertine, and caliche)*
- **CARBONIFEROUS**
  - **Pennsylvanian**
    - Cmf — Marble Falls limestone (unrestricted) *(Gray to black, cherty, in part with interbedded calcareous shale)*
  - *UNCONFORMITY*
  - **Mississippian**
    - Cb — Barnett formation *(Gray shale with limestone lenses, mostly covered)*
  - *UNCONFORMITY*
    - Cc — Chappel limestone *(Crinoidal, rose to gray. Basal contact commonly collapsed or inferred, but not so shown because of pattern)*
- *UNCONFORMITY*
- **DEVONIAN**
  - TF-233 — Joint-filling arenaceous limestone
- *UNCONFORMITY*
- **ORDOVICIAN**
  - **Lower Ordovician**
    - ***Ellenburger group***
      - Og(ca), Oga, Og(mg), Og(ca) — Gorman formation *(Showing calcitic, Og(ca), and dolomitic, Og(mg), facies and principal Archaeoscyphia bed, Oga. Within the mainly dolomitic lower zone, Og(mg), intertonguing limestones, Og(ca), are separately mapped; but dolomites within the mainly calcitic zone are not shown. Chert-bearing. Dolomite predominantly fine to medium grained below Oga, fine grained to microgranular above Oga)*
    - **Tanyard formation**
      - Ots(ca), Ots(mg) — Staendebach member *(Principally in the dolomitic facies, Ots(mg), with minor occurrences of limestone, Ots(ca). Chert-bearing. Dolomite fine to medium grained)*
      - Ott(ca) — Threadgill member *(Essentially nonglauconitic, predominantly sublithographic, thinly to thickly bedded limestone)*
- **CAMBRIAN**
  - **Upper Cambrian**
    - **Wilberns formation**
      - €ws — San Saba limestone member *(Intermittently glauconitic, granular, and thinly bedded in upper part; a zone of stromatolitic bioherms in lower 70 to 80 feet)*
      - €wpp — Point Peak shale member *(Green, with interbedded glauconitic limestone)*

Inferred fault *(U, upthrown side, D, downthrown side)*

Observed and inferred contact

Laterally gradational contact *(Diagrammatic)*

Collapse contact

2° — Strike and dip of beds

Prevailing dip of beds

+ TF-406 — Locality of fossil collection

F — Fossils noted but not collected

Line of Bald Ridge section, showing offset *(Highway section not marked)*

T. Brook — Fence, showing identical contiguous ownership

Land grant boundary where not coincident with a fence *(Survey number and name in upper right-hand corner. Ownership not affected)*

Windmill

Tank *(Earth-dammed pond for water storage)*

NOTE:—The zone of stromatolitic bicherms included at the base of the San Saba limestone member of the Wilberns formation on this map is now considered to belong at the top of the Point Peak shale member.

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by P. E. Cloud, Jr., and Virgil E. Barnes
1945

Scale

0 — 1/8 — 1/4 — 1/2 — 3/4 — 1 Mile

0 — 500 — 1000 — 3000 — 2000 — 4000 — 5000 Feet

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc. 1939–1940

Geology by P. E. Cloud, Jr. 1944–1945

GEOLOGIC MAP OF THE BEAR SPRING AREA, MASON COUNTY, TEXAS

Scale

0 ⅛ ¼ ½ ¾ 1 Mile

0 500 1000 2000 3000 4000 5000 Feet

EXPLANATION

QUATERNARY

Qal — Alluvium
(Includes terrace alluvium in Honey Creek and Llano River valleys, and travertine downstream from some springs)

CARBONIFEROUS

Pennsylvanian

Csm — Smithwick shale
(Black fissile shale, in large part capped by terrace alluvium and exposed only in draws and bed of Honey Creek)

Cmf — Marble Falls limestone (unrestricted)
(Gray to black, cherty, in part with interbedded calcareous shale)

UNCONFORMITY

Mississippian

B — Barnett formation
(White to gray crinoidal limesand and limestone with covered zones probably representing shale. Includes limesand of Osage age at base)

UNCONFORMITY

Ch — Chappel limestone
(Crinoidal, rose to gray. Basal contact commonly collapsed or inferred, but not as shown because of pattern)

DISCONFORMITY

Cic — Ives breccia
(Fragmental chert, in part with calcareous matrix)

UNCONFORMITY

DEVONIAN

D — Zesch and Bear Spring formations
(Granular limestones, in part siliceous and cherty)

UNCONFORMITY

ORDOVICIAN

Lower Ordovician

Ellenburger group

Tanyard formation

Og(cc) Og(cm) Og(mg) — Gorman formation
(Showing calcitic, Og(cc), and dolomitic, Og(mg), facies and principal Archaeocyathia bed, Oga. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)

Ots(mg) — Staendebach member
(Thickly to thinly bedded, cherty, predominantly fine to medium grained dolomite)

Ott(ca) — Threadgill member
(Essentially nonglauconitic, predominantly sublithographic, thinly to thickly bedded limestone)

CAMBRIAN

Upper Cambrian

Cc — Wilberns formation (undivided)
(Showing the fourth or upper sandstone, S, of the San Saba limestone member. Intermittently glauconitic granular limestone, sandstone, and minor green shale)

U/D — Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

Collapse contact
(Except at base of Chappel limestone)

12° — Strike and dip of beds

Horizontal beds

Prevailing dip of beds

+TF-420 — Locality of fossil collection

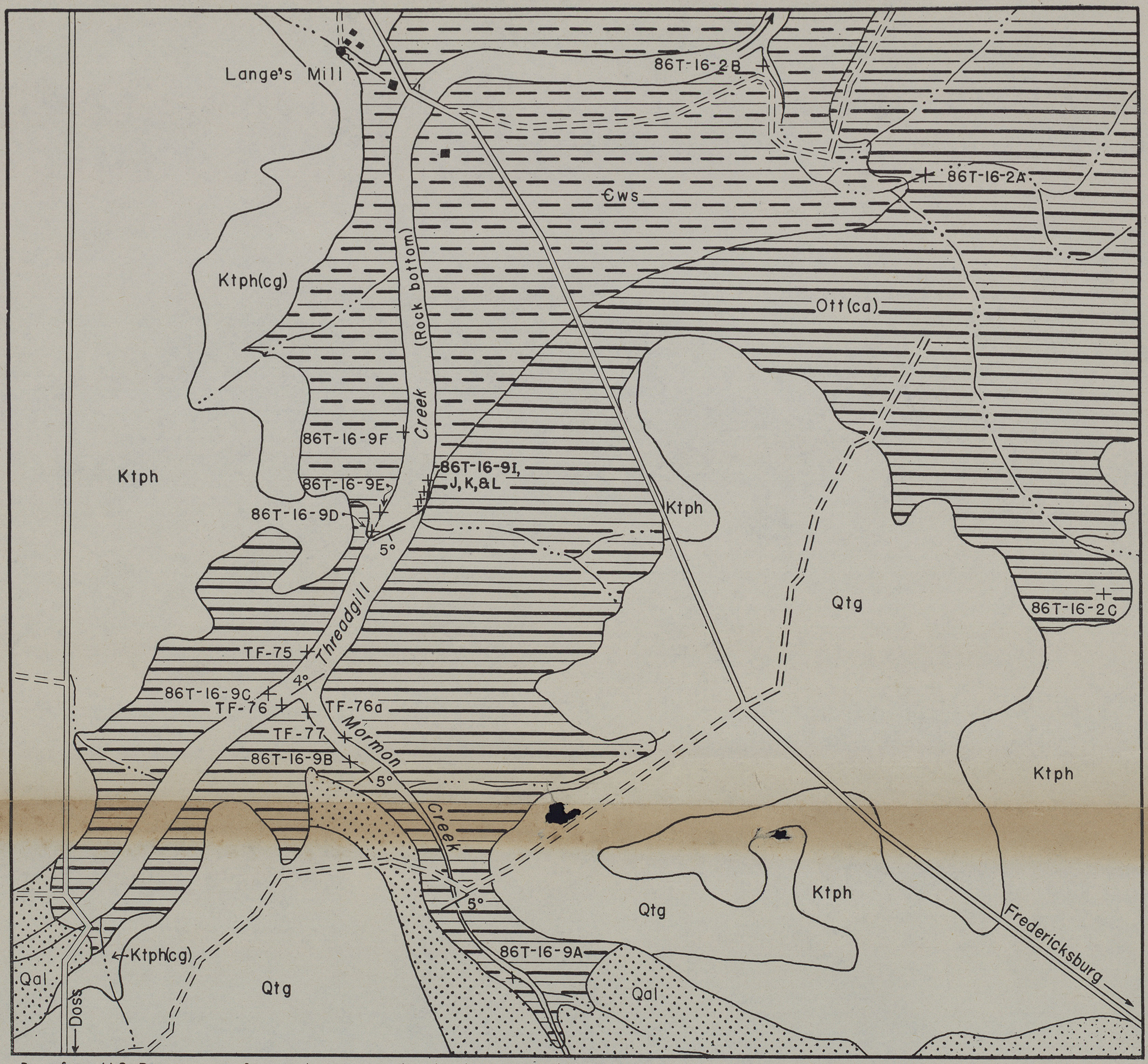
F — Fossils noted but not collected

Line of described section, showing offset
(S, undescribed supplementary section)

Roy Zesch — Fence, showing identical contiguous ownership

Windmill

Tank
(Earth-dammed pond for water storage)



Base from U.S. Department of Agriculture, Agricultural Adjustment Administration, aerial photographs flown by Kargl Aerial Surveys, Ltd., 1938.

Geology by Virgil E. Barnes, 1940–1941

GEOLOGIC MAP OF LANGE'S MILL AREA, GILLESPIE COUNTY, TEXAS

EXPLANATION

QUATERNARY

Qal — Alluvium

Qtg — Terrace gravel

CRETACEOUS

Lower Cretaceous

Comanche series

Travis Peak formation of Hill 1901

Ktph — Ktph(cg) — Hensell sand member *(Red, with conglomerate, Ktph(cg), at base)*

UNCONFORMITY

ORDOVICIAN

Lower Ordovician

Ellenburger group

Tanyard formation

Ott(ca) — Threadgill member *(Essentially nonglauconitic, predominantly sublithographic, thinly to thickly bedded limestone)*

CAMBRIAN

Upper Cambrian

Wilberns formation

Cws — San Saba limestone member *(Intermittently glauconitic, granular, thinly to thickly bedded)*

10° — N

5° — Strike and dip of beds

+ TF-77 + 86T-16-9A — Locality of fossil collection

Scale,

0 — 1/8 — 1/4 — 1/2 — 3/4 — 1 Mile

0 — 500 — 1000 — 2000 — 3000 — 4000 — 5000 Feet

GEOLOGIC MAP OF A PART OF THE CHEROKEE AREA, SAN SABA COUNTY, TEXAS

Base from U. S. Agricultural Adjustment Administration aerial photographs flown by Kargl Aerial Surveys, Ltd., 1938

Geology by P. E. Cloud, Jr., and R. L. Heller
1943 – 1944

Scale
1/4 1/8 0 1/4 1/2 3/4 1 mile
1000 500 0 1000 2000 3000 4000 5000 feet

EXPLANATION

QUATERNARY

Qal — Alluvium

CARBONIFEROUS

Pennsylvanian

Cp — Strawn formation, Smithwick shale, and Marble Falls limestone
(Sandstone, siltstone, shale, and cherty limestone)

UNCONFORMITY

Mississippian

Cm — Barnett formation, Chappel limestone, and Ives breccia
(Gray shale, crinoidal gray limestone, and chert breccia)

UNCONFORMITY

ORDOVICIAN

Lower Ordovician

Ellenburger group

Oha, Oh — Honeycut formation
(Showing principal Archaeoscyphia *bed,* Oha. *Thinly to thickly bedded cherly limestone and dolomite; dolomite predominantly fine grained to microgranular)*

Og (ca), Oga, Og (mg) — Gorman formation
(Showing calcitic, Og(ca), *and dolomitic,* Og(mg), *facies, and principal* Archaeoscyphia *bed,* Oga. *Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)*

Tanyard formation

Ots(ca), Ots(mg) — Staendebach member
(Showing calcitic, Ots(ca), *and dolomitic,* Ots(mg), *facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)*

Ott(mg), Ott(ca) — Threadgill member
(Showing dolomitic, Ott(mg), *and calcitic,* Ott(ca), *facies. Thickly to thinly bedded, sparingly cherty dolomite and limestone; dolomite predominantly medium to coarse grained)*

DISCONFORMITY

CAMBRIAN

Upper Cambrian

Wilberns formation

Cwp — Pedernales dolomite member
(Thickly to thinly bedded, sparingly cherty, predominantly fine to very fine grained)

Cws — San Saba limestone member
(Granular to sublithographic, moderately glauconitic, gray)

Cpe, Cw — Point Peak shale, Morgan Creek limestone, and Welge sandstone members
(Showing Plectotrophia *bed,* Cp, *in Point Peak shale. Green shale, gray to pink glauconitic limestone, and brown, sparingly glauconitic sandstone)*

U D — Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

Collapse contact

7° — Strike and dip of beds

⊕ — Horizontal beds

Prevailing dip of beds

+TF 31 — Locality of fossil collection

F — Fossils noted but not collected

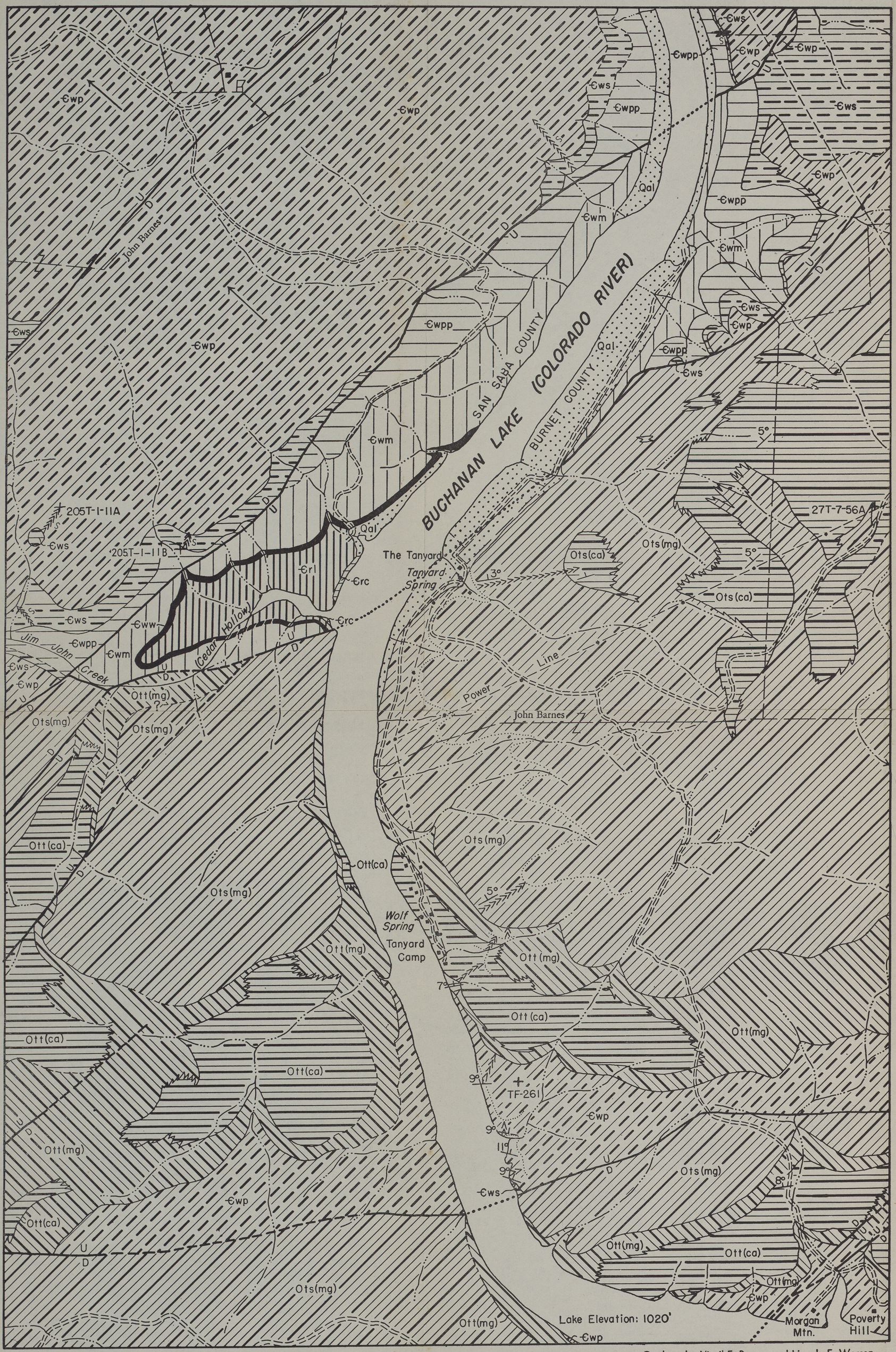
Line of described section, showing offset

T. H. Young — Fence, showing identical contiguous ownership

Land grant boundary

Windmill

T — Earthen storage tank for water



Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by Virgil E. Barnes and Lincoln E. Warren
1944–1945

GEOLOGIC MAP OF THE TANYARD AREA, BURNET AND SAN SABA COUNTIES, TEXAS

Scale

1/4 1/8 0 1/4 1/2 3/4 1 Mile

1000 500 0 1000 2000 3000 4000 5000 Feet

EXPLANATION

QUATERNARY

Qal — Alluvium

ORDOVICIAN

Lower Ordovician — Ellenburger group — Tanyard formation

Ots(ca), Ots(mg) — Staendebach member
(Showing calcitic, Ots(ca), and dolomitic Ots(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)

Ott(mg), Ott(ca) — Threadgill member
(Showing dolomitic, Ott(mg), and calcitic, Ott(ca), facies. Thickly to thinly bedded dolomite and limestone; dolomite predominantly coarse to medium grained)

DISCONFORMITY

CAMBRIAN

Upper Cambrian — Wilberns formation

Ewp — Pedernales dolomite member
(Thickly to thinly bedded, cherty, predominantly fine to very fine grained with middle portion coarse grained)

Ews — San Saba limestone member
(Thickly bedded, girvanella-bearing)

Ewpp — Point Peak shale member
(Green, with interbedded glauconitic limestone)

Ewm — Morgan Creek limestone member
(Granular, glauconitic, pink at base)

Eww — Welge sandstone member
(Sparingly glauconitic, brown)

DISCONFORMITY

Riley formation

Erl — Lion Mountain sandstone member
(Highly glauconitic, with limestone lenses)

Erc — Cap Mountain limestone member
(Granular, glauconitic, gray)

U D — Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

5° — Strike and dip of beds

Prevailing dip of beds

TF-261 205T-1-11A — Locality of fossil collection

Line of described section, showing offset
(S, undescribed supplementary section)

John Barnes — Fence, showing identical contiguous ownership

10° N

GEOLOGIC MAP OF THE GORMAN FALLS AREA, SAN SABA, LAMPASAS, AND BURNET COUNTIES, TEXAS

Geology by Virgil E. Barnes and Lincoln E. Warren, 1945

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Scale

1/4 1/8 0 1/4 1/2 3/4 1 Mile

1000 500 0 1000 2000 3000 4000 5000 Feet

EXPLANATION

Known, concealed, and inferred fault (*U, upthrown side; D, downthrown side*)

Observed and inferred contact

Laterally gradational contact (*Diagrammatic*)

Collapsed areas (*Only a few mapped*)

Strike and dip of beds

Horizontal beds

Prevailing dip of beds

205T-1-17A + TF-253 — Locality of fossil collection

F — Fossils noted but not collected

Line of described section, showing offset (*S. undescribed supplementary section*)

T. S. Lemons — Fence, showing identical contiguous ownership

Corrals, or pens

Tank (*Earth-dammed pond for water storage*)

GEOLOGIC COLUMN

QUATERNARY	Qal	Alluvium	
	Travertine		
CARBONIFEROUS	Pennsylvanian	Cp	Marble Falls limestone (unrestricted) (*Gray to black limestone and shale!*)
	UNCONFORMITY		
	Mississippian	Cm	Barnett formation and Chappel limestone (*Yellow-weathering shale, and crinoidal limestone*)
	UNCONFORMITY		
ORDOVICIAN	Lower Ordovician	Ohc, Oh, Ohs	Honeycut formation (*Locally showing Archaeocyphia, Ohs, and Ceratopea, Ohc, beds. Thinly to thickly bedded, cherty limestone and dolomite; dolomite predominantly fine grained to microgranular*)
	Ellenburger group	Og(ca), Oga, Og(mg)	Gorman formation (*Showing calcitic, Og(ca), and dolomitic, Og(mg), facies and principal Archaeocyphia bed, Oga. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained*)
	Tanyard formation	Ots(ca), Ots(mg)	Staendebach member (*Showing calcitic, Ots(ca), and dolomitic Ots(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained*)

FAULTS OF SMALL AREA

Gorman Falls

Gorman Spring

Gorman Cave

Gorman Falls Camp

Bear Spring

Tie Slide Creek

Sulphur Spring

Seven Springs

Clark Spring

Devil's Hollow

Malcolm Chism

T S Lemons

S Aylor

P H & W M Jackson Ranch

S J Smith Ranch

John Vann Ranch

Vann's Camp

Lake Elevation 1020'

COLORADO RIVER

BUCHANAN LAKE

LAMPASAS CO.

BURNET CO.

SAN SABA CO.

Property line

205T-1-4A

205T-1-17B

205T-1-17A

141T-6-43A

141T-6-39B

141T-6-39C

141T-6-39A

TF-250 TF-251 TF-252 TF-253 TF-254 TF-255 TF-256 TF-257 TF-258 TF-259 TF-260 TF-275 TF-276

Bend
Devil's Hollow
Qal
Cp
Cm
Oh
Sulphur Spring
205T-1-4A
S Aylor
205T-1-17B
205T-1-17A
Og(ca)
Og(mg)
Oga
Og(cg)
TF-260
TF-259
TF-258
TF-257
TF-256
TF-255
TF-254
TF-253
TF-252
TF-251
Tie Slide Creek
Bear Spring
Gorman Falls
Gorman Falls Camp
TF-250
Malcolm Chism
141T-6-43A
Property line
T S Lemons
Gorman Spring
Gorman Creek
Gorman Cave
P H & W M Jackson Ranch
S J Smith Ranch
COLORADO

GEOLOGIC MAP OF THE GORMAN FALLS AREA, SAN SABA, LAMPASAS, AND BURNET COUNTIES, TEXAS

Geology by Virgil E. Barnes and Lincoln E. Warren, 1945

' Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

EXPLANATION

Known, concealed, and inferred fault (U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact (Diagrammatic)

Collapsed areas (Only a few mapped)

Strike and dip of beds

Horizontal beds

Prevailing dip of beds

2057-1-17A Locality of fossil collection

TF-253

F Fossils noted but not collected

Line of described section, showing offset (S, undescribed supplementary section)

T. S. Lemons Fence, showing identical contiguous ownership

Corrals, or pens

Tank (Earth-dammed pond for water storage)

Scale

1/4 1/8 0 1/4 1/2 3/4 1 Mile

1000 500 0 1000 2000 3000 4000 5000 Feet

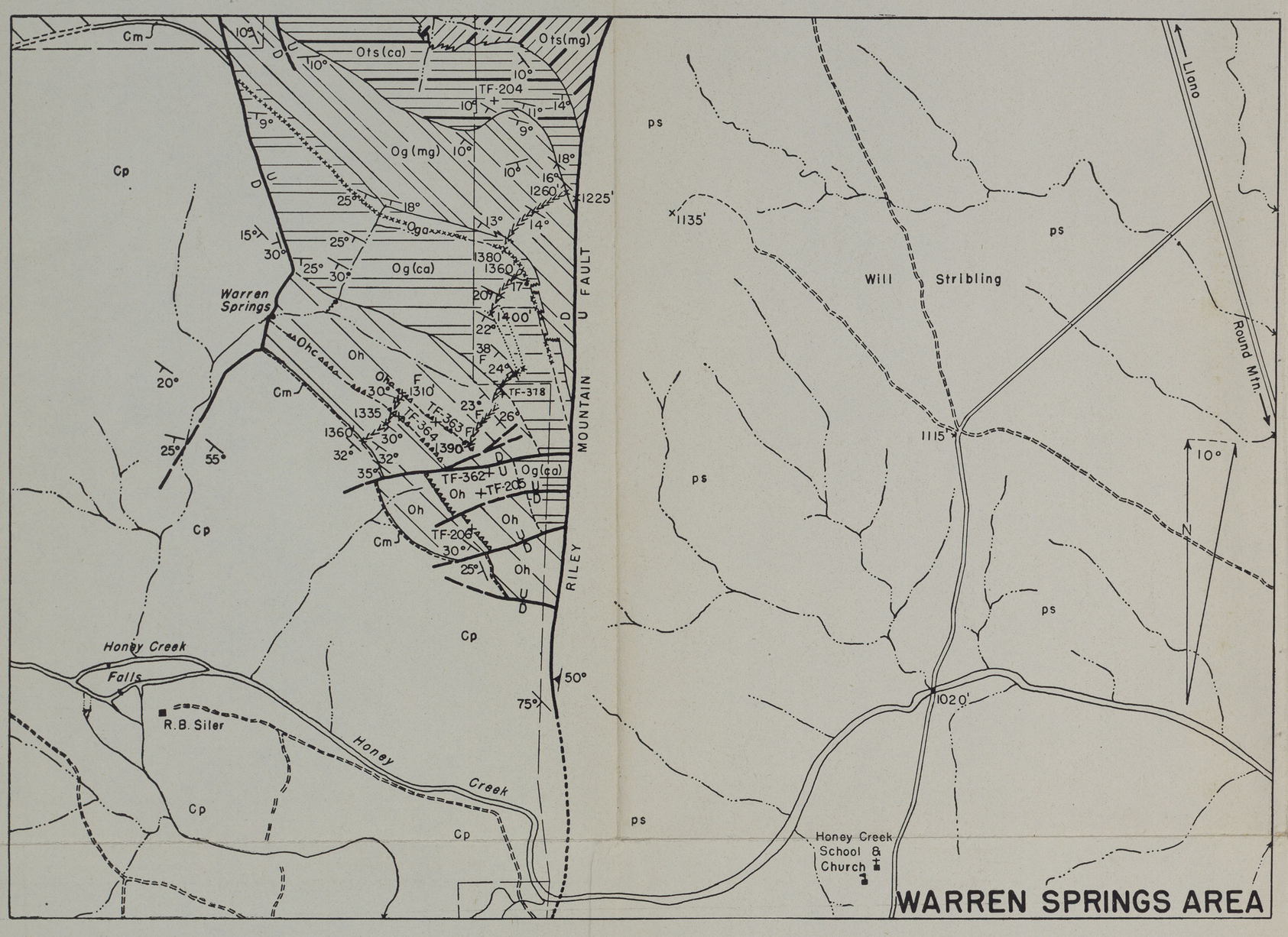
N 10°

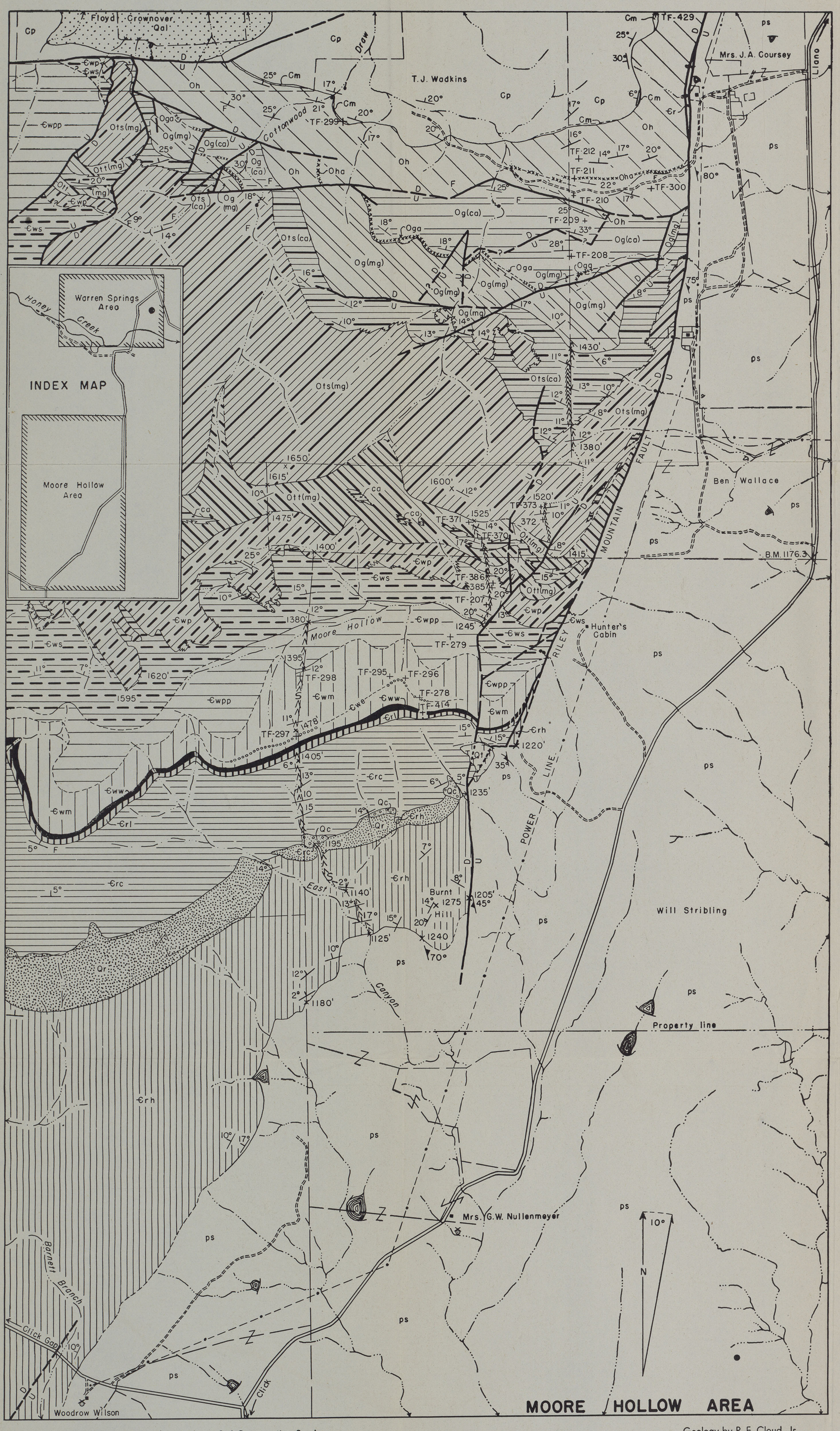
GEOLOGIC COLUMN

QUATERNARY
- Qal — Alluvium
- Qt — Travertine

CARBONIFEROUS
- Pennsylvanian — Cp — Marble Falls limestone (unrestricted) (Gray to black limestone and shale)
- UNCONFORMITY
- Mississippian — Cm — Barnett formation and Chappel limestone (Yellow-weathering shale, and crinoidal limestone)
- UNCONFORMITY

ORDOVICIAN
- Lower Ordovician — Ellenburger group — Tanyard formation
  - Oh — Honeycut formation (Locally showing Archaeoscyphia, Oha, and Ceratopea, Ohc, beds. Thinly to thickly bedded, cherty limestone and dolomite; dolomite predominantly fine grained to microgranular)
  - Og(ca), Oga, Og(mg) — Gorman formation (Showing calcitic, Og(ca), and dolomitic, Og(mg), facies and principal Archaeoscyphia bed, Oga. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)
  - Ots(ca), Ots(mg) — Staendebach member (Showing calcitic, Ots(ca), and dolomitic Ots(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)





Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939

Geology by P. E. Cloud, Jr. 1945

GEOLOGIC MAP OF THE MOORE HOLLOW AND WARREN SPRINGS AREAS, RILEY MOUNTAINS, LLANO COUNTY, TEXAS

Scale

0 1/8 1/4 1/2 3/4 1 Mile

0 500 1000 2000 3000 4000 5000 Feet

EXPLANATION

QUATERNARY

- Qal — Alluvium
- Qt — Residual and colluvial bench cover
- Caliche and caliche-cemented slope-wash
- Travertine

CARBONIFEROUS

Pennsylvanian

- Cp — Smithwick shale and Marble Falls limestone (unrestricted) *(Gray to black shale and cherty limestone. Quaternary cover not separately mapped)*

UNCONFORMITY

Mississippian

- Cm — Barnett formation and Chappel limestone *(Shale? and crinoidal gray limestone)*

UNCONFORMITY

ORDOVICIAN

Lower Ordovician

Ellenburger group

- Ohc, Oha, Oh — Honeycut formation *(Locally showing Archaeoscyphia, Oha, and Ceratopea, Ohc, beds. Thinly to thickly bedded, cherty limestone and dolomite; dolomite predominantly fine grained to microgranular)*
- Og(ca), Oga, Og(mg) — Gorman formation *(Showing calcitic, Og(ca), and dolomitic, Og(mg), facies and principal Archaeoscyphia bed, Oga. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)*

Tanyard formation

- Ots(ca), Ots(mg) — Staendebach member *(Showing calcitic, Ots(ca), and dolomitic Ots(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)*
- Ott(mg), Ott(ca), Ott(mg) — Threadgill member *(Showing dolomitic, Ott(mg), and calcitic, Ott(ca), facies. Thickly to thinly bedded sparingly cherty dolomite and limestone; dolomite predominantly medium to coarse grained)*

DISCONFORMITY

CAMBRIAN

Upper Cambrian

Wilberns formation

- €wd — Pedernales dolomite member *(Thickly to thinly bedded, predominantly fine grained to microgranular, sparingly cherty, locally glauconitic)*
- €ws — San Saba limestone member *(Granular to sublithographic, sparingly glauconitic, gray. A zone of stromatolitic bioherms in lower 100 feet)*
- €wpp — Point Peak shale member *(Green, with interbedded glauconitic limestone)*
- €wm, €wc — Morgan Creek limestone member *(Locally showing Eoorthis bed, €wc. Granular, glauconitic, pink at base)*
- €ww — Welge sandstone member *(Sparingly glauconitic, brown)*

Riley formation

- €rl — Lion Mountain sandstone member *(Highly glauconitic, with limestone lenses)*
- €rc — Cap Mountain limestone member *(Granular, glauconitic, gray to brown; grades to calcareous sandstone at base)*
- €rh — Hickory sandstone member *(Noncalcareous, nonglauconitic)*
- €r — Riley formation (undivided) *(Cap Mountain limestone and Hickory sandstone members in slivers along Riley Mountain fault)*

UNCONFORMITY

PRE-CAMBRIAN

- ps — Packsaddle schist *(Varied metasedimentary rocks. Quaternary cover not separately mapped)*

Known, concealed, and inferred fault *(U, upthrown side; D, downthrown side)*

Observed and inferred contact

Laterally gradational contact *(Diagrammatic)*

Collapse contact

15° — Strike and dip of beds

45° — Strike and dip of schistosity

+TF-414 — Locality of fossil collection

F — Fossils noted but not collected

Line of described section, showing offset *(S, undescribed supplementary section)*

Woodrow Wilson — Fence, showing identical contiguous ownership

Windmill

Tank *(Earth-dammed pond for water storage)*

NOTE:—The zone of stromatolitic bicherms included at the base of the San Saba limestone member of the Wilberns formation on this map is now considered to belong at the top of the Point Peak shale member.

98°25'00"

98°22'30"

30°40'00"

LLANO COUNTY

BURNET COUNTY

COLORADO RIVER

J.F. Bauer

Roaring Spring

Inks Lake

Williams Creek

Mill Creek

Hoover Quarry

Kingsland

Backbone Mtn. 1180

1320 Bald Knob

Ernest M Closuit
L.C. Nolen

Ballast Pit

Dry Creek

Morgan Falls

POWER LINE

ROARING SPRING FAULT ZONE

BALD KNOB FAULT ZONE

HOOVER POINT

BACKBONE MOUNTAIN

NEW ORLEANS (SP) AND TEXAS

BM 919

BM 874

Qal

cgr

Oh

Oha

Oho

Og(ca)

Oga

Og(mg)

Ots(ca)

Ots(mg)

Ott(ca)

Ott(mg)

€wp

€ws

€wpp

€wm

€ww

€rl

€rc

€rh

agr

ps

9-44A

9-44B

9-44C

9-44D

9-44F

9-44G

9-45A

9-45B

9-45C

9-45D

9-45E

9-45G

9-45H

9-45I

9-45J

9-45K

9-46A

9-46B

9-46C

9-46D

9-46E

9-56A

9-56B

9-56C

9-56D

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by Virgil E. Barnes and Lincoln E. Warren
1944–1945

GEOLOGIC MAP OF THE BACKBONE MOUNTAIN AREA BURNET AND LLANO COUNTIES, TEXAS

Scale

1/4 1/8 0 1/4 1/2 3/4 1 Mile

1000 500 0 1000 2000 3000 4000 5000 Feet

EXPLANATION

QUATERNARY

- Qal — Alluvium
- Qc — Colluvium

ORDOVICIAN

Lower Ordovician

Ellenburger group

- Oho / Oh / Oha — Honeycut formation
  (Showing Archaeoscyphia *beds,* Oha, *and oölite bed,* Oho. *Thinly to thickly bedded cherty limestone and dolomite; dolomite predominantly fine grained to microgranular)*
- Og(ca) / Oga / Og(mg) — Gorman formation
  (Showing calcitic, Og(ca), *and dolomitic,* Og(mg), *facies and principal* Archaeoscyphia *bed,* Oga. *Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)*

Tanyard formation

- Ots(ca) / Ots(mg) — Staendebach member
  (Showing calcitic, Ots(ca), *and dolomitic,* Ots(mg), *facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)*
- Ott(mg) / Ott(ca) — Threadgill member
  (Showing dolomitic, Ott(mg), *and calcitic,* Ott(ca), *facies. Thickly to thinly bedded dolomite and limestone; dolomite predominantly coarse to medium grained)*

DISCONFORMITY

CAMBRIAN

Upper Cambrian

Wilberns formation

- €wp — Pedernales dolomite member
  (Thickly to thinly bedded, cherty, predominantly fine to very fine grained)
- €ws — San Saba limestone member
  Thickly to thinly bedded, girvanella-bearing)
- €p / €wpp — Point Peak shale member
  (Showing Plectotrophia *bed,* €p. *Green, with interbedded glauconitic and stromatolitic limestones)*
- €wm — Morgan Creek limestone member
  (Granular, glauconitic, pink at base)
- €ww — Welge sandstone member
  (Sparingly glauconitic, brown)

DISCONFORMITY

Riley formation

- €rl — Lion Mountain sandstone member
  (Highly glauconitic, with limestone lenses)
- €rc — Cap Mountain limestone member
  (Granular, glauconitic, gray to brown; grades to calcareous sandstone at base)
- €rh — Hickory sandstone member
  (Noncalcareous, nonglauconitic)

UNCONFORMITY

PRE-CAMBRIAN

- agr / cgr — Granite
  (Coarse grained granite, cgr, *and aplogranite,* agr)
- ps — Packsaddle schist
  (Dark colored metasedimentary rocks)

U D — Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

5° — Strike and dip of beds

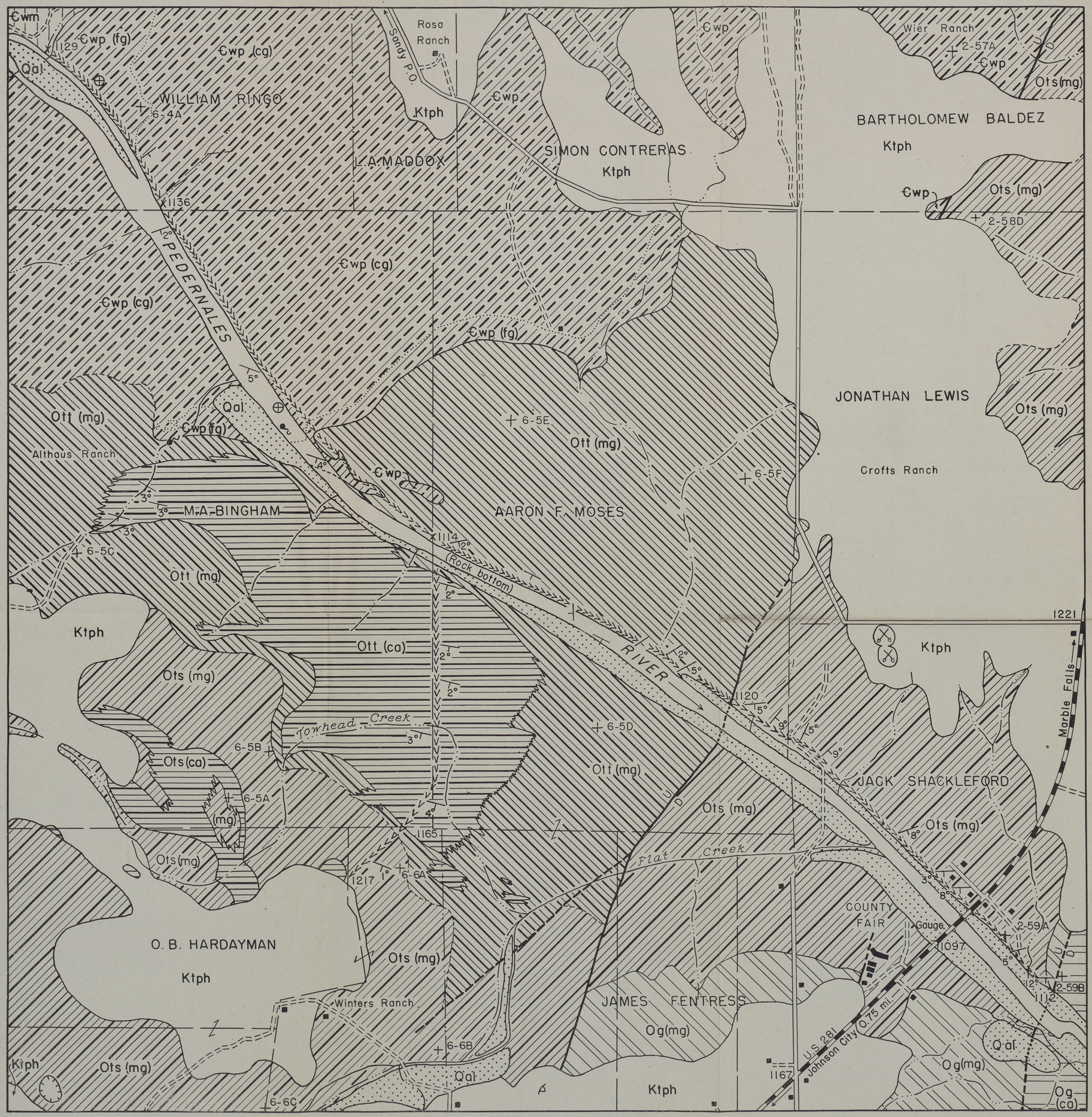
⊕ Horizontal beds

+ 9-46C — Locality of fossil collection

Line of described section, showing offset

Ernest M. Closuit — Fence, showing identical contiguous ownership

10° N



Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by Virgil E. Barnes and Lincoln E. Warren
1942–1944

GEOLOGIC MAP OF A PART OF THE JOHNSON CITY AREA, BLANCO COUNTY, TEXAS

Scale

1/4 1/8 0 1/4 1/2 3/4 1 mile

1000 500 0 1000 2000 3000 4000 5000 feet

EXPLANATION

QUATERNARY

Alluvium (Qal)

CRETACEOUS

Lower Cretaceous — *Comanche series* — Travis Peak formation of Hill 1901

Hensell sand member (Ktph)
(Red and gray, with conglomerate at base)

UNCONFORMITY

ORDOVICIAN

Lower Ordovician — *Ellenburger group* — Tanyard formation

Gorman formation (Og(ca), Og(mg))
(Showing calcitic, Og(ca), and dolomitic, Og(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly microgranular to fine grained)

Staendebach member (Ots(ca), Ots(mg))
(Showing calcitic, Ots(ca), and dolomitic Ots(mg), facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly fine to medium grained)

Threadgill member (Ott(ca), Ott(mg))
(Showing dolomitic, Ott(mg), and calcitic, Ott(ca), facies. Thickly to thinly bedded dolomite and limestone; dolomite predominantly coarse to medium grained)

DISCONFORMITY

CAMBRIAN

Upper Cambrian — Wilberns formation

Pedernales dolomite member (Ewp(fg), Ewp(cg), Ewp(fg))
(Showing coarse grained, Ewp(cg), and fine grained, Ewp(fg), facies. Sparingly cherty)

Morgan Creek limestone member (Ewm)
(Granular, glauconitic, pink at base)

Known, concealed, and inferred fault (U, D)
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

Strike and dip of beds (5°)

Horizontal beds

Locality of fossil collection (+ 6-5E)

Line of described section

Winters Ranch
Fence, showing identical contiguous ownership

Land grant boundary

Tank
(Earth-dammed pond for water storage)

10°
N

GEOLOGIC MAP OF HONEYCUT BEND, BLANCO COUNTY, TEXAS

EXPLANATION

QUATERNARY

Qal — Alluvium

CRETACEOUS

Lower Cretaceous — *Comanche series* — Travis Peak formation of Hill 1901

Kgr — Glen Rose limestone
(Alternating beds of limestone, marl, and clay)

Ktph — Hensell sand member
(Red and gray, with conglomerate at base)

DISCONFORMITY

Ktpcc — Cow Creek limestone member
(Massive, cliff-forming, fossil coquina)

Ktps — Sycamore sand
(Poorly sorted, with conglomerate abundant)

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian — Marble Falls limestone (unrestricted)

Cmf(sp) — Calcareous spiculite
(Fissile, dark gray to black)

UNCONFORMITY

Cmf(l) — Lower biohermal limestone
(Dark gray, with irregular black shale lenses)

UNCONFORMITY

Mississippian

Cc — Chappel limestone
(Crinoidal, medium gray)

DISCONFORMITY

Ci — Ives breccia
(Fragmental chert, in part with calcareous matrix)

UNCONFORMITY

DEVONIAN

Lower or Middle Devonian

Ds — Stribling formation
(Limestone and chert)

UNCONFORMITY

Lower Devonian (?)

Dp — Pillar Bluff (?) limestone
(Fillings in upper surface of Honeycut formation)

UNCONFORMITY

ORDOVICIAN

Lower Ordovician — *Ellenburger group*

Ohc, Oh, Oha — Honeycut formation
(Showing Ceratopea, Ohc, *and* Archaeoscyphia, Oha, *beds. Thinly to thickly bedded cherty limestone and dolomite; dolomite microgranular to medium grained)*

Ogd, Og(ca), Oga, Og(mg) — Gorman formation
(Locally showing principal Diaphelasma, Ogd, *and* Archaeoscyphia, Oga, *beds. Thickly to thinly bedded cherty limestone and dolomite* Og(ca) *above* Oga, *and dolomite* Og(mg) *below* Oga; *dolomite predominantly microgranular to fine grained)*

Tanyard formation

Ots(ca), Ots(mg) — Staendebach member
(Showing calcitic, Ots(ca), *and dolomitic* Ots(mg), *facies. Thickly to thinly bedded cherty limestone and dolomite; dolomite predominantly medium to coarse grained)*

U / D — Known, concealed, and inferred fault
(U, upthrown side; D, downthrown side)

Observed and inferred contact

Laterally gradational contact
(Diagrammatic)

15° — Strike and dip of beds

Prevailing dip of beds

+ 2-43M — Locality of fossil collection

Line of described section, showing offset

Z — Stribling (7L) Ranch
Fence, showing identical contiguous ownership

Land grant boundary

Scale
1/4 1/8 0 1/4 1/2 3/4 1 mile
1000 500 0 1000 2000 3000 4000 5000 feet

N 10°

Base from U.S. Department of Agriculture, Soil Conservation Service, aerial photographs flown by Park Aerial Surveys, Inc., 1939–1940.

Geology by Virgil E. Barnes and Lincoln E. Warren
1942–1944

CORRELATION OF THE ELLENBURGER GROUP AND ASSOCIATED ROCKS IN CENTRAL TEXAS

(Datum is contact of Tanyard and Gorman formations)

INDEX FOSSILS IN CENTRAL TEXAS

STRATIGRAPHIC COLUMN

BRACHIOPODA — GASTROPODA — CEPHALOPODA — TRILOBITA

"Rhabdoporella" — ALGAE
Archaeoscyphia — PORIFERA
Billingsella
Dagnaesma
Eoorthis
Nuxiella
Plectorthella
Symphysurina
Terrolobella
Xenelasma
Ceratopea 1 (n. sp.)
Ceratopea 2 (cappiliformis)
Ceratopea 3 (robusta)
Ceratopea 4 (n. sp.)
Ceratopea 5 (n. sp.)
Ceratopea 6 (Ferth.)
Kirkpatia
Calaspeada
Helicotoma uniangulata
Hormotoma
Lecanospira
"Maclurites affinis"
Obtusella
Orospira
Owenella
Clarkina
"Roubidouxia"
Scalpaxis
Schizopea
Sinuopea
Burtoceras
Clarkoceras
Estenoceras
Lenoceras
Tarphyceras
Jelfersonia
"Plethopeltis" van der Pluymi
Rhombella
Sub family Saukiinae
Stenopilus
Ribeiria — ARCHAEOSTRACA
Eoptericaris

COLUMNAR SECTIONS

AREA	1 BALD RIDGE		2 BEAR SPRING	3 LANGE'S MILL	4 CHEROKEE		5 GORMAN FALLS and TANYARD	6 WARREN SPRINGS and MOORE HOLLOW	7 BACKBONE MOUNTAIN	8 JOHNSON CITY	AREA
SECTION	Highway 87 (1B)	Bald Ridge (1C) Camp San Saba (1A)	Llano River (Composite, 2A-D)	Threadgill Creek (3)	Cherokee Creek (4D)	Kirk Ranch (4C) Harris Ranch (4B) Salt Branch (4A)	Gorman—Tanyard (Composite, 5A-D)	Riley Mountains (Composite, 6A-C)	Backbone Ridge (Composite, 7A-D)	Johnson City (Composite, 8A-F)	SECTION
OVERLYING ROCKS	Mississippian Barnett formation and Chappel limestone	sequence not complete	Mississippian Barnett formation and Chappel limestone	Cretaceous Hensell sand member of the Travis Peak formation	Mississippian Barnett formation Chappel limestone and Ives breccia	sequence not complete	Mississippian Barnett formation and Chappel limestone	Mississippian Barnett formation and Chappel limestone	sequence not complete	Devonian Stribling formation	OVERLYING ROCKS

INDEX MAP

McCULLOCH · SAN SABA · LAMPASAS · MASON · BURNET · LLANO · KIMBLE · GILLESPIE · BLANCO
Camp San Saba · Mason · Llano · Burnet · Marble Falls · Doss · Fredericksburg · Johnson City · Lampasas · Kingsland · Click · White's Crossing · Cherokee · Chappel
Ideal line of section · Actual line of section · San Saba River · Llano River · Colorado River · Pedernales River
Scale 0 10 20 30 Miles

VERTICAL SCALE 200' 400' 600' 800' 1000' 1200' 1400' 1600' 1800' 2000' 2200' 2400'

PRE-CARBONIFEROUS · SURFACE

LOWER ORDOVICIAN
ELLENBURGER GROUP
GORMAN FORMATION — dolomitic facies Og(mg) — calcitic facies Og(ca)
TANYARD FORMATION — Threadgill member — calcitic facies Ott(ca) — dolomitic facies Ott(mg)
Staendebach member — dolomitic facies Ots(mg) — calcitic facies Ots(ca)
HONEYCUT FORMATION Oh — dolomitic facies — facies of alternating limestone and dolomite — calcitic facies
UPPER CAMBRIAN
WILBERNS FORMATION
San Saba limestone member €ws — Pedernales dolomite member €wp
Point Peak shale member €wpp
Morgan Creek limestone member €wm
Welge sandstone member (€ww)
Lion Mountain sandstone member of Riley formation (Upper Cambrian)

Archaeoscyphia zone in the Gorman formation
Plectorthis zone
Eoorthis zone

Bald Ridge Section (1C) · Hill Section (2D) · Rattlesnake Section (2C) · Pete Hollow Section (2B) · Bluff Creek Section (2A) · Mason Section · San Saba Section (1A)
Harris ranch Section (4B) · Kirk ranch Section (4C) · Salt Branch Section (4A) · Supplementary Tanyard Section (5)
Gorman Falls Section (5D) · Gorman Section (5C) · Tanyard Section (5A) · Section (6A) · Section (6B) · Section (6C)
Warren Springs Section (6E) · Rattlesnake Creek Section (7C) · Roaring Spring Section (7D) · Mill Creek Section (7B) · Backbone Mountain Section (7A)
Upstream Honeycut Bend Section (8D) · Downstream Honeycut Bend Section (8F) · Rough Hollow Section (8E) · Section (8C) · Section (8A) · Tomhead Creek Section (8B)
Fault

EXPLANATION

(Symbolism in columnar sections is only roughly quantitative, and gradation or alternation is indicated by adjacent symbols)

DOMINANT ROCK
Limestone: sublithographic · granular · dolomitic
Dolomite: coarse grained · medium grained · fine grained · very fine grained · microgranular
Shale
Sandstone

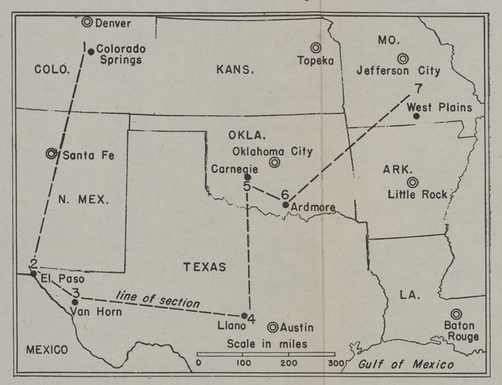
PRINCIPAL ACCESSORY LITHIC CONSTITUENTS
Glauconite: globular · interstitial
Quartz other than chert: sand grains · crystalline druse, or quartzose inclusions in chert
Chert: chalcedonic to semichalcedonic · porcelaneous to semiporcelaneous · subgranular to granular · dolomoldic or interstitial · colitic · oömoldic · cannonball chert · Chert-matrix sand

FOSSILS IN THE COLUMNAR SECTIONS
Stromatolitic bioherms more than 6 feet thick
Archaeoscyphia
Brachiopods
Ceratopea

OTHER SYMBOLS
Section described in detail, interval designations at left
Section generalized
Bedrock concealed
Absent by faulting
Arbitrary termination of section
Formation boundary
Inconspicuously gradational boundary between sections
Conspicuously gradational boundary between sections
Collapse contact
Faunal zone between sections
Stratigraphic range of index fossil in central Texas: epidi line · known range · probable range

*In the column "Index Fossils in Central Texas," the trilobite there referred to as n. gen. aff. *Plethopeltis* has been named *Parapiethopeltis*, and the gastropods called "*Roubidouxia*" and "*Maclurites affinis*" have been named respectively *Rhombella* and *Barnesella* (Bridge and Cloud, 1947).

1	2	3	4	5	6	7
ROCKY MOUNTAIN FRONT CENTRAL COLORADO	FRANKLIN MOUNTAINS TRANS-PECOS TEXAS	SIERRA DIABLO REGION TRANS-PECOS TEXAS	LLANO UPLIFT CENTRAL TEXAS	WICHITA MOUNTAINS SOUTHERN OKLAHOMA	ARBUCKLE MOUNTAINS SOUTHERN OKLAHOMA	OZARK UPLIFT SOUTHERN MISSOURI AND NORTHERN ARKANSAS
WILLIAMS CANYON SECTION	EL PASO SECTION	BEACH MOUNTAIN SECTION	GENERALIZED SECTION	SECTION 4 OF C. E. DECKER, 1939 WITH SLIGHT MODIFICATION	ADAPTED FROM SECTION 2 OF C. E. DECKER, 1939	GENERALIZED SECTION ADAPTED FROM PUBLISHED SOURCES



INDEX MAP

0' 1000' 2000' 3000' 4000' 5000' 6000' 7000'

VERTICAL SCALE

Williams Canyon limestone (M. Ord.(?))
Manitou formation
Sawatch qtz.(?) pre-Cambrian granite
Montoya limestone (U. Ord.)
Unit C
Sub unit B2
Sub unit B1
Unit A
Bliss sandstone
pre-Cambrian rhyolite porphyry
El Paso formation
Cambrian(?) or pre-Cambrian Van Horn sandstone
Bliss(?) sandstone
Devonian to Cretaceous
Honeycut formation
Gorman formation
Tanyard formation
Wilberns formation
Permian
Kindblade formation
Cool Creek formation
McKenzie Hill formation
Signal Mountain formation
Royer dolomite
Fort Sill limestone
Honey Creek formation
Simpson group (M. Ord.)
West Spring Creek formation
Kindblade formation
Cool Creek formation
McKenzie Hill formation
Butterly dolomite
Signal Mountain formation
Royer dolomite
Fort Sill limestone
Honey Creek formation
Devonian to Cretaceous
Black Rock formation
Smithville formation
Powell dolomite
Cotter dolomite
Theodosia formation
Rich Fountain formation
Roubidoux formation
Gasconade dolomite
Eminence dolomite
Potosi dolomite
Elvins group
Jefferson City Group

EXPLANATION

Line of approximate correlation

Boundary established, or within close limits *(undulating where known to be unconformable)*

Provisional boundary between faunal divisions

Boundary as tentatively located by C. E. Decker

Laterally gradational boundary

17. Stratigraphic position of a numbered collection of fossils *(refers to CF-, TF-, or OF- numbers according to state)*

. Stratigraphic position of fossils recorded in the field

D. Stratigraphic position of fossils listed by Decker, 1939

B. Stratigraphic position of fossils listed by Bridge, 1936

U. Stratigraphic position of fossils listed by Ulrich, 1932

F. Stratigraphic position of fossils listed by Frederickson, 1941

All fossils referred to are listed in Part 3 of text, or published sources

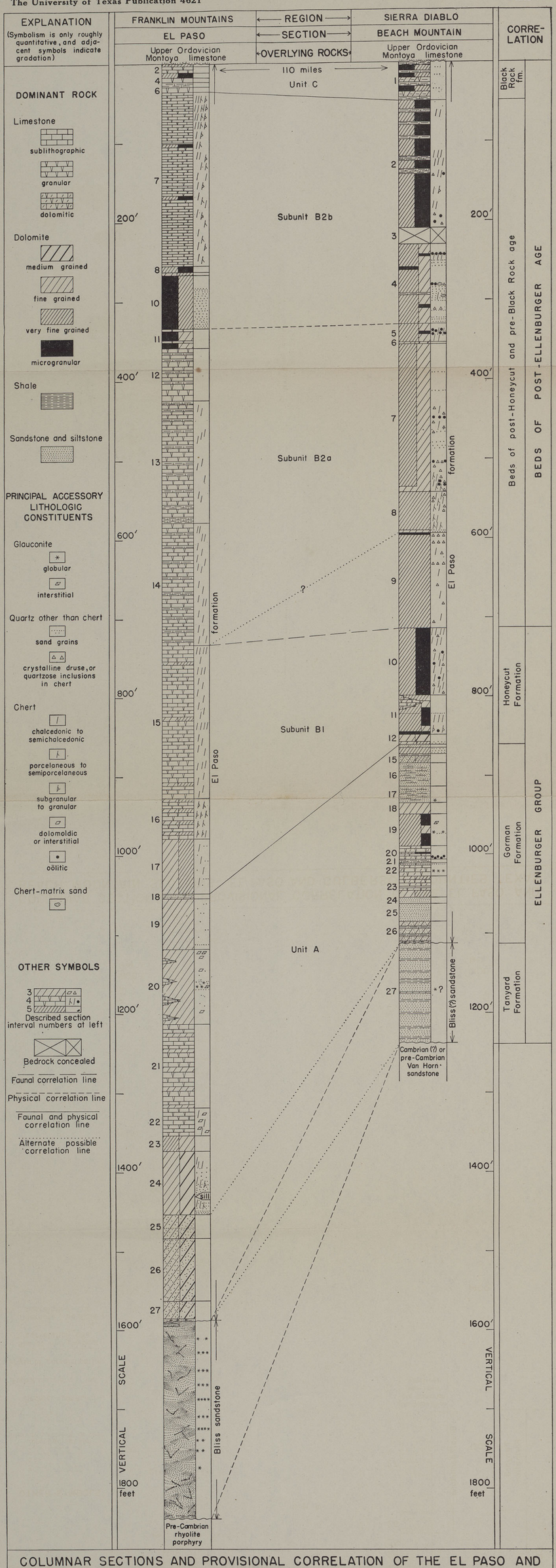
For fossils of the Llano uplift see Plate 14 and text

For fossils of the Ozark uplift see Bridge (1930) and Cullison (1944)

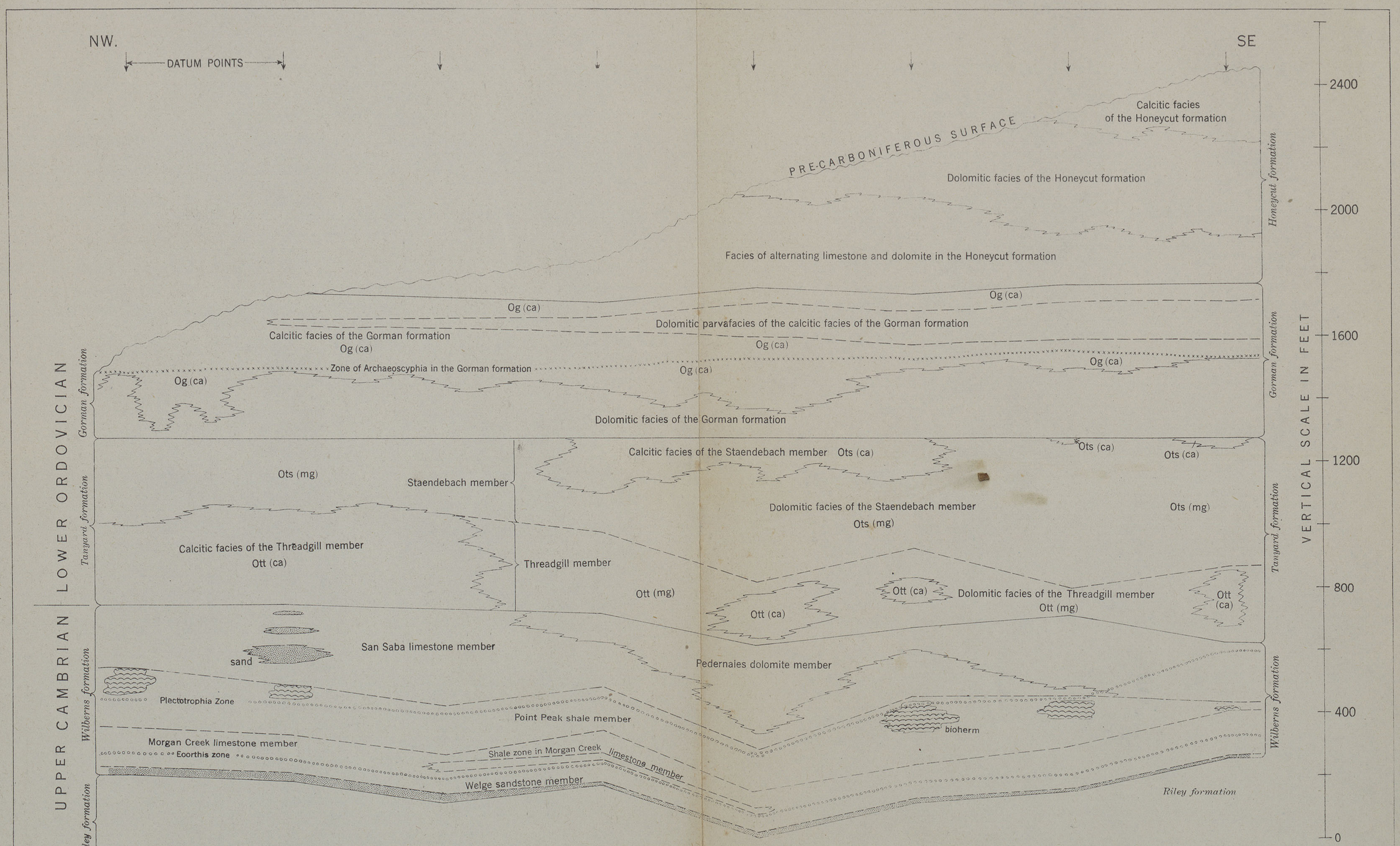
For detailed columnar sections of sections 2, 3, and 4 see Plates 14 and 16

JCK

Provisional correlation of some Lower Ordovician rocks in the mid-Continent.



COLUMNAR SECTIONS AND PROVISIONAL CORRELATION OF THE EL PASO AND BEACH MOUNTAIN SECTIONS EL PASO AND CULBERSON COUNTIES, TEXAS



DIAGRAMMATIC REPRESENTATION OF THE ELLENBURGER GROUP AND WILBERNS FORMATION IN THE LLANO UPLIFT OF CENTRAL TEXAS

(Datum is contact of Tanyard and Gorman formations)

Airline distance northwest to southeast equals 80 miles.