BUREAU OF ECONOMIC GEOLOGY
The University of Texas at Austin
Austin, Texas 78712

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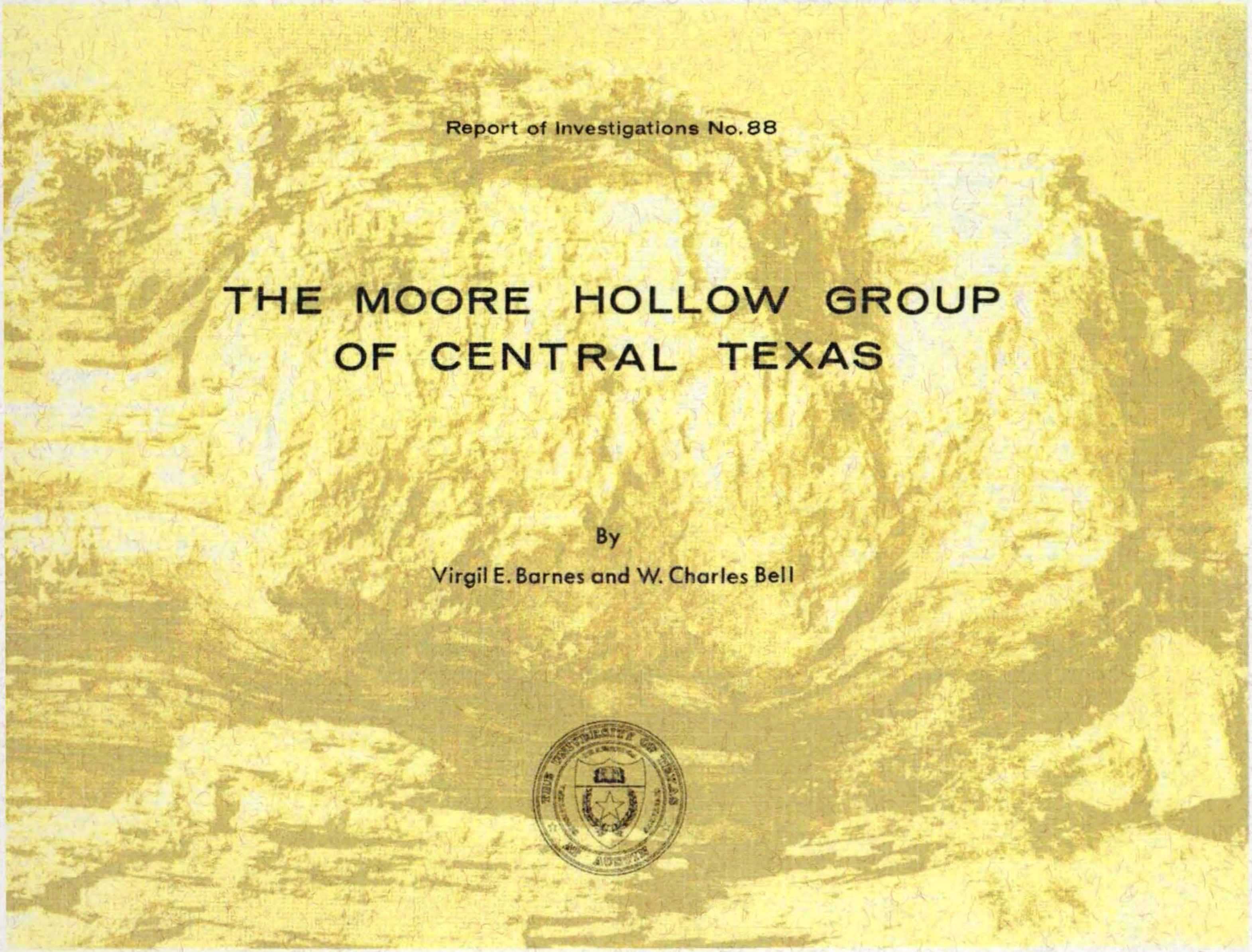

Report of Investigations No. 88

# THE MOORE HOLLOW GROUP OF CENTRAL TEXAS

By
Virgil E. Barnes and W. Charles Bell

1977

Bureau of Economic Geology
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**Report of Investigations No. 88**

# The Moore Hollow Group of Central Texas

**By**
**Virgil E. Barnes**
**and**
**W. Charles Bell**

*Report of Investigations No. 88 is Part I of a three-part report. Parts II and III are on open file at the Bureau of Economic Geology.*

**1977**

*Cover photograph:* Stromatolitic bioherm at the top of the Point Peak Member of the Wilberns Formation, Mason County, Texas. Bioherm shown is about 50 feet thick.

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*NOTE: Parts II and III of this paper (contents listed below) are on open file at the Bureau of Economic Geology, The University of Texas at Austin, Austin, Texas.*

## INTRODUCTION

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## PART III. SUBSURFACE STRATIGRAPHIC DATA

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- Carpenter Exploration Company No. 1-A, McCollum, McCulloch County
- Continental Oil Company No. 1 Wiley, Erath County
- Fish Production Company No. 1 Postell, Kinney County
- Fredericksburg city water well No. 9, Gillespie County
- N. D. Gallagher and O. G. Lawson No. 1 Mrs. Bobbie I. Terry, Comanche County
- Garland-Anthony No. 1 Hammons (Anthony No. 1 Gilbert on sample sacks), Parker County
- Gilcrease Oil Company No. 1 Feril, Comanche County
- Gregg et al. (Danewood Oil Company et al.) No. 1 M. L. Smith, Brown County
- Harvey No. 1 Giesecke, Runnels County
- Humble Oil and Refining Company No. 1 Autry, Comanche County
- Humble Oil and Refining Company No. 1 Millican et al., San Saba County
- Humble Oil and Refining Company No. 1 White, San Saba County
- Magnolia Petroleum Company and Western Natural Gas No. 1 Brown and Bassett, Terrell County
- Dempsey Montgomery Oils No. 1 Yates, San Saba County
- T. F. Murchison ranch well, Burnet County
- H. M. Naylor No. 1 Lloyd Mitchell, Edwards County
- Naylor No. 1 Stone, Coleman County
- Phillips Petroleum Company No. 1-A Towson (Townson on samples), Hamilton County
- Shaw No. 1 Jordan, San Saba County
- Stratoray Oil Corporation No. 1 Stribling, Blanco County

Supplementary thin-section data
- Bandera County
  - G. L. Rowsey No. 2 Fee
- Blanco County
  - Roland K. Blumberg No. 1 Wagner
- Kendall County
  - Magnolia Petroleum Company No, 1 Below
- Kerr County
  - G. L. Rowsey No. 2 Nowlin
  - Tucker Drilling Company No. 1 Dr. Roy E. Perkins

References

## ILLUSTRATIONS

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1. Diagrammatic representation of Moore Hollow Group rocks in Central Texas.
14. Index map showing location of described sections and wells used in preparing "Correlation of Moore Hollow Group Rocks in Central Texas," plate 2 of Part I.
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# THE MOORE HOLLOW GROUP OF CENTRAL TEXAS

VIRGIL E. BARNES[1] AND W. CHARLES BELL[2]

## ABSTRACT

Middle and Upper Cambrian rocks and locally up to 90 feet of Lower Ordovician rocks in Central Texas, are here named the Moore Hollow Group. In ascending order, the Moore Hollow Group is composed of the Riley Formation (Hickory Sandstone, Cap Mountain Limestone, and Lion Mountain Sandstone Members) and the Wilberns Formation (Welge Sandstone, Morgan Creek Limestone, Point Peak, and San Saba Members).

A sequence of Dresbachian to earliest Ordovician faunas, as complete as any known in North America, was found during the field and laboratory work on this sequence of rocks. The mostly granular limestone of the Moore Hollow Group is composed dominantly of pelmatozoan debris; trilobite debris is abundant and in a few beds is dominant. These rocks accumulated in shallow water in a broad bay-like area.

The boundary between the Moore Hollow and overlying Ellenburger Group is identified using lithic evidence only. It is in a gradational sequence formed during continuous sedimentation, and in general the boundary is younger toward the shore. Within the Llano region the boundary between lithic types crosses the Cambrian-Ordovician boundary; consequently, Ordovician rocks are included in the Moore Hollow Group to the west and Cambrian rocks are included in the Ellenburger Group to the east.

Although the Moore Hollow Group is composed of distinctly mappable units in the Llano region, shoreward in the subsurface the carbonate rocks give way to terrigenous materials and the identity of the various units is no longer maintained. In the opposite direction in the subsurface, terrigenous units give way to carbonate rocks, a disconformity between the Riley and Wilberns Formations disappears, and dolomite becomes the principal carbonate of the Wilberns Formation.

## 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 Moore Hollow Group of rocks. A preliminary report by Cloud, Barnes, and Bridge (1945) summarized what was then known of rocks above the *Plectotrophia* Bed in the Point Peak Member, and Bridge, Barnes, and Cloud (1947) described all the units so named or redefined in order to furnish standard reference for them. Their nomenclature is used today except that Barnes and Bell (1954b) dropped the name Pedernales Dolomite, including all dolomite so-named with the San Saba and changing the name San Saba Limestone to San Saba Member, a member defined as having dolomitic and calcitic facies, thus bringing the nomenclature of the upper part of the Wilberns Formation into conformity with that of the overlying Threadgill and Staendebach Members of the Tanyard Formation of the Ellenburger Group.

The present report gives the results of work intermittently in progress starting in 1939, when Barnes began

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a quadrangle-mapping program in Gillespie County and discovered the excellently exposed section of Wilberns Formation rocks along Threadgill Creek, and terminating in 1960. The present publication originally was intended to be a companion volume to the "Ellenburger Group of Central Texas" (Cloud and Barnes, 1948) with reference to that volume for material dealing with Cambrian and Ordovician rocks included in the Moore Hollow Group of the present report. Unfortunately, the Ellenburger volume is out of print and for that reason most of the material concerning the Moore Hollow Group has been extracted from that volume for inclusion in the present report. This report differs from the Ellenburger report in another respect, in that supporting data are not included in this publication but instead are placed on open file at the Bureau of Economic Geology.

The bulk of the typescript for this publication was placed in the file July 22, 1960, awaiting the completion of the paleontological portion of the report by Bell. Prior to this date Barnes (1956c) reported on the lead deposits in the Upper Cambrian of Central Texas, and Bell's students studied and reported on the faunas of the Moore Hollow Group. Students involved include Wilson (1949, *Elvinia* Zone trilobites of the Wilberns), Palmer (1954, faunas of the Riley Formation), Ellinwood (1953, Late Upper Cambrian and Lower Ordovician faunas), Winston (1957, Upper Trempealeauan faunas), and Harry Nicholls (thesis not completed, Lower Ordovician faunas). Since 1960 Bell and Ellinwood (1962) have published the portion of Ellinwood's dissertation on the Upper Franconian and Lower Trempealeauan trilobites and brachiopod faunas, and Winston and Nicholls (1967) have published jointly their earlier thesis efforts. Longacre (1970) made a detailed study of the trilobites of the Ptychaspid biomere of the Wilberns Formation.

Although the faunal studies in 1960 were adequate for the present publication, Bell wanted to write a more complete synthesis of the paleontological material and was still preparing fossils at the time of a stroke in 1970 which incapacitated him. Rather than let the Moore Hollow manuscript languish, Barnes extracted pertinent paleontologic data from the various publications of Bell's students so that the manuscript could be published. It is unfortunate for the reader that Bell was unable to complete his portion of this publication; also the publication has lost considerably in currency because of the delay. For example, several theses on these rocks, not related to our effort, were completed subsequent to 1960 (Ahr, 1967; Chafetz, 1970; Daugherty, 1960; Dekker, 1966; Hooks, 1961; Wilson, 1962); Folkian carbonate terminology (Folk, 1959) has become established during that time; parallel studies of the Cambrian have been going on elsewhere; and Barnes and Schofield (1964) published a report on the Cambrian sands because of their current and potential commercial value. Now that a publication deadline has been set, in order that the previously collected basic data concerning the Moore Hollow Group can be published, it is expedient to forego a synthesis of these data in light of recent literature.

Barnes did most of the mapping, measuring, and describing of sections, petrography, and subsurface work. Bell, in charge of the paleontological part of the project, supervised theses on the various faunas in the Moore Hollow Group and saw that the results of these studies were published. While supervising a group of Humble Oil & Refining Company trainees during the summer of 1954, he described the East Canyon section and measured and described the Taylor Ranch section.

This report summarizes the stratigraphy of the Moore Hollow Group on the basis of detailed local observations in various parts of the Llano region of Central Texas. The areas worked in detail were selected on the basis of previous work (Bridge, Barnes, and Cloud, 1947), quality of exposure, and geographic distribution. Primary objectives were to show how to recognize the various subdivisions, how to correlate them from place to place, and how the information obtained may be applied. To accomplish this we first defined some of the descriptive terms used, stated the methods followed, and the sorts of evidence on which subdivisions and correlation were based, then provided descriptions of the units themselves. Basic information on this group of rocks is furnished by a section on petrography that includes thin-section, heavy-mineral, and insoluble-residue data, and other sections are concerned with sedimentary structures, depositional history, biostratigraphy, paleontology, and a comparison of recent sediments and Moore Hollow Group rocks. The final sections treat geologic structure and economic resources.

The index map (pl. 1) shows the general region involved and the areas mapped for this report, as well as other areas in which Moore Hollow rocks have been mapped in detail. The area covered by the subsurface work is shown in figures 2 through 11. The geologic map of Texas, scale 1:500,000, by Darton, Stephenson, and Gardner (1937) shows the general geologic setting and the current State Geologic Atlas, Llano and Brownwood sheets, scale 1:250,000, when completed, will accurately portray the distribution of Moore Hollow rocks in the Llano region (Barnes, proj. director, in preparation; Barnes, proj. director, 1976).

Rocks of the Moore Hollow Group are known to crop out only in the Llano region, a basinlike structural uplift at the geographic center of Texas. It is rimmed by the Edwards Plateau on the west, south, and east and adjoins the Carboniferous rocks of the Osage Plains to the north. Primarily it is a region of Precambrian and early

Paleozoic rocks that have been exposed by gentle doming and erosion of the overlying Cretaceous and late Paleozoic rocks. It is essentially oval, about 80 miles long in a northwest-southeast direction, 55 miles wide, and about 4,400 square miles in area. This is the region referred to in the present report as the Llano region, also called the Central Mineral Region in some reports. The Llano region is at the apex of the Llano uplift, the subsurface expression of which is about 175 miles across in an east-west direction and about 250 miles long in a north-south direction (Barnes, 1959, fig. 1).

The following introductory material by Cloud (Cloud and Barnes, 1948) is quoted with slight modifications but without paraphrasing:

> 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 Precambrian rocks were intensively folded, faulted, and injected with igneous intrusions before Middle 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 Precambrian rocks, the Paleozoic strata being preserved either as marginal deposits, or as outlying block-faulted peninsulas or on monadnocks in the Precambrian terrane. Schistose and granitic rocks that are poorly resistant to weathering comprise the larger part of the Precambrian, 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 steepsided, 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 Precambrian 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 10 counties. Its principal industry is ranching and the ranches range in size from under 1,000 to about 80,000 acres, with the average ranch comprising perhaps 2,000 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 2,000 to 6,000, 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.

For pronunciation of geologically important place-names in the Llano region the reader is referred to Cloud and Barnes (1948, p. 15) and for a glossary of selected technical terms he should consult the same publication (p. 15–19) and Barnes (1959, p. 20).

## ACKNOWLEDGMENTS

Sincere thanks are here expressed to the persons who have aided, advised, and befriended the writers in the ways noted below during the years this study has been in progress.

The late Dr. Josiah Bridge most generously made available his entire collection of unpublished notes on the Llano region, consulted with Cloud, Barnes, and Bell in the field on several occasions, identified some of the fossils during the early stages of the work, and gave general scientific supervision and enthusiastic encouragement, especially during the time Cloud and Barnes were working on the Ellenburger Group and immediately underlying rocks.

Dr. Preston E. Cloud, Jr., has been so closely identified with the work on Moore Hollow rocks that it is almost impossible to separate the credits due him. Bridge, Barnes, and Cloud (1947) coauthored the paper summarizing the stratigraphy of the Cambrian rocks in Central Texas. The upper portion of the Moore Hollow sequence was included in the several sections which Cloud measured and described in the Ellenburger report (Cloud and Barnes, 1948). And more recently, he has contributed to the understanding of some of the problematica and lebensspurren in Moore Hollow rocks. Cloud's cooperation took place chiefly during his employment by the U. S. Geological Survey; the authors express sincere thanks to the Survey for this informal participation.

Mr. L. E. Warren is also closely allied with work on Moore Hollow rocks, having helped measure, describe, and sample the upper portion of this sequence during the Ellenburger studies; he also helped map these rocks in numerous 7½-minute quadrangles in Gillespie and Blanco Counties.

Barnes was assisted in the field during various stages of the work by T. A. Anderson, W. A. Anderson, Louis Dixon, P. L. Dixon, H. L. Ellinwood, A. R. Palmer, and T. R. Walker. To these men the writers express deep appreciation, especially to A. R. Palmer who, as a direct result of his year's assistantship, published "The Faunas of the Riley Formation in Central Texas" (1954). Barnes is especially indebted to Dr. Palmer for his help in modernizing all fossil lists in this publication as well as in described sections on open file at the Bureau of Economic Geology. His identification of Cambrian fossils from the subsurface is also appreciated (Cloud and Palmer, 1959). H. L. Ellinwood (1953) and T. R. Walker (1952) filed dissertations on facets of the Central Texas Cambrian work; the availability of this work for use in the present report is gratefully acknowledged.

Appreciation is also expressed to Don Winston II and Harry Nicholls for the very fine faunal studies in the vicinity of the Cambrian-Ordovician boundary; to Winston and Robert Alexander for mapping the Leon Creek area and furnishing the Leon Creek sections; to Gehardt Jansen for mapping the Goodrich Ranch area and furnishing the various sections in that area; to David L. Amsbury for compiling a list of Cambrian wells and describing samples from them; and to M. E. Taylor and E. L. Yochelson, U.S. Geological Survey, for identification of Central Texas fossils housed in Washington, D.C., prior to the time at which all the Moore Hollow Group collections were transferred to the U.S. National Museum.

C. G. Groat, formerly Acting Director of the Bureau of Economic Geology, The University of Texas at Austin, and his predecessors, Drs. W. L. Fisher, P. T. Flawn, J. T. Lonsdale, and E. H. Sellards, furnished continuing support and active interest in this project over the years and to them the writers owe a debt of gratitude.

All drafting was under the supervision of J. W. Macon. The report was read and criticized by Patricia Wood Dickerson. Editorial work over the years, in addition to that by Patricia Wood Dickerson, includes stints by Josephine Casey and Lori McVey, each with her own ideas, and finally by Jennifer Evans whose efforts are greatly appreciated.

Cystoids collected from the Point Peak Member were in the hands of Dr. Edwin Kirk, U. S. National Museum, at the time of his death. Through the office of Dr. G. A. Cooper, Head Curator, Department of Geology, these fossils were sent for study November 13, 1956, to Dr. Gerhard Regnéll, Department of Paleontology, University of Lund. A report on this material is being prepared by Regnéll for publication. Dr. J. B. Knight described two new genera of gastropods from the Central Texas Cambrian and identified others.

Some additional acknowledgments are made at appropriate places in the report. To the ranchers and other local residents of Central Texas, various oil company personnel, and many others too numerous to mention who have befriended the authors in many ways, a very great debt must be satisfied by a general expression of thanks.

## METHODS AND TECHNIQUES

Pertinent information on methods and techniques applicable to Moore Hollow Group rocks is paraphrased from Cloud and Barnes (1948).

The whole effort of Barnes and his 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 sections. 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.

Measurement of each of the sections of Moore Hollow Group rocks described in Part II 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 mappable characters of the rocks. Both geology and base data were plotted in the field on aerial photographs. Contacts and faults were walked out except where so evident on the photographs that there was no chance of misinterpretation.

Mapping was done on U. S. Department of Agriculture vertical aerial photographs enlarged to the approximate scale of 1:7,920. Almost all maps prior to 1960 were plotted planimetrically from the enlarged aerial photographs for reproduction at a scale of 4 inches to 1 mile (1:15,840). Since then, the completion of 1:24,000–scale topographic mapping of the Llano region by the U. S. Geological Survey has made available a more satisfactory base although at reduced scale. These maps have been used as a base; however, in order to reduce the cost of preparation and printing, the contours have been removed and only the culture, drainage, geological data, and the geologic units identified by symbol are shown. All small areas, originally considered for page-sized illustrations in the text, have been placed on plate 7.

Sections were measured directly in the field and 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 topographic advantages.

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, was scouted out and marked; (2) attitudes of beds were determined as frequently as was practicable along and near the line of section and averaged at appropriate intervals; (3) the section was directly measured and marked; (4) finally the section was described in detail.

Direct measurements of strata were made with a Brunton compass set at the proper angle of inclination, usually without the aid of a staff for flat and gently dipping beds, as the observer's eye height is exactly 5 feet. When the dip became sufficient to produce error, a 5-foot staff positioned normal to the bedding was used to assure that a 5-foot interval was measured. In order to facilitate chip and spot sampling and fossil collecting each 5-foot interval was marked with yellow paint spots and at appropriate intervals the footage from the base of the section was painted on some convenient surface.

Without vertical aerial photographs the work would have been vastly more difficult, especially in view of the lack of 7.5–minute topographic maps at the time the work was done. The photographs are perhaps at their maximum usefulness in regions such as the Llano area where topographic distinctions are well expressed but not extreme, where vegetation is neither dense nor very sparse for the most part, and where soil cover is not great. They furnish many useful clues in 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, and they guide one to significant outcrops.

## BASIS OF CORRELATION

Correlation of the various rock units mapped within the Moore Hollow Group of the Llano region is based on the lithic character of the dominant rocks or suite of rocks, macroscopically visible accessory lithic constituents, topographic expression, and vegetation. Fossils furnish contributory evidence, but as most member boundaries transgress time, fossil zones may cross boundaries from one unit to another. Regional correlation, on the other hand, should be based wholly on fossils. For correlation on physical evidence in and near the Llano uplift, the distribution of sandstone, siltstone, and glauconite, as well as grain sizes and color of dolomites and limestone, are particularly helpful. Topographic expression, color value, and vegetal patterns are most helpful in mapping on aerial photographs.

Physical criteria applied to the subdivision of the Moore Hollow Group of rocks and correlation of its various units are as follows:

### Distribution of Glauconite

In the western part of the Llano region the presence of significant glauconite helps separate the Moore Hollow Group from the nonglauconitic Ellenburger Group. Within the Moore Hollow Group the Lion Mountain Member is distinguished by its greensand content; the overlying Welge, except in the southeastern part of the region, is essentially glauconite-free. Glauconite is absent in the lower two-thirds or so of the Hickory Sandstone, but elsewhere in the Moore Hollow Group glauconite is fairly generally distributed except that it is very scarce to absent in most dolomite.

### Distribution of Quartz Sand

Quartz sand is the chief constituent of the Hickory and Welge Sandstone Members and is an important part of the Lion Mountain Sandstone Member. It forms thick beds in the San Saba Member from the western part of the Llano region westward, and sandy beds are scattered through the lower gradational part of the Cap Mountain Limestone. All carbonate units in the subsurface grade to quartz sand toward the shore. In the Llano region the overlying Tanyard Formation of the Ellenburger Group is sand-free but south and southwestward it is somewhat sandy.

Much of the sand in the Moore Hollow is exceptionally well rounded, but where not protected by a coating of iron oxide, it may be rough from reconstitution and solution pitting. The roundest and smoothest grains are those composing the hematitic upper unit of the Hickory Sandstone to the northwest, which grades laterally to red sandy Cap Mountain Limestone to the southeast.

### Distribution of Feldspathic Siltstone

Abundance of feldspathic siltstone and silt helps identify the middle member of the Cap Mountain and the Point Peak Member. Silt is common in all other units except in the Welge Sandstone and in the dolomites of the eastern part of the Llano region. The proportion of feldspar and the amount of authigenic feldspar increase upward, and the amount of weathering and the particle size of the detrital feldspar (not counting the authigenic overgrowth) decrease upward. Mica in the siltstone unit of the Cap Mountain Limestone is much more deeply weathered than mica in the Point Peak. In the western area silt-sized feldspar, mostly authigenic, is common in the Threadgill Member of the Tanyard Formation; eastward silt content gradually decreases until none is present.

### Grain Size and Color of Dolomite

In the eastern part of the Llano region, grain size and color of dolomite are locally used to help distinguish Moore Hollow rocks from Ellenburger rocks. The Threadgill Member in this area is dominantly coarse-grained, light-colored dolomite, and the underlying San Saba Member is dominantly fine-grained, dark-colored dolomite.

### Grain Size and Color of Limestone

In the western part of the Llano region grain size helps distinguish the dominantly aphanitic, light-colored limestone of the Ellenburger Group from the dominantly granular, darker colored limestone of the Moore Hollow Group, except that the stromatolitic limestone in the Moore Hollow may be aphanitic. The peculiar light-greenish to brownish cast of this limestone is usually sufficient to distinguish it from the light yellowish-gray limestone of the Threadgill Member. In the eastern part of the Llano region the aphanitic limestones of the San Saba and the Threadgill Members are indistinguishable.

# GENERAL STRATIGRAPHY

## INTRODUCTORY NOTES

This section on general stratigraphy treats chiefly the stratigraphic features of the Moore Hollow Group, which rests on Precambrian rocks and lies beneath Ellenburger rocks. Brief mention only is given to rocks which lie directly on the Moore Hollow Group and to the Precambrian rocks beneath. The Precambrian surface rocks are discussed by Paige (1911, p. 9–23; 1912, p. 3–5) and Stenzel (1934, p. 74–79), and information about them is summarized by Barnes, Shock, and Cunningham (1950, p. 7–8) and by Clabaugh and McGehee (1962). The Precambrian subsurface rocks are discussed by Flawn (1956). For further information about the Ellenburger group the reader is referred to Cloud and Barnes (1948); for descriptions of the Cretaceous rocks locally resting on Moore Hollow Group rocks, the reader is referred to the texts of various quadrangle maps by Barnes (1952a-k, 1956a, b, 1965a, b). The rocks in Menard County shown on the geologic map of Texas (Darton, Stephenson, and Gardner, 1937) as Canyon in age were identified by Harlton (1929) on the basis of ostracods.

Geologic units in the Llano region are listed as follows:

- Mesozoic Era
  - Cretaceous System
    - Lower Cretaceous
      - Fredericksburg Division
        - Edwards Limestone
        - Comanche Peak Limestone
        - Walnut Clay
      - Trinity Division
        - Upper Trinity
          - Glen Rose Limestone
          - Hensell Sand
        - Middle Trinity
          - Cow Creek Limestone
          - Hammett Shale (Lozo and Stricklin, 1956)
        - Lower Trinity
          - Sycamore Sand
- Paleozoic Era
  - Carboniferous System
    - Pennsylvanian Series
      - Canyon Group
      - Strawn Formation
      - Smithwick Shale
      - Marble Falls Limestone
      - Unnamed phosphorite (Barnes, 1954)
    - Mississippian Series
      - Barnett Formation
      - Chappel Limestone
    - Mississippian Series and Upper Devonian
      - Houy Formation (Cloud, Barnes, and Hass, 1957)
        - Unnamed phosphorite
        - Doublehorn Shale
        - Ives Breccia
  - Devonian System
    - Middle Devonian
      - Unnamed Limestone, Locality TF-233
      - Zesch Formation
      - Bear Spring Formation
      - Stribling Formation
    - Lower Devonian
      - Pillar Bluff Limestone
  - Silurian System
      - Starcke Limestone
  - Ordovician System
    - Upper Ordovician
      - Burnam Limestone (Barnes, Cloud, and Duncan, 1953)
    - Lower Ordovician
      - Ellenburger Group
        - Honeycut Formation
        - Gorman Formation
        - Tanyard Formation
          - Staendebach Member
          - Threadgill Member
  - Ordovician and Cambrian Systems
    - Lower Ordovician and Upper Cambrian
      - Ellenburger Group
        - Tanyard Formation
          - Threadgill Member
      - Moore Hollow Group
        - Wilberns Formation
          - San Saba Member
  - Cambrian System
    - Upper Cambrian
      - Moore Hollow Group
        - Wilberns Formation
          - San Saba Member
          - Point Peak Member
          - Morgan Creek Limestone Member
          - Welge Sandstone Member
        - Riley Formation
          - Lion Mountain Sandstone Member
          - Cap Mountain Limestone Member
    - Upper and Middle Cambrian
      - Moore Hollow Group
        - Riley Formation
          - Hickory Sandstone Member
- Precambrian Era
  - Metasedimentary rocks
    - Packsaddle Schist
        - Click Formation
        - Rough Ridge Formation

Sandy Formation
Honey Formation
Valley Spring Gneiss
Metasedimentary or Meta-igneous rock
Lost Creek Gneiss (Barnes and Schofield, 1964)
Meta-igneous rocks
Coal Creek Serpentine
Big Branch Gneiss
Red Mountain Gneiss
Igneous rocks
Quartz porphyry (llanite)
Sixmile Granite
Oatman Creek Granite
Town Mountain Granite

Table 1 summarizes the measured thicknesses of the various units in the Moore Hollow Group, and a diagram (fig. 1) is included as an aid for visualizing the various units and facies being discussed.

## PRE-MOORE HOLLOW SURFACE

The Cambrian sea encroached from the southeast upon a mature, semiarid surface rising gently to the north and west. The less resistant rocks, such as most of the Packsaddle Schist, most of the granites, and some of the Valley Spring Gneiss, were eroded to an essentially common level; whereas, the rocks resistant to erosion, such as the Oatman Creek Granite and portions of the Valley Spring Gneiss, formed isolated hills and ridges standing as much as 800 feet above their surroundings.

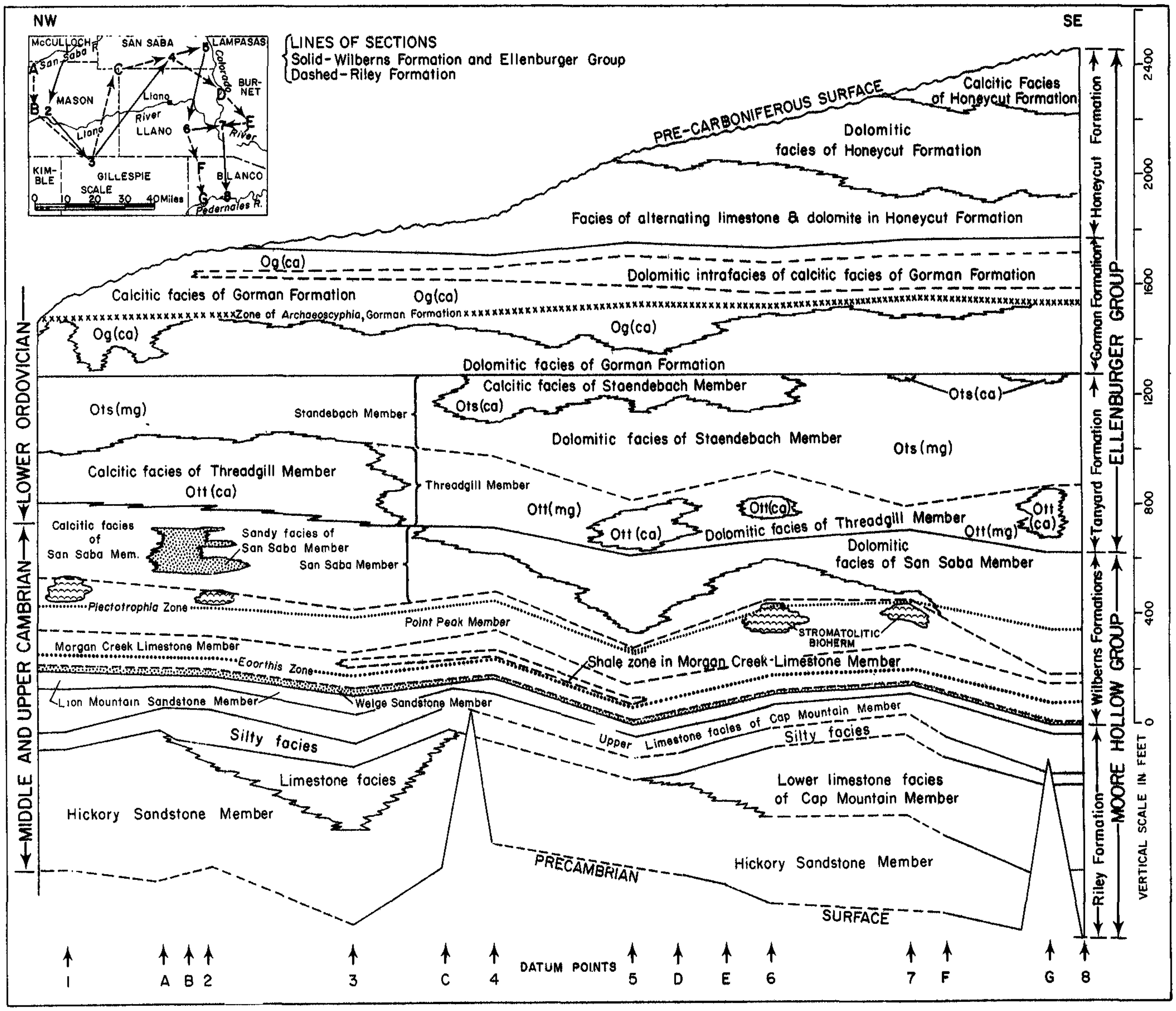



Figure 1. Diagrammatic representation of Moore Hollow Group rocks in Central Texas.

**Table 1. Thicknesses* of units of the Moore Hollow Group and contiguous Threadgill Member rocks in measured sections, Llano region.**

| Measured sections | | Hickory Sandstone | Cap Mountain Limestone | Lion Mountain Sandstone | Riley Formation | Welge Sandstone | Morgan Creek Limestone | Point Peak Member | San Saba Member: Calcitic facies | San Saba Member: Dolomitic facies | San Saba Member: Total | Wilberns Formation | Moore Hollow Group | Threadgill Member |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bluff Creek | BC | | | | | | | 2+ | 260 | 0 | 260 | 262+ | 262+ | 18+ |
| Calf Creek | CA | | | | | | | | 149 | 3+ | 152+ | 152+ | 152+ | 5+ |
| Camp San Saba | SS | | | | | 9+ | 114 | 94 | 299 | 0 | 299 | 516+ | 516+ | 76+ |
| Carter Ranch | CR | 338 | 239 | 40 | 617 | 27 | 136 | 160 | 75+ | | 75+ | 398+ | 1015+ | |
| Cold Creek | CC | | | 47– | 47– | 28+ | 128 | 140 | 74+ | | 74+ | 370+ | 417+ | |
| Everett Ranch–Point Peak | EP | | 14+ | 28 | 42+ | 22 | 171 | 198 | 132 | 61 | 193 | 584 | 626+ | 10+ |
| Goodrich Ranch | GR | 244+ | 179 | 42 | 465+ | 12 | 141 | 147 | 42 | 125+ | 167+ | 468+ | 933+ | |
| James River, downstream | JRD | | 225+ | 55 | 280+ | | | | | | | | 280+ | |
| James River, upstream | JRU | | | 57 | 57+ | 20 | 127 | 188 | 284 | 0 | 284 | 619 | 676+ | 19+ |
| Klett-Walker | KW | 0 | 98 | 31 | 129 | 12 | 126 | 25 | 0 | 121+ | 121+ | 284+ | 413+ | |
| Leon Creek | LC | | | | | | 40+ | 71 | 253+ | 0 | 253+ | 364+ | 364+ | 152.5+ |
| Lion Mountain | LM | | | 49 | 49+ | 13 | | | | | | 13+ | 62+ | |
| Little Llano River | LL | 363 | 174 | 61 | 598 | 27 | 121 | 139 | 46+ | | 46+ | 333+ | 931+ | |
| Morgan Creek | MC | 340 | 204 | 47 | 591 | 15 | 130 | 114 | 59 | 169+ | 228+ | 487+ | 1078+ | |
| Pontotoc | P | 470 | 170 | 26+ | 666+ | 9+ | | | | | | 9+ | 675+ | |
| Riley Mountains | RM | 330 | 411 | 33 | 774 | 16 | 113 | 214 | 144 | 73 | 217 | 560 | 1334 | 250 |
| Slick Mountain** | SM | 286 | 177 | 57 | 520 | 18 | 102+ | | | | | 120+ | 640+ | |
| Squaw Creek | SC | | 14+ | 69 | 83+ | 22 | 3+ | | | | | 25+ | 108+ | |
| Streeter | ST | 116+ | 273 | 29 | 418+ | 22 | 141 | | | | | 163+ | 581+ | |
| Tanyard | T | | 3+ | 35 | 38+ | 19 | 131 | 136 | 47 | 277 | 324 | 610 | 648+ | 202 |
| Taylor Ranch | TR | | 165 | 50 | 215+ | 25 | 126 | 77+ | | | | 228+ | 443+ | |
| Threadgill Creek | TC | 364 | 418 | 78 | 860 | 23 | 142 | 154 | 281 | 0 | 281 | 600 | 1460 | 280+ |
| White Creek | WC | 276 | 497 | 41 | 814 | 11 | 143 | 111 | 0 | 56+ | 56+ | 421+ | 1235+ | |

** Measured in feet.*

*** Composed of the East Canyon, EC, and Moore Hollow, MH, sections.*

Marble in the Packsaddle Schist also formed ridges, but these were not so high. It is surmised that the topography of the old surface resembled somewhat that of the Precambrian portion of the Llano region today.

The distribution of the various Precambrian rock types beyond the Llano region in the subsurface is shown by Flawn (1956, pl. 1); he found that local relief existed on the pre-Paleozoic surface from Coke County north to Cottle County where hard granite or arkose gneiss protrudes above a metasedimentary surface of mica schist and phyllite (p. 53). To the east of the Llano region, Shell Oil Company No. 1 Purcell, Williamson County, entered a buried hill with perhaps 100 feet of relief in excess of that of buried hills in the nearby area of outcrop (Barnes, 1959, p. 25).

That the land was semiarid and with about the same amount of rainfall as at present may be reasoned from several lines of evidence: (1) Wind-abraded pebbles and cobbles are common at the base of the Moore Hollow sequence. (2) The clay fraction is mostly absent or scarce in the Moore Hollow Group, probably having been removed by wind before the coarser sediments were flushed into the sea. (3) Marble formed ridges on the pre-Moore Hollow Group surface, indicating insufficient moisture for solution to keep pace with the disintegration of the adjacent rocks. (4) Some sand grains show chatter marks that can be produced only by the work of wind.

Barnes (1959, p. 26) concluded that the degree of weathering of the Precambrian prior to the deposition of pre-Simpson rocks should differ from place to place, with least weathering prior to the deposition of Moore Hollow Group rocks and most prior to the deposition of Ellenburger Group rocks. Additional evidence on the probable climate during Moore Hollow time is discussed in the section on depositional history (this report, p. 80).

## MOORE HOLLOW GROUP

### History and summary statement

Detailed paleontological work in the vicinity of the Wilberns-Tanyard formational boundary revealed Ordovician fossils in the upper 50 or so feet of the Wilberns Formation in numerous stratigraphic sections measured in the western part of the Llano region. Before this finding the systemic boundary was thought to coincide with the Wilberns-Tanyard boundary (Cloud and Barnes, 1948, p. 31), and that a group name for Wilberns and Riley Formations strata was unnecessary. Now that it is known that Ordovician fossils (Barnes and Bell, 1954b, p. 36; Bell and Barnes, 1961) are in the uppermost Wilberns Formation beds, and also that the bulk of the Hickory Sandstone is probably of Middle Cambrian age (Palmer, 1954, p. 715; Bell and Barnes, 1961), a group name is needed so that all the beds beneath the Ellenburger Group and above the Precambrian in Central Texas can be easily designated.

Of the available names in the Llano region, East Canyon and Moore Hollow are the two most desirable for these strata. Of these, East Canyon would have been best except for the possibility of confusion with the Canyon Series of Pennsylvanian beds occurring in the same region. Because of this chance for confusion, Moore Hollow is used for the group name. Moore Hollow, located in the southeastern part of the Riley Mountains, is the site of the Moore Hollow section of Wilberns Formation and Ellenburger Group rocks (Cloud and Barnes, 1948, p. 275–286).

East Canyon, just south of Moore Hollow, is the type locality of the Riley Formation, and in this area the Wilberns and Tanyard Formations are in unfaulted sequence above the Riley Formation. Stratigraphic sections have been measured and described from the base of the Cambrian to the base of the Gorman Formation of the Ellenburger group; the sections are easily accessible and generally well exposed. Another advantage in using this area as the type locality for the Moore Hollow Group is that the standard section of the Ellenburger Group is also here and the two can be viewed in sequence.

The Moore Hollow Group, comprised of formations and members named between 1911 and 1954, includes at its base the Riley Formation, composed from the base up of the Hickory Sandstone, Cap Mountain Limestone, and Lion Mountain Sandstone Members, and at its top the Wilberns Formation, composed from the base up of the Welge Sandstone, Morgan Creek Limestone, Point Peak, and San Saba Members, the latter composed of dolomitic and calcitic facies and some sandstone.

A diagrammatic representation of Moore Hollow and Ellenburger rocks is shown in figure 1; a graphic summary and local correlation of Moore Hollow and immediately overlying Ellenburger rocks is shown in plate 2; correlation with rocks in the adjacent subsurface is given in plates 3 to 5; and the type section is described in Part II on open file at the Bureau of Economic Geology.

Evidence now available suggests continuous sedimentation across the Moore Hollow—Ellenburger boundary; the truncation in the southeastern part of the Llano region (Cloud and Barnes, 1948, p. 31) appears not to exist (Cloud and Barnes, 1957, p. 168). In the western part of the Llano region the Ellenburger—Moore Hollow boundary is in limestone, and the two groups are distinguished chiefly by grain size, with the Ellenburger predominantly aphanitic and the Moore Hollow mostly granular. Glauconite associated with granular limestone, essentially confined to the Moore Hollow Group, also helps mark the boundary.

In the eastern part of the Llano region, where the boundary between the two groups is in dolomite, Cloud and Barnes (1948, p. 30) used grain size to distinguish the two. For a considerable distance the contact is sharp between the fine-grained dolomite of the Moore Hollow Group below and the coarse-grained dolomite of the Ellenburger Group above, and this boundary appears to hold a fairly constant stratigraphic level. In the extreme eastern part of the Llano region Cloud and Barnes (1948, p. 30) found coarse-grained dolomite of Cambrian age in contact with coarse-grained dolomite of Ordovician age. In such areas it was realized that a boundary would be difficult to draw and that such dolomite would have to be lumped as Cambrian and Ordovician in age.

Additional work in this area and in the subsurface to the east and southeast shows that this condition is even more widespread than suspected by Cloud and Barnes, and also that the fine-grained/coarse-grained dolomite boundary probably does not remain at a constant level. Rocks in the subsurface in this direction, equivalent to the Moore Hollow Group at the surface, are slightly glauconitic, showing that the Ellenburger Group essentially as defined by Cloud, Barnes, and Bridge (1945, p. 139) and Cloud and Barnes (1948, p. 30) should be retained (Barnes, 1959, p. 28). The absence of glauconite in these rocks at the surface may be explained by weathering with removal of glauconite or its change to clay within the zone reached by sampling.

The placement of the boundary between the Moore Hollow and Ellenburger Groups in coarse-grained dolomite will be less exact than where the boundary is in limestone, and even in limestone the boundary is nebulous and seldom will be chosen between the same two beds on successive visits unless it is permanently marked. If the boundary between the Moore Hollow and Ellenburger Groups coincides at any place with the boundary between the Cambrian and Ordovician, it will be fortuitous. In the western area the boundary between the two is primarily in the Ordovician, and in the eastern area it may be mostly in the Cambrian; however, this is purely a guess based on the increase in distance from shore with time, and on the possibility that there is a critical distance beyond which glauconite or the source material for the formation of glauconite cannot be transported. If this is true, then glauconite may not extend as far upward in the section as the Ordovician in the eastern area.

**Areal distribution**

The only known outcrops assignable to the Moore Hollow Group are in the Llano region of Central Texas extending from Blanco and Burnet Counties on the east to Mason and Menard Counties on the west. In the subsurface these rocks are traceable into the marginal part of the Ouachita fold belt in one direction and in the opposite direction to where they terminate against Precambrian rocks. Laterally in the subsurface they have hot been traced either to the Marathon area to the west or the Arbuckle area of Oklahoma to the north; however, some rocks in all three areas are probably equivalent.

Within the Llano region the occurrence of Moore Hollow rocks is determined by structure and topography. They occur either at the margins of the topographic basin eroded in the crest of the Llano uplift or in block-faulted outliers of Paleozoic rocks that are largely or entirely surrounded by Precambrian rocks. The general pattern of the outcropping Moore Hollow Group rocks is shown on the geologic map of Texas (Darton, Stephenson, and Gardner, 1937) under the names Hickory Sandstone, Wilberns and Cap Mountain Formations, and lower part of the Ellenburger Limestone. Detailed geologic maps showing outcrops of Moore Hollow Group rocks include the Blowout, Crabapple Creek, Gold, Hilltop, Live Oak Creek, Morris Ranch, North Grape Creek, Palo Alto Creek, Squaw Creek, Stonewall, and Willow City geologic quadrangle maps (Barnes, 1952a-k); the Fall Prong and Threadgill Creek geologic quadrangle maps (Barnes, 1956a, b); the Johnson City geologic quadrangle map (Barnes, 1963, reprinted 1969); the Hye and Rocky Creek (North Grape Creek) geologic quadrangle maps (Barnes, 1965a, b); the Stonewall geologic quadrangle map (Barnes, 1966); the Cave Creek School (Gold) and Kingsland quadrangle maps (Barnes, 1967, 1976); and the Cap Mountain, Click, Dunman Mountain, Howell Mountain, Pedernales Falls, and Round Mountain geologic quadrangle maps (Barnes, in preparation a-f). Other detailed maps of Moore Hollow rocks are contained in publications by Romberg and Barnes (1944), Cloud and Barnes (1948), Barnes and Bell (1954a), and Barnes (1956c, 1958). The location of the areas mapped in detail, as well as those mapped in connection with the measurement of sections for this report, is shown on plate 1. Moore Hollow Group rocks at a scale of 1:250,000 are shown on the Llano and Brownwood Sheets of the Texas Geologic Atlas (Barnes, proj. director, in preparation, 1976).

**Thickness**

The Moore Hollow Group in its outcrop area of the Llano region attains a maximum known thickness of

1,460 feet in the Threadgill Creek section of Gillespie and Mason Counties. The group thickens southward in the subsurface (Barnes, 1959, pl. 1); in Tucker Drilling Company No. 1 Dr. Roy E. Perkins, Kerr County, 1,795 feet of Moore Hollow Group rocks including only 135 feet of Hickory Sandstone were drilled without reaching the Precambrian. The minimum thickness in this region is controlled by irregularities of the Precambrian floor, including monadnocks, one of which (in the Silver Creek area, Burnet County) reaches as high as the base of the Morgan Creek Limestone Member. Moore Hollow rocks deposited above this monadnock probably were less than 600 feet thick. In the subsurface to the east, in Shell Oil Company No. 1 Purcell, Williamson County, a similar peak was encountered reaching even higher into the Morgan Creek Member. The overall thickness of the Moore Hollow Group in the subsurface is largely controlled by the slope of the Precambrian floor, which rises in a general northwestward direction. The shoreward boundary and the thickness of the Moore Hollow Group are shown in figure 2.

In the extreme northwestern part of the Llano region, and in places in the subsurface to the northwest, post-Marble Falls—pre-Canyon erosion has truncated the upper beds of the Moore Hollow Group (pl. 7, fig. 4) and in places in the subsurface has entirely removed them.

### Lithic character

The limestones of the Moore Hollow Group are predominantly granular, fossiliferous, and colored various shades of gray, greenish gray, olive gray, and grayish brown; a few generally thin zones are pinkish to red. A few aphanitic beds are found in the uppermost part of the Moore Hollow Group in the western part of the region; aphanitic stromatolites are common in the top of the Morgan Creek Limestone Member and upward; and in the eastern part of the region aphanitic limestone grades laterally into coarse-grained dolomite (Barnes, 1952g, 1965b).

In some beds fossil debris, along with sand and silt, accounts for the granularity of the granular limestone. The character of the limestone and sandstone units indicates a shelf environment of deposition existed and that the water was probably shallow at all times. The shoreline, with only minor pauses and one retreat marked by the unconformity at the Riley-Wilberns boundary, migrated steadily and sedimentation appears to have kept pace. The position of the shoreline, and to a lesser extent the presence of barrier reefs of stromatolites, controlled the distribution of the various lithic types. Sand and silt formed the shoreward and lagunal facies, and limestone was deposited farther out. Because of this depositional pattern, Moore Hollow rocks are predominantly carbonate to the southeast with carbonates less abundant to the northwest, until in the subsurface in this direction they eventually disappear.

Most of the dolomite is either fine and very fine grained or coarse grained; very little is medium grained and microgranular. Most of the finer grained portion has purplish or reddish splotches and is apt to be more drab than dolomite of similar grain size in the Ellenburger Group, The coarse-grained dolomite in general cannot be distinguished from similar dolomite in the lower part of the Ellenburger Group.

Dolomite, scarce in the northwestern area, except as scattered rhombs and locally dolomitized stromatolite reefs in the Calf Creek area, becomes progressively more abundant eastward. In general, it is laterally gradational with aphanitic limestone in the southeastern part of the region, Most of the Point Peak Member grades to dolomite in this direction, and in the subsurface still farther east most of the Morgan Creek Limestone has also graded to dolomite. The coarse-grained dolomite and aphanitic limestone in the Moore Hollow Group of the eastern part of the region cannot be distinguished, if fossils are absent, from similar rocks in the overlying Threadgill Member. This fact indicates that both units formed under similar conditions, isolated from a source of terrigenous material.

Chert, except in the finer grained dolomites of the eastern part of the region, is unimportant in Moore Hollow Group rocks. Where present it is generally dolomoldic to drusy, dirty white, and chalk textured to compact. Dolomolds may be few where the chert is compact or so numerous that the chert is interstitial or forms lacy masses.

Glauconite is an important constituent of Moore Hollow rocks, distinguishing them from Ellenburger rocks, in which glauconite is exceedingly uncommon. In many Moore Hollow rocks feldspar is common to abundant as tiny detrital grains, and detrital grains with authigenic overgrowth; it is increasingly more common upward as authigenic grains. Similar authigenic feldspar is common in the lower few hundred feet of the Ellenburger Group in the western part of the Llano region. All feldspar is exceedingly scarce in the upper few hundred feet of Moore Hollow Group rocks in the southeastern part of the region.

### Porosity

The chief zone of porosity in Moore Hollow rocks is in the prolific water-bearing lower part of the Hickory

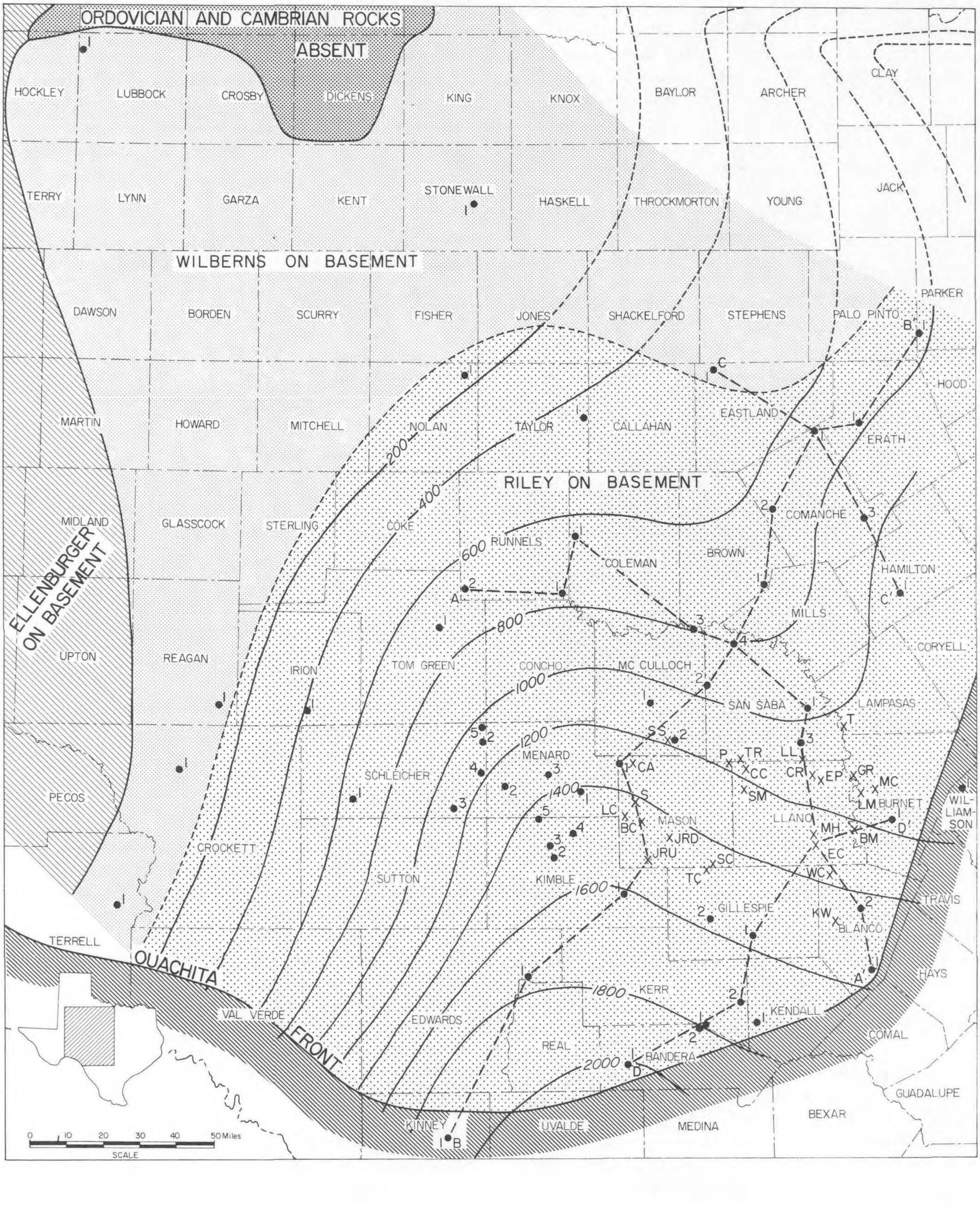



**Figure 2. Isopach map of Moore Hollow Group rocks in Central Texas showing wells and surface sections from which samples were examined.**

Sandstone in the northwestern part of the region. Stratoray Oil Corporation No. 1 Stribling, Blanco County, also encountered abundant water in the lower part of the Hickory Sandstone, but a well on the Murchison ranch south of Burnet yielded very little water from the Hickory; the yield in the Fredericksburg area also seems to be low. In the subsurface to the south of the Llano region the lower part of the Hickory Sandstone has not been reached; however, the upper part is more tightly cemented than it is in the outcrop area, indicating that the lower part also may be cemented.

In the western part of the area the middle part of the Hickory Sandstone is silty and argillaceous and the upper part is cemented by hematite. Neither appears to have much porosity, as indicated by low water yield. The porosity of the Lion Mountain Sandstone is likely to be low because of glauconite mud and argillaceous material, and the Welge Sandstone, which appears quite porous in some outcrops, is cemented by calcite in others. Sandstone in the San Saba Member is present only in the extreme western portion of the Llano region and is mostly calcite-cemented. However, calcite cementation may be a reflection of the lateral proximity of carbonate rocks, as there has been prolific petroleum production from equivalent rocks along the Cambrian trend of Coke and Nolan Counties. The writers know of no water well data for the Lion Mountain and Welge Sandstone Members or for the sandstone in the San Saba Member.

The limestone as well as the finer grained dolomites of the Moore Hollow Group appear to be without appreciable porosity. The coarse-grained dolomite of both the surface and the subsurface in part contains small vugs which, however, may not be interconnected.

#### Topographic and dendrologic expression

On aerial photographs most of the Moore Hollow strata show well-defined vegetation alignments along bedding. The dolomitic facies of the San Saba Member is an exception which, like the Ellenburger Group, forms a zone of few bedding alignments, typically expressing itself as an upland flat, or as an intermediate flat at the foot of Ellenburger hills. Locally the surface is strewn with chert and commonly displays numerous well-developed pimple mounds; in fact, such areas of pimple mounds are typical of its outcrop where chert is present, though not restricted to it. Cedar, prior to the cedar eradication program, grew thickly on most of the dolomite outcrops of the Moore Hollow Group; live oak is prominent in some areas; and deciduous oaks are locally abundant in excessively cherty areas.

The calcitic facies of the San Saba Member as well as that of the Morgan Creek Limestone Member show well-defined bedding alignments of vegetation. Both are distinct from the Point Peak Member with its gray band of blue brush, bee brush, and other stiff and thorny bushes covering the scarp formed by this member. The sandstones of the San Saba Member are marked by thick growths of black persimmon and, as with most quartz sandstones of the Llano region, deciduous oaks are common.

The Welge Sandstone Member forms a vegetation-covered scarp distinguished on aerial photographs by a narrow black band more dense than that of any of the bedding alignments in the Morgan Creek Limestone Member. In sharp contrast is the bench formed by the Lion Mountain Sandstone Member with its widely spaced live oak clumps.

The vegetation alignments along the bedding of the Cap Mountain Limestone Member are less distinct than those of the Morgan Creek Limestone and calcitic facies of the San Saba Member. The Hickory Sandstone Member displays even less bedding alignment; deciduous oaks are prominent. The vegetation of the Hickory is distinct from that of the Cap Mountain Limestone, which supports cedar and other carbonate-loving plants.

The above generalizations hold true for most of the Llano region except in the eastern and southeastern areas where rainfall is heavier. Here cedar grows profusely on all units except the Hickory Sandstone Member, and bedding alignments are not nearly so distinct. In the northwestern part of the Llano region, cedar is less strongly entrenched. In general, this area is more sparsely vegetated and more of the vegetation is thorny.

The vegetation of the Precambrian shows little alignment; mesquite is common because of the weathering of feldspar to form clay. Where the Precambrian is calcareous, such as in portions of the Packsaddle Schist, carbonate-loving vegetation similar to that on the limestone members of the Moore Hollow Group is dominant and in sharp contrast to the deciduous vegetation of the overlying Hickory Sandstone. In many areas where the Hickory Sandstone overlies Valley Spring Gneiss, the topographic and dendrologic patterns of the two are so similar that the boundary between them cannot be traced photogeologically.

Fault alignments are commonly shown by narrow black bands of vegetation and generally joints are similarly marked. A zone in the Cap Mountain Limestone of the eastern part of the Llano region has a joint pattern which produces a pattern on aerial photographs resembling the Widmanstatten figures of a coarse octahedrite.

Crosscutting faults may be revealed by bringing into juxtaposition units with different dendrologic patterns.

## Riley Formation

### Type section

The Riley Formation was named by Cloud, Barnes, and Bridge (1945, p. 154) and further discussed by Bridge, Barnes, and Cloud (1947, p. 111–114). Its type section is in East Canyon, Riley Mountains, about 18 miles by road southeast of Llano and west of the road to Click, and includes all Cambrian strata in Central Texas beneath the Wilberns Formation. It includes, from base to top, rocks formerly known as the Hickory Sandstone, the Cap Mountain Formation, and the Lion Mountain Sandstone Member of the Cap Mountain Formation.

Cloud, Barnes, and Bridge (1945, p. 154) stated:

> The contacts of these three rock units intergrade laterally, crossing faunal zones. For this reason they are here considered to be members of a single formation and are designated the Hickory Sandstone, the Cap Mountain Limestone, and the Lion Mountain Sandstone Members of the Riley Formation.
>
> The Riley Formation takes its name from the Riley Mountains in southeastern Llano County, where the included members are well and typically exposed. Better sections of the Riley Formation are known from other parts of the Llano region; but the only complete section in the Riley Mountains for which measurements are available is in the Moore Hollow area, about 18 miles by speedometer south [actually southeast] of the town of Llano and west of the Llano-Click road. In this area Cloud computed thicknesses of 335 feet for the Hickory Sandstone Members, 421 feet for the Cap Mountain Limestone Member, and 24 feet for the Lion Mountain Sandstone Member; making a total of 780 feet for the Riley Formation.

Cloud (*in* Cloud and Barnes, 1948, pl. 10) mapped the area and showed the line of section along which the type section was measured; a portion of Cloud's map is reproduced here (pl. 7, fig. 23). Bell in 1954 measured, painted, and described the East Canyon section, and in about 1956, Harry Nicholls, one of Bell's students, assisted by Elbert A. King, Jr., collected the section faunally and Nicholls identified the fossils. The section description and faunal list are on open file at the Bureau of Economic Geology.

### Thickness

Measurements of the Riley Formation range from 860 feet in the Threadgill Creek section to 129 feet in the Klett-Walker section, the latter section starting near the top of a monadnock. Another monadnock in the Silver Creek area, Burnet County, extends entirely through the Riley Formation, and a similar monadnock was penetrated by Shell Oil Company No. 1 Purcell, Williamson County. Irregularities of the Precambrian surface are the main factor controlling the thickness of the Riley Formation; however, the upper surface is marked by an unconformity and erosion may have caused some thinning to the northwest. Paleontological evidence supports this conclusion. The Precambrian floor appears to slope down to the south and southeast, and in these directions the Riley Formation probably thickens, but no well in this direction has penetrated its full thickness. The Riley Formation thins out against the Precambrian surface about 100 miles west and a slightly greater distance northwestward from the Llano region (fig. 3). The Riley Formation appears to have accumulated in a northwest-extending arm of the sea and in this direction very likely extended beyond its present limits, as the disconformity at its top indicates some erosion.

### Lithic character

The Riley Formation consists of two sandstone units, the upper one essentially a greensand, separated by a middle granular limestone unit, the lower boundary of which rises stratigraphically northwest. Proof of this rise is furnished by faunas and by a color zone in Hickory Sandstone to the northwest which passes laterally into Cap Mountain Limestone to the southeast. All boundaries in the Riley Formation are gradational, and boundaries were chosen so that easily detected changes in vegetational patterns can be used for mapping on aerial photographs. The boundary between the lower sandstone unit and the limestone is drawn at a vegetational boundary controlled predominantly by calcite content, and for this reason some rocks which are dominantly sandstone are included with the limestone member. The upper boundary of the limestone is drawn at the edge of the rather sterile bench of greensand distinguished by widely spaced clumps of live oak. In the southeastern part of the region there is a silty zone in the limestone member, in the northwestern part the limestone is all very silty, and silt and argillaceous material are common in both sandstone units.

### Hickory Sandstone Member

The name Hickory series, from Hickory Creek, Llano County, was originally used by Comstock (1890,

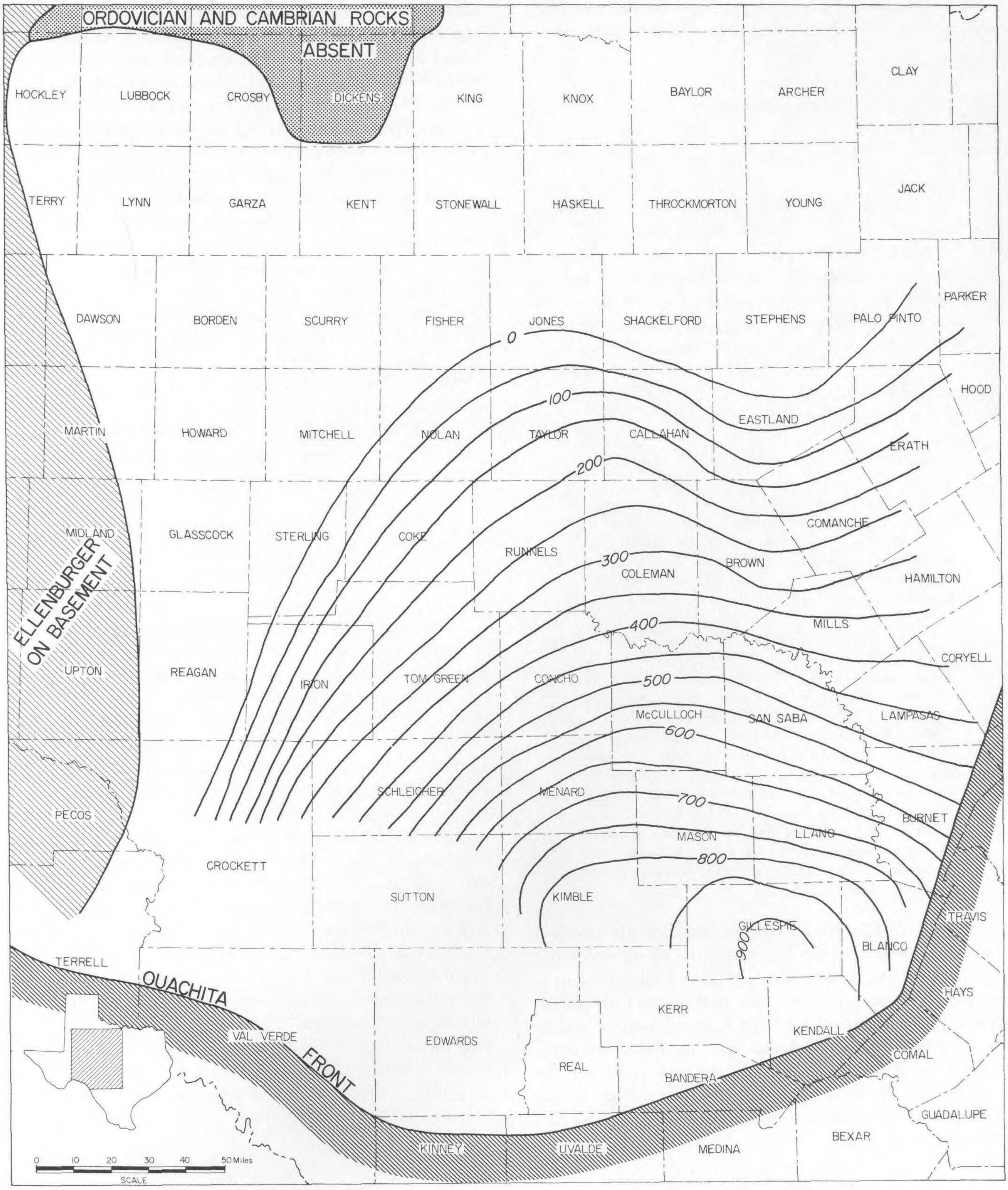



Figure 3. Isopach map of Riley Formation, Central Texas.

p. 285–286). Paige (1912, p. 5) adopted the name, gave it formational status, and defined it to include strata between the Precambrian and the Cap Mountain Formation. Its upper limit was determined by the highest dominantly sandy beds. Paige stated: "The identification of these upper beds at particular localities is necessarily a matter of judgment, for, instead of an abrupt change, there is a transition from sandstone to the limestone of the overlying Cap Mountain Formation."

Cloud, Barnes, and Bridge (1945, p. 154) reduced the Hickory Sandstone to member status and lowered the upper boundary to conform to a change from calcareous to noncalcareous sandstone, which produces a marked topographic and vegetational break well exhibited on aerial photographs. The calcareous beds form steep cedar-covered slopes, whereas the noncalcareous sandstone disintegrates, forming a sandy bench supporting clumps of oaks. Barnes and Parkinson, (1940) noted the presence of ventifacts at the base of the Hickory Sandstone and thought part of the Hickory might be eolian.

In 6 complete sections of the Hickory Sandstone Member, it ranges in thickness from 276 feet in the White Creek section to 470 feet in the Pontotoc section; in a seventh, the Klett-Walker section, the Hickory Sandstone is absent. The Klett-Walker section starts near the top of a monadnock, and several other similar monadnocks are known in the Llano region. One of these, extending high into the Cap Mountain Limestone, is only 1 mile east of the Pontotoc section (pl. 7, fig. 9), which contains the thickest section of Hickory Sandstone measured.

The thickness of the Hickory Sandstone is controlled by the irregularity of the Precambrian floor, its rise in a general northwestward direction, and by lateral gradation between the Hickory Sandstone and the Cap Mountain Limestone. Because of this gradation the thickest known Hickory Sandstone is not in the thickest known section of the Riley Formation. The isopach map of the Hickory (fig. 4) disregards thickness measurements above monadnocks. The greatest thickness of Hickory Sandstone yet measured, 530 feet, was found by Barnes (1959) in Phillips Petroleum Company No. 1 Spiller, Kimble County; the Riley Formation in this well totaled 740 feet, which is 120 feet less than in the Threadgill section where the Hickory is only 364 feet thick. South and southeast of the Llano region the maximum penetration of the Hickory Sandstone in 4 wells examined by Barnes (1959, pl. 1) is 250 feet in G. L. Rowsey No. 2 Fee, Bandera County; the Precambrian was not reached in any of the 4 wells.

The Hickory is for the most part a quartz sandstone. Cross-lamination is present throughout the member, and only locally is it conglomeratic at the base, with the pebbles mostly quartz. Feldspar is important in the basal part in only a few places and where present is usually indicative of a nearby buried granite hill. The Hickory Sandstone, except in its upper part, is generally various shades of yellowish gray, light to medium olive gray, and greenish gray. Grain size ranges from 2 inches and larger where conglomeratic near the base to very coarse, coarse, medium, and finer grained upward; silty units with shaly bedding occur sporadically at all levels and are more numerous in the middle unit.

In many areas of the Llano region the quartz pebbles at the base of the Hickory Sandstone are wind faceted; however, bedding characteristics, sorting, and at many levels the presence of *Cruziana* and at a few levels that of trails, suggest that little if any of the Hickory is wind deposited. *Cruziana* is present near the base of the Pontotoc section, which is the thickest section of Hickory Sandstone measured in the Llano region; however, there is about 200 feet of sandstone below this level in the Threadgill Creek section.

The cuneiform markings extending through 6 inches or more of many beds of the Hickory Sandstone, because of their shape and uniform density of distribution, are interpreted as ice-crystal markings. If this is the correct interpretation, then, on some frosty Cambrian mornings these beds were barely awash. Even if these markings prove to be burrows of a peculiar shape, the depth of water in which they formed probably was shallow.

In a study of the sedimentary petrography and sedimentary structures of the Hickory Sandstone, Wilson (1962) found that the sand was chatter marked and frosted and concluded that the area was covered by a great sand sea such as the one that forms the Rab'al Khali (Empty Quarter) in Saudi Arabia. He found a greater abundance of metamorphic quartz and orthoclase in the southeastern area and concluded that sand came from both the Texas craton and Llanoria to form the sand sheet. The sand is bimodal and Wilson suggested that either the source area furnished two sizes of material or more likely that the encroaching sea formed fine-grained beach sand which became mixed with the ever-present dune sand. The sand grains are relatively well oriented, indicating unidirectional currents. Abundant crossbedding with well-defined south-southeastward dip, at least in the lower part of the Hickory, also indicates uniformity of current direction.

The Hickory Sandstone in the northwestern part of the region is divisible into three units. The top unit is a very distinctive dusky red, hematite-cemented, medium- to coarse-grained unit with exceedingly well-rounded sand grains; the top of this unit is mostly in the lower part of a scarp formed by the Cap Mountain Limestone. Most of the lower part of this unit occupies a cultivated bench

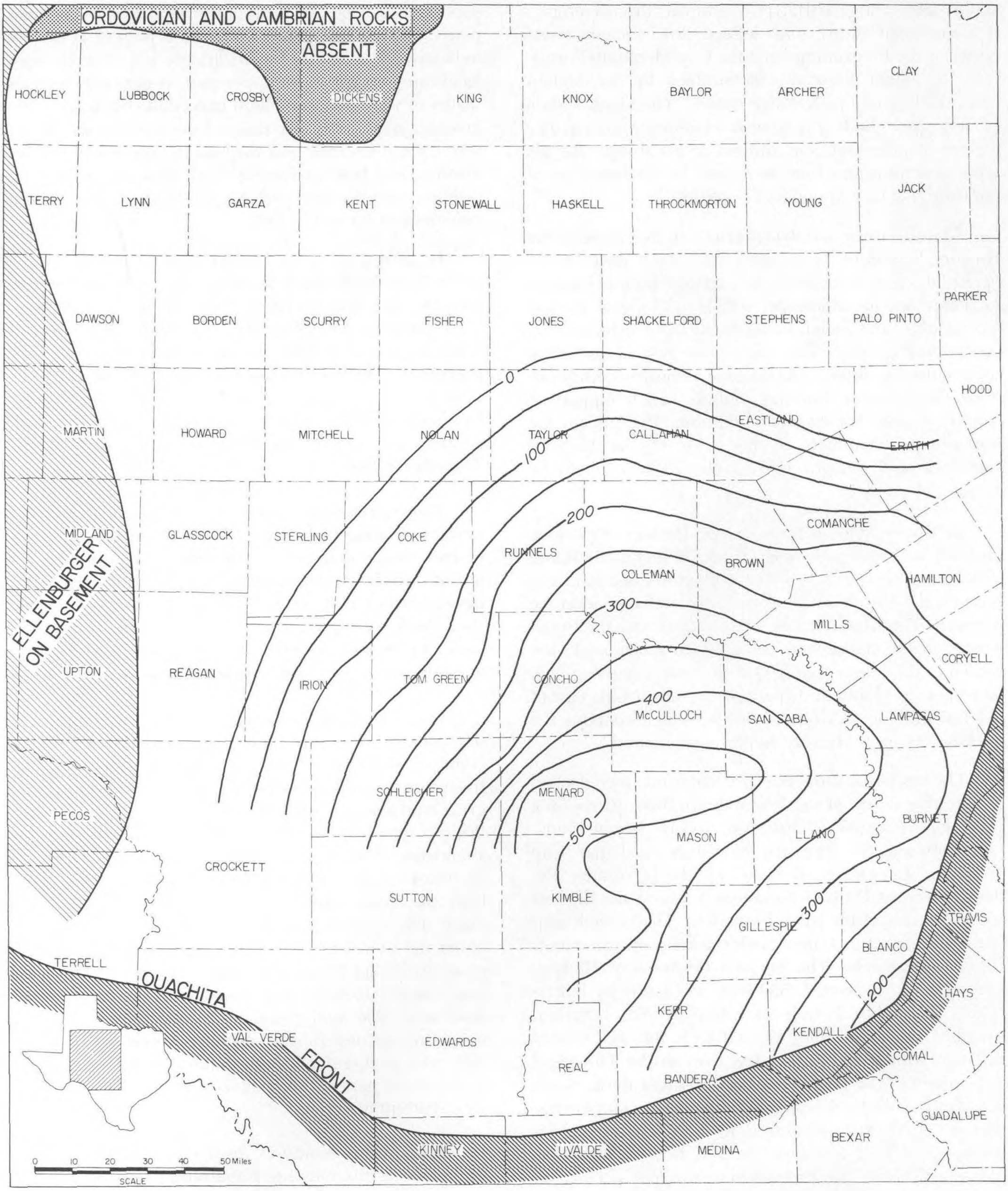



Figure 4. Isopach map of Hickory Sandstone Member of Riley Formation, Central Texas.

astride the boundary between the upper and middle units. The upper unit of the Hickory Sandstone grades laterally to Cap Mountain Limestone to the southeast.

The middle unit, mostly uncultivated, forms a low hilly scarp distinct on aerial photographs from the units above and below. No measurable section of the middle unit was found in the northwestern region; the nearest one is the Pontotoc section in which the middle and lower part of the Hickory Sandstone is poorly exposed. Road cuts and stream exposures of the middle unit show that it is argillaceous, silty, micaceous in places, and thin bedded at many localities. In addition to deciduous oaks, mesquite is common on the outcrop of the middle unit, confirming its argillaceous nature. In the southeastern part of the region the middle unit may be represented by the argillaceous and silty zone forming the upper part of the Hickory Sandstone Member exposed in the White Creek section.

The lower unit of the Hickory Sandstone in the northwestern part of the region is generally cultivated, forms gently rolling topography, and the upper boundary is indistinct in most places except in the Threadgill Creek section. On aerial photographs the boundary between the middle and lower units can be traced approximately; however, the more gentle the topography the higher stratigraphically the boundary is likely to be drawn. The sand in the lower unit is poorly sorted, mostly rounded to subrounded. Larger grains may be well rounded, but many are rough, and microcline is important locally. Southward in the Threadgill Creek section, and around the eastern margin of the Llano region in general, the lower member is better cemented, forms more rugged topography, and is not amenable to cultivation.

### Cap Mountain Limestone Member

The Cap Mountain Limestone Member of the Riley Formation as defined by Cloud, Barnes, and Bridge (1945, p. 154) is somewhat different from the original Cap Mountain Formation of Paige (1911, p. 23). The recognition of the Lion Mountain Sandstone Member by Bridge (1937, p. 234) restricts it at the top, but more than counterbalancing this loss is the addition of beds at the bottom.

Concerning the Hickory—Cap Mountain boundary, Bridge, Barnes, and Cloud (1947, p. 113) stated:

> The boundary is now placed at a distinct topographic as well as vegetational break which shows well on aerial photographs. This boundary is at the top of a noncalcareous sandstone zone and beneath a zone of alternating impure, dark-brown limestones and calcareous sandstones which become more calcareous upward; finally grading into the fairly pure, granular limestones that comprise the bulk of the member. . . . Formerly the Hickory—Cap Mountain boundary was placed at an indefinite point within the sequence of calcareous sandstones in the lower part of the Cap Mountain Limestone Member of the present report.
>
> The Cap Mountain Limestone Member, especially in the eastern part of the Llano uplift, is typically a massive, cliff-forming member.

The boundary with the overlying Lion Mountain Sandstone is gradational and is usually chosen at the appearance upward of appreciable terrigenous material and a flat or gentle slope. From the Llano region northward, in the subsurface the boundary is usually placed where terrigenous material largely disappears downward and limestone becomes dominant; southward, including the southernmost part of the Llano region, the boundary is placed at the top of the very oolitic, massive, yellowish-gray to light olive-gray limestone so characteristic of the upper part of the Cap Mountain in this area.

Thicknesses in surface sections range from 170 feet in the Pontotoc section to 497 feet in the White Creek section, reflecting the southeastward thickening of the member. An aberrant thickness of 98 feet in the Klett-Walker section represents only the part of the Cap Mountain Limestone deposited above a monadnock. It is likely that the Cap Mountain in the nearby subsurface exceeds 500 feet in thickness. South of the Llano region in Tucker Drilling Company No. 1 Dr. Roy E. Perkins, Kerr County, the Cap Mountain Limestone reaches a thickness of 650 feet, and to the east of this well in Roland K. Blumberg No. 1 Wagner, Blanco County, it is about 600 feet thick. To the north and west the Cap Mountain Limestone feathers out (fig. 5).

The Cap Mountain in the southeastern part of the Llano region consists of sandy, silty, glauconitic, and oolitic limestone, roughly in ascending order stratigraphically. The carbonate part is mostly granular, clastic-calcite; dolomite is present only as occasional rhombs or replacements of various small objects such as ooids and fossil fragments. The Cap Mountain Limestone is various shades of light olive gray, moderate to dark yellowish brown, yellowish gray, and greenish gray with lesser amounts of very pale to dark yellowish orange, dusky yellow, olive gray, pale olive, pale brown, moderate brown, grayish brown, reddish brown, and pale to dusky red. In the subsurface, where the rock is unweathered, the color is more subdued, mostly very light to medium olive gray with some greenish gray where glauconitic.

Northwestward across the Llano region the lower sandy unit is replaced laterally by Hickory Sandstone;

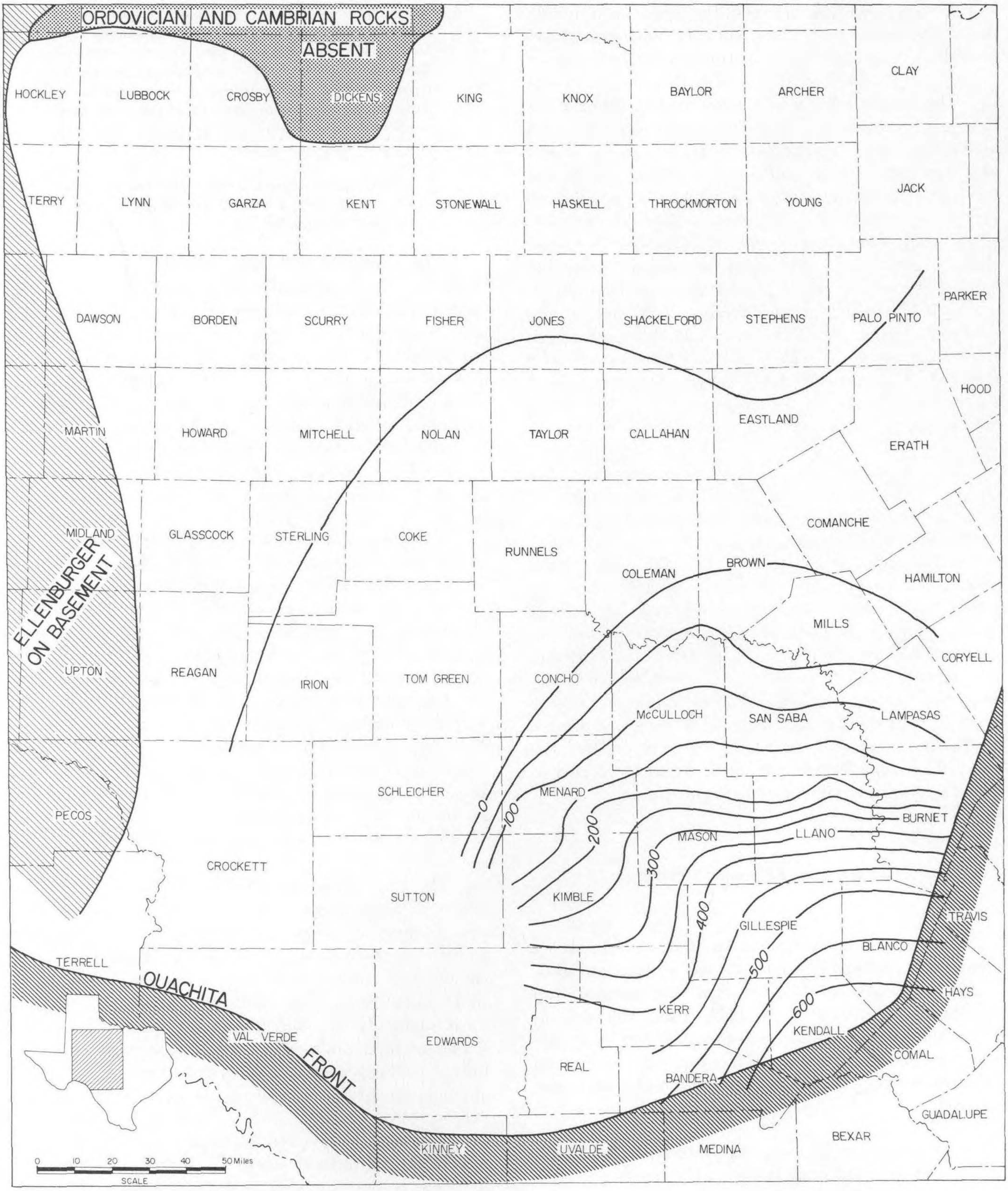



**Figure 5. Isopach map of Cap Mountain Limestone Member of Riley Formation, Central Texas.**

continuing in the subsurface in this direction the middle unit is next replaced; and finally the upper unit also grades laterally to Hickory Sandstone. In western Menard County the Cap Mountain Limestone is composed entirely of terrigenous materials. In the subsurface southward from the Llano region the silty middle unit grades to limestone and the sandy lower unit grades to limestone and siltstone.

### Lion Mountain Sandstone Member

The Lion Mountain Sandstone Member, originally named by Bridge (1937, p. 234) as the top member of the Cap Mountain "Formation," was revised by Cloud, Barnes, and Bridge (1945, p. 154) to become the top member of the newly designated Riley Formation. Otherwise, the member retains the definition originally given by Bridge and consists of quartzose greensand, glauconitic quartz sandstone, sandy limestone, trilobite coquinite lenses, impure limestone beds containing phosphatic brachiopods, and minor shale and siltstone. It is characteristically dusky green to grayish olive green where fresh and, especially in the lower part, is studded by the contrasting white to yellowish-gray, crossbedded coquinite lenses.

The upper boundary is sharp except in the southeastern part of the region, and the lower boundary is generally ill defined, being placed at the point where limestone dominates. In mapping, the lower boundary is most conveniently located at the lower edge of a sparsely vegetated bench.

The Lion Mountain Sandstone is 49 feet thick in its type section at Lion Mountain and ranges from 29 feet in the Klett-Walker and Streeter sections to 69 feet in the Squaw Creek section. An isopach map of the member (fig. 6) shows that it varies in thickness from place to place; it is thickest in the subsurface west of the Llano region and thinnest in the Streeter area and the southeastern part of the Llano region. In general, the thickest portion of the Lion Mountain is in the direction of the sediment source and the thinnest in the opposite direction, suggesting that availability of sediment near the source was the chief factor in determining its thickness. As the upper surface of the Lion Mountain is an unconformity, erosion also may have been important, removing more material from some areas than from others. This is substantiated by the faunal studies of Palmer (1954, p. 716), who found some faunas missing at the top of the member in the northwestern area where the Lion Mountain Sandstone is thin. In some wells to the west a limonitic zone at the top of the Lion Mountain may represent a fossil soil.

The Lion Mountain Sandstone cannot be traced with certainty beyond about 50 miles west and northwest of the Llano region. To the southeast it thins and perhaps plays out beneath the Ouachita fold belt. In this direction the Lion Mountain and overlying Welge Sandstones are both glauconitic and so lithologically similar that the two cannot be distinguished except on the basis of fossils. This fact suggests that the sea retreated little beyond the Llano region before again migrating inland.

## Wilberns Formation

### Type section

The Wilberns Formation was named by Paige (1911, p. 23) for Wilberns Glen in Llano County. Cloud, Barnes, and Bridge (1945, p. 155–156; further discussed by Bridge, Barnes, and Cloud, 1947, p. 114–123) retained the lower boundary defined by Paige (1911, p. 23; 1912, p. 6), but the upper boundary was redefined and placed at the top of the Cambrian. The Wilberns was further redefined by Barnes, Bell, and Pavlovic (1954, p. 30–31), and Bell and Barnes (1961) show that the Wilberns in the western part of the Llano region includes some Lower Ordovician rocks.

Cloud, Barnes, and Bridge (1945, p. 155) divided the Wilberns Formation into five members, and Barnes and Bell (1954b, p. 35) reduced the number to four by eliminating the name Pedernales Dolomite, placing all dolomite so named within the San Saba, and changing the name San Saba Limestone to San Saba Member. This change brought the nomenclature of the upper part of the Wilberns Formation into conformity with that of the overlying Tanyard Formation of the Ellenburger Group. The San Saba Member as now constituted consists of limestone, dolomite, and some sandstone.

Bell and Barnes (1961) dropped shale from the name, because of the paucity of shale and predominance of siltstone, limestone, and intraformational conglomerate in the Point Peak "Shale" Member. The Wilberns Formation now includes, from base to top, four members: the Welge Sandstone, the Morgan Creek Limestone, the Point Peak, and the San Saba.

West, north, and possibly south of the Llano region, usage suggested by Cloud and Barnes (1948, p. 30) and adopted by petroleum geologists (Barnes, 1959, p. 28) places the Tanyard-Wilberns boundary in the vicinity of the first appearance downward of glauconite. The first appearance downward of glauconite does not approximate a time plane. In the eastern part of the region,

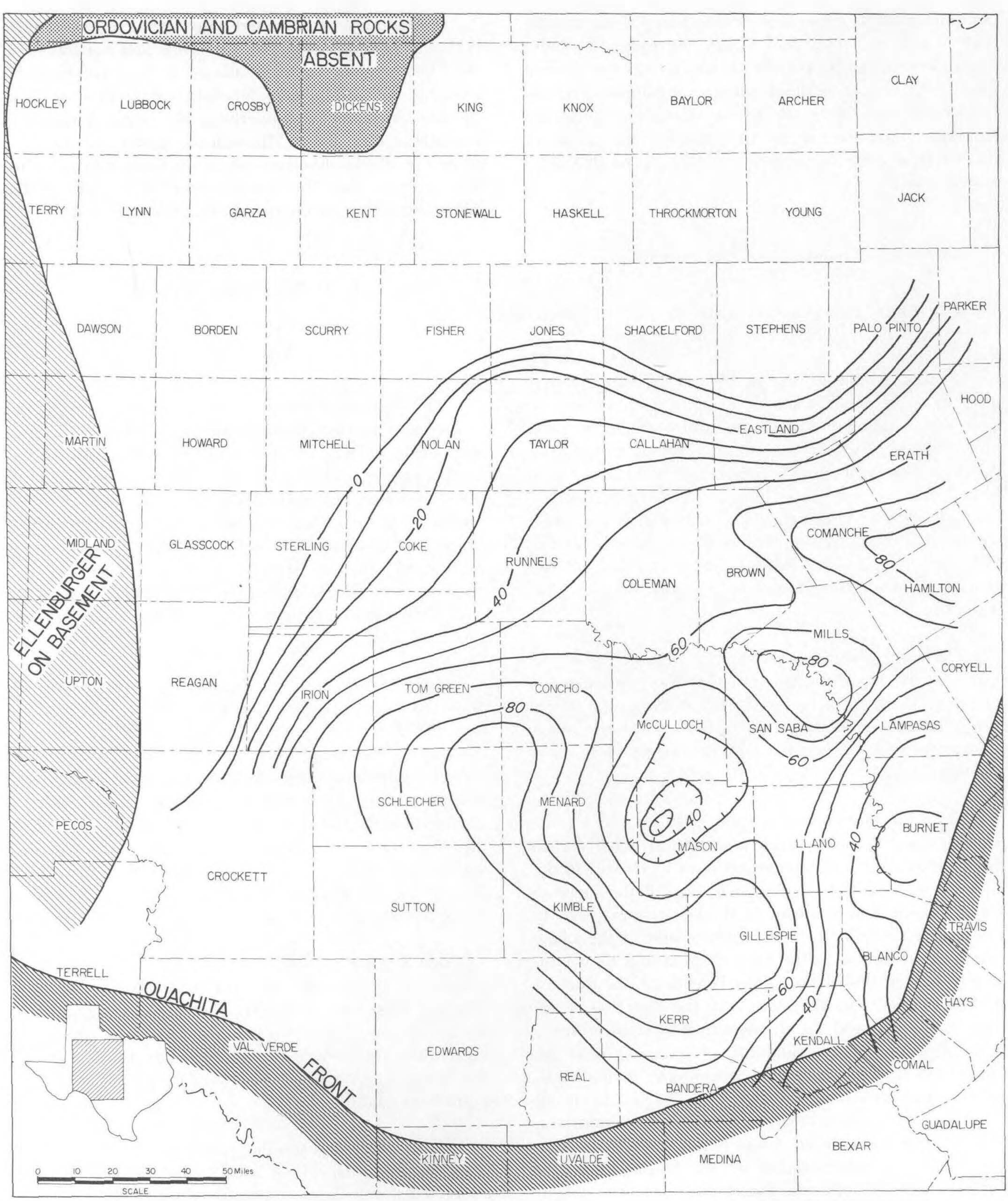



**Figure 6. Isopach map of Lion Mountain Sandstone Member of Riley Formation, Central Texas.**

Cloud and Barnes (1948, pl. 1) placed several hundred feet of nonglauconitic dolomite in the upper part of the Wilberns Formation. The Wilberns-Tanyard boundary (Moore Hollow—Ellenburger boundary) is more fully **discussed on pages 30–33.**

The exact line of Paige's type section, if he ever had one in mind, could not be identified, and no attempt was made to measure one in the vicinity because of faulting, travertine cover, and poor exposures. All except approximately the upper 50 feet of the rocks assigned to the Wilberns Formation by Paige are in unfaulted sequence in the nearby Little Llano River section (pl. 7, fig. 14), and this section could be used as a substitute for the type section. The 333 feet of Wilberns rocks measured in the Little Llano River section is more than 100 feet in excess of the footage assigned to the Wilberns by Paige, suggesting that the section measured by Paige was faulted. Now that the Wilberns Formation is defined to extend even higher stratigraphically, a standard section containing all Wilberns rocks is needed. The Riley Mountain sections are ideal for this purpose because of the presence in these sections of the type section of the Riley Formation and the standard section of the Ellenburger Group. The best exposed section of the Wilberns Formation is in the upstream James River section, Mason County.

#### Thickness

The Wilberns Formation in the Llano region ranges in thickness from about 537 feet in McCulloch County to 610 feet in the Tanyard section of Burnet and San Saba Counties, and to 619 feet along James River in Mason County. The 360–foot thickness in the Johnson City area reported by Barnes (Cloud and Barnes, 1948, p. 29) is now known to be too small (Cloud and Barnes, 1957, p. 168), because part of the sequence is missing through faulting. That the thickness of the Wilberns Formation in this part of the Llano region is not far from normal is shown by the thickness found in Stratoray Oil Corporation No. 1 Stribling, Blanco County, only a few miles from the faulted section.

In the subsurface southeastward from the Johnson City area, Barnes (1959, pl. 1) found that the Wilberns Formation thickens to about 730 feet in Roland K. Blumberg No. 1 Wagner, Blanco County. To the west-southwest of this well the Wilberns thickens to about 1,130 feet in General Crude Oil Company No. 1 Anderson, Bandera County. West of the Llano region the Wilberns maintains a fairly uniform thickness through Kimble and Menard Counties and thins appreciably in The Atlantic Refining Company No. 1 Noelke, Irion County, just before it terminates against the Precambrian a short distance to the west. Northwestward it thins to about 230 feet in the Honolulu Oil Corporation Whitaker wells, Nolan County, and to 70 feet in Humble Oil & Refining Company No. 1 Farris, Lubbock County. The approximate line along which the Wilberns Formation thins out against the Precambrian and the thickness of the Wilberns in its area of known extent are shown in figure 7.

#### Lithic character

The boundaries between members in the Wilberns Formation are all gradational, including the boundary at its top, and, locally in the southeastern part of the area, the boundary at its base as well. Elsewhere, the basal boundary is sharp between the greensand beneath and the nonglauconitic sandstone of the basal member of the Wilberns above. This unit, the Welge Sandstone, is represented on aerial photographs by a thin black line of vegetation distinct from the bench formed by the greensand with its widely scattered clumps of live oak.

The second member of the Wilberns Formation, the Morgan Creek Limestone, is mostly coarse-grained clastic limestone, sandy at the base, with silty beds and a few beds of stromatolites at the top. It has a pattern of vegetational alignment along the bedding which is distinct from the generally uniformly distributed vegetation of the overlying member.

The third member, the Point Peak, is primarily argillaceous siltstone in its lower part with increasingly more limestone upward, much of it intraformational conglomerate. Beds of stromatolites are common and in places the entire upper half of the unit may be stromatolitic limestone for several miles along the outcrop. Similar stromatolites overlap the boundary between this member and the top member of the Wilberns Formation and are included with the member with which they appear to be most closely allied.

The top member, the San Saba, constituting almost half of the Wilberns Formation, is the most variable of all the members of the Wilberns. It is dominantly limestone to the west, grading laterally to dolomite to the east. A short distance east of the Calf Creek section in the western area the member is almost entirely dolomite replacing a stromatolitic reef. Elsewhere in the western and central areas large stromatolites of aphanitic limestone are common and similar stromatolites, now altered to dolomite, may be present in the eastern area but not recognized. The limestone of the western area is mostly granular and clastic with aphanitic matrix becoming

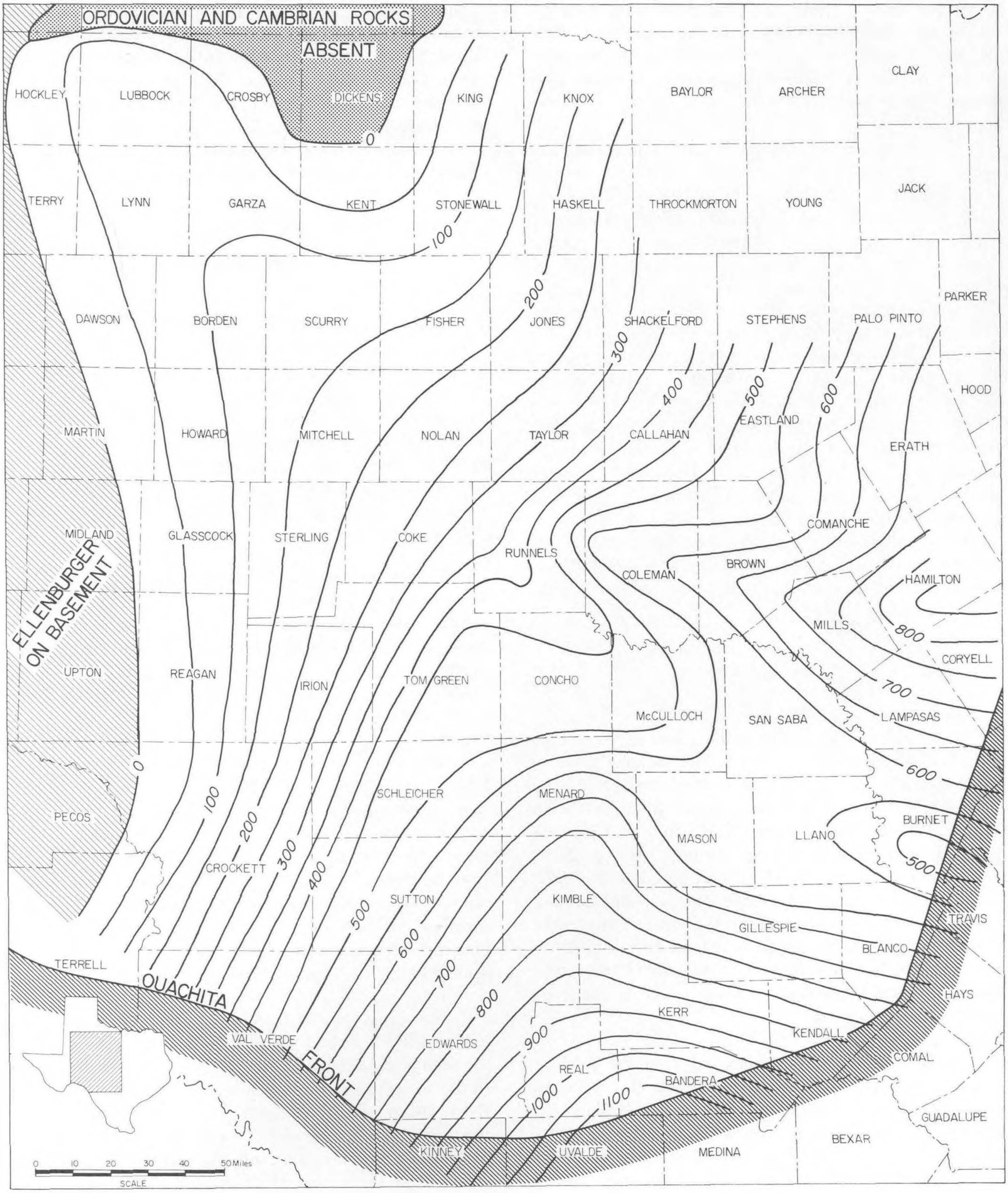



**Figure 7. Isopach map of Wilberns Formation, Central Texas.**

perhaps more abundant upward; in the eastern area aphanitic limestone is present to the exclusion of granular limestone in the few eyes or islands not replaced by coarse-grained dolomite. The dolomite of the eastern area is both fine and coarse grained and it too is gradational from one type to the other in some areas (Barnes, 1952g, 1965b).

### Welge Sandstone Member

The first mentions of the Welge Sandstone Member (Barnes, 1944, p. 37; Romberg and Barnes, 1944; Howell and other, 1944) were with scant definition. Cloud, Barnes, and Bridge (1945, p. 155) added to the definition, but the definition by Bridge, Barnes, and Cloud (1947, p. 114) should be used as the standard reference. They stated: "The Welge Sandstone Member of the Wilberns Formation is named by Barnes from the Welge land surveys between Threadgill and Squaw Creeks, Gillespie County, where it crops out. The best exposure of the Welge Sandstone in this area, here designated the type section, is along Squaw Creek half a mile north of the Gillespie County line."

The Welge Sandstone is a coarse- to medium-grained, mostly pale to dark yellowish-brown, typically nonglauconitic, sparsely fossiliferous, well-sorted, quartz, marine sandstone. The grains are characteristically reconstituted and glitter in the sunlight. Locally in the eastern part of the Llano region the Welge is in part glauconitic, and in the subsurface to the south and southeast it is a greensand indistinguishable from that in the Lion Mountain Sandstone beneath. The disconformity so well documented in the area of outcrop probably does not exist in these directions.

The base is characterized locally by 2 or 3 feet of earthy, reworked Lion Mountain Sandstone or by poorly sorted granule beds marking the surface of disconformity on which the Welge was deposited. Its boundary with the overlying and more distinctly bedded Morgan Creek Limestone is gradational within narrow limits.

The Welge Sandstone ranges in thickness from 11 feet in the White Creek section, Blanco County, to 30 feet, south of Camp San Saba, McCulloch County. In general it is thicker along the northern and western sides of the Llano region and thinner along the southern and eastern sides (fig. 8). In the subsurface in all directions from this region, it generally remains within this thickness range, being perhaps thinnest to the southeast.

Northwestward beyond the line where the Morgan Creek Limestone ceases to be mainly carbonate, Barnes (1959, p. 30) found that the Welge can be traced on the basis of poorly defined electric-log characteristics, and that eventually it can no longer be recognized in this direction.

### Morgan Creek Limestone Member

The Morgan Creek Limestone Member, like the Welge Sandstone Member, was first mentioned with scant definition (Barnes, 1944, p. 37; Romberg and Barnes, 1944; Howell and others, 1944). It is further described by Cloud, Barnes, and Bridge (1945, p. 155) and Bridge, Barnes, and Cloud (1947, p. 114–115) who stated: "The Morgan Creek Limestone Member of the Wilberns Formation is named by Bridge from exposures on both the north and south forks of Morgan Creek in Burnet County."

The Morgan Creek Limestone Member consists of coarsely granular, greenish-gray to light olive-gray, glauconitic limestone with interbeds of fine-grained, darker greenish-gray, silty limestone in the upper part; beds of aphanitic stromatolites are near the top in some areas. The member is typically sandy and pinkish to reddish in the basal part where it grades to the underlying Welge Sandstone; elsewhere in a few areas pinkish limestone is also seen at the very top. The top of the Morgan Creek is usually chosen at the top of the uppermost thick limestone bed rather than at the base of the lowest thin-bedded unit, except where stromatolite beds invade the lower part of the Point Peak Member; in such areas the top is arbitrarily placed at a point convenient for mapping.

The Morgan Creek Limestone is commonly oolitic, and ooids and other small objects may be replaced by yellowish-orange dolomite; in some zones thin, foot-long patches of yellowish-orange dolomite are common. In the Llano region significant dolomite and chert have been seen in the Morgan Creek in only one small area northwest of Hye, Blanco County.

The Morgan Creek Limestone is 130 feet thick in its type section and ranges from 114 feet in the Camp San Saba section, McCulloch County, to 143 feet in the White Creek section, Blanco County. It maintains this thickness southward from the Llano region (fig. 9) where it becomes increasingly difficult to distinguish from the overlying member. In Roland K. Blumberg No. 1 Wagner, Blanco County, all except the lower 25 feet is dolomite. In this well the top of the Morgan Creek is arbitrarily placed at the top of coarse-grained dolomite and beneath slightly silty, fine-grained dolomite. Siltstone

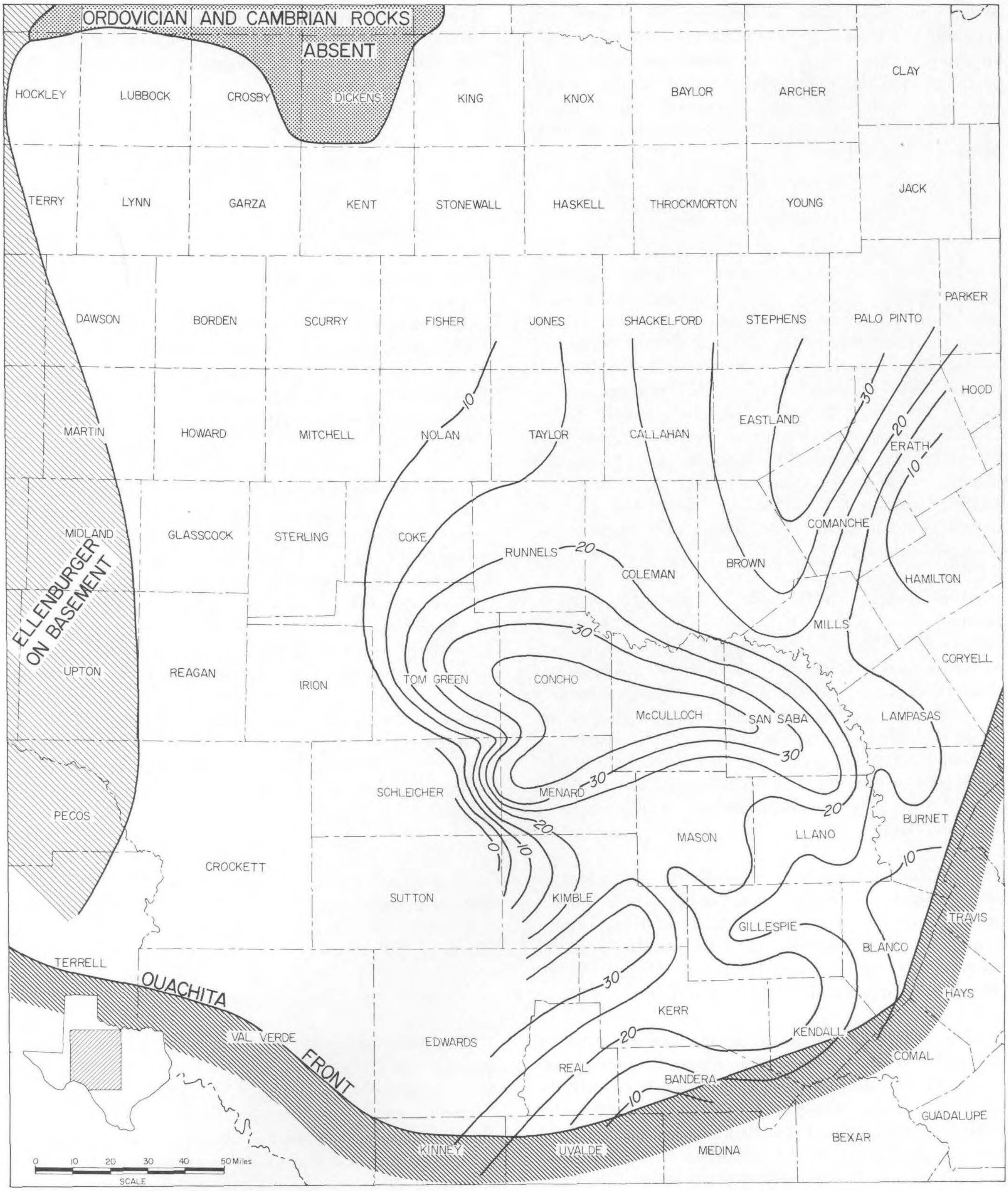



**Figure 8. Isopach map of Welge Sandstone Member of Wilberns Formation, Central Texas.**

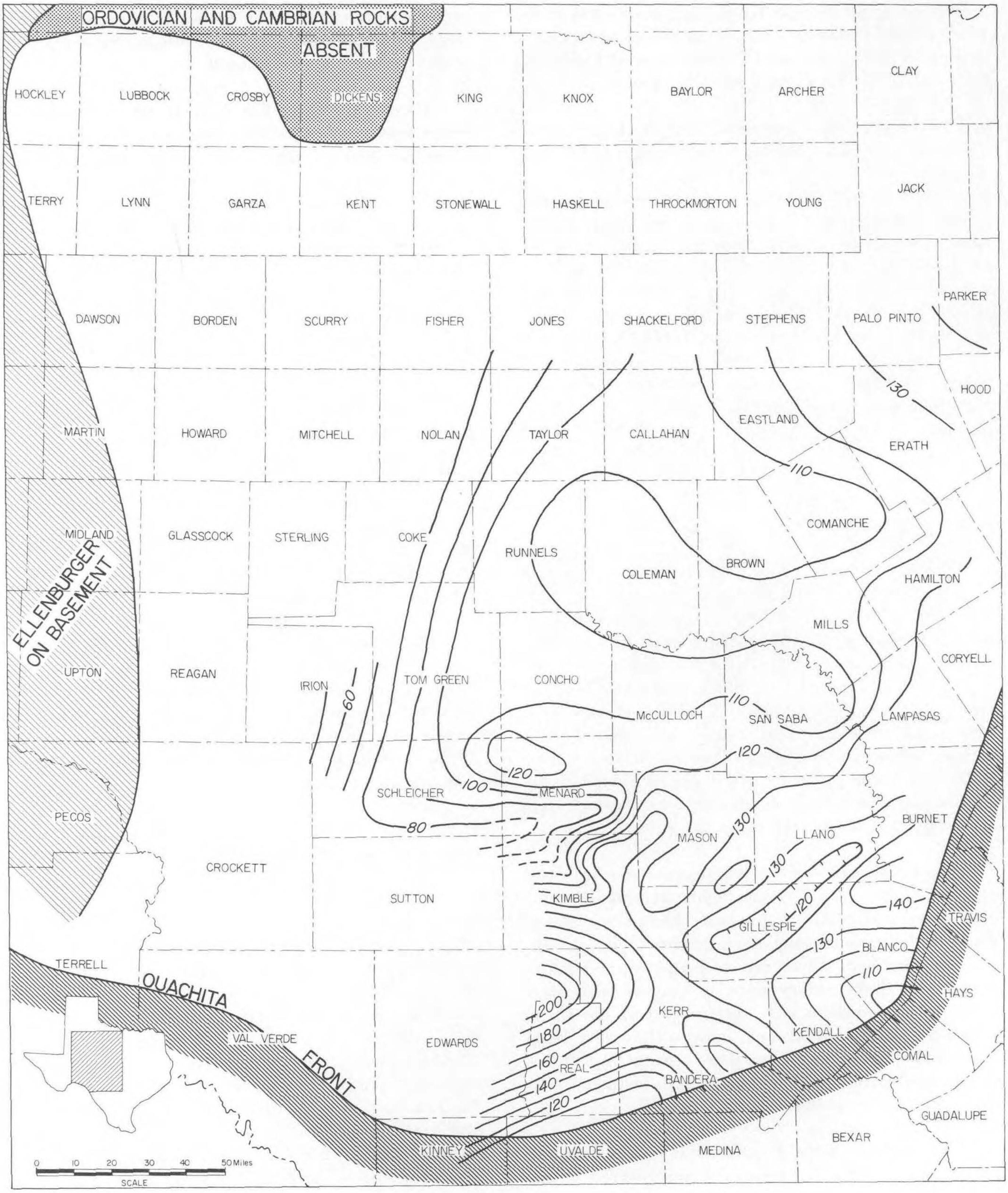



**Figure 9. Isopach map of Morgan Creek Limestone Member of Wilberns Formation, Central Texas.**

is common in the Morgan Creek Limestone south of the Llano region. Dolomite is prominent and some sandstone is present in the Morgan Creek in General Crude Oil Corporation No. 1 Anderson, Bandera County.

In the subsurface westward from the Llano region the Morgan Creek retains its identity through Kimble and Menard Counties, except that it grades to dolomite east of Deep Rock Oil Corporation No. 1 Bevans, Menard County; still farther west it is mostly sandstone. Northwest a few tens of miles from the Llano region the Morgan Creek Limestone is dominantly terrigenous; carbonate, except in a few wells, is limited to cement. Where the characteristic carbonate rocks are absent, electric logs give a hint of the interval to be assigned to the Morgan Creek, and characteristic Morgan Creek fossils were found in one well, Honolulu Oil Corporation No. 2 Whitaker, Nolan County.

**Point Peak Member**

The Point Peak "Shale" Member, too, when first mentioned, received scant definition (Barnes, 1944, p. 37; Romberg and Barnes, 1944; Howell and others, 1944), It is further described by Cloud, Barnes, and Bridge (1945, p. 155) and by Bridge, Barnes, and Cloud (1947, p. 115–116) who stated: "The Point Peak Shale Member of the Wilberns Formation is named by Bridge from Point Peak, a conspicuous, isolated hill about 4 miles northeast of Lone Grove, Llano County." Bell and Barnes (1961), because of the paucity of shale and predominance of siltstone, limestone, and intraformational conglomerate, dropped shale from the name.

The Point Peak Member is a sequence of calcareous, very light olive-gray siltstone; light olive-gray to light olive-green and yellowish-gray silty limestone; varicolored intraformational conglomerate; very light greenish-gray to very light olive-gray stromatolites; and minor amounts of dusky yellow-green to grayish-green clay-shale. In the northern and western part of the Llano region the calcareous siltstone forms a distinctive basal unit which grades upward into more calcareous siltstones interbedded with silty limestone, intraformational conglomerate, and stromatolites.

The siltstone of the Point Peak is nonresistant and rarely forms ledges; it generally forms covered slopes. The intraformational conglomerate commonly crops out to form discontinuous ledges. Thin, flat, silty limestone pebbles are the major constituent of the conglomerate. They are somewhat rounded, commonly laminated, and are either parallel to the bedding planes or without preferred orientation. The matrix is fine-grained limestone, generally light gray, and both matrix and pebbles contain scarce fragmental fossils.

The stromatolitic limestone is present in various forms: masses a few inches in diameter widely scattered along one horizon; continuous beds 1 foot or so thick, traceable for miles; isolated larger masses 40 or more feet thick and slightly larger horizontally; great bodies of rock up to 100 feet thick which can be traced for miles; or in masses of practically any size or configuration between these extremes. There are large stromatolitic bioherms on the eastern side of the Llano region, in the Riley Mountains, and in the easternmost exposures in Burnet County. In the Calf Creek area, Mason County, they are entirely of dolomite.

A laterally persistent, 1– to 3–foot, fossiliferous limestone bed near the top of the Point Peak Member over much of the Llano area contains silicified valves of two brachiopod genera, *Billingsella* and *Plectotrophia,* largely confined to this interval. In the extreme eastern part of the region this zone is not definitive, as *Plectotrophia* occur throughout 40 or more feet of beds vertically and is also found laterally in rocks of the dolomitic facies of the San Saba Member.

The boundary between the Point Peak and the overlying San Saba Member ranges from gradational to fairly sharp. Where typical Point Peak siltstone is overlain by girvanella limestone, as in the Cherokee Creek and Little Llano River areas, the boundary is distinct. Elsewhere, the boundary is in a gradational sequence and must be arbitrarily chosen; where stromatolitic bioherms transgress the boundary, it is placed either at the bottom or at the top of the bioherm, depending upon which unit contains most of the mass.

The Point Peak Member is 198 feet thick in its type section and ranges from 216 feet in the Riley Mountain section, Llano County, to 25 feet in the Klett-Walker section, Blanco County (fig. 10). A thickness of 216 feet in the Riley Mountains may be excessive, as the section in which this amount was measured was partly on a dip slope and the section was offset along the base of a stromatolitic biostrome which may not be at a constant stratigraphic level. A thickness of 94 feet in the Camp San Saba section is too little, but here a thick stromatolitic bioherm has been included with the San Saba Member since it extends high into that member. The 71-foot thickness found in the Leon Creek area is truly anomalous as stromatolitic bioherms are not present. Disregarding the anomalous values, the Point Peak averages 150 feet in thickness over most of the Llano region, thinning somewhat in the northeastern part of its outcrop area and rapidly from southern Burnet County

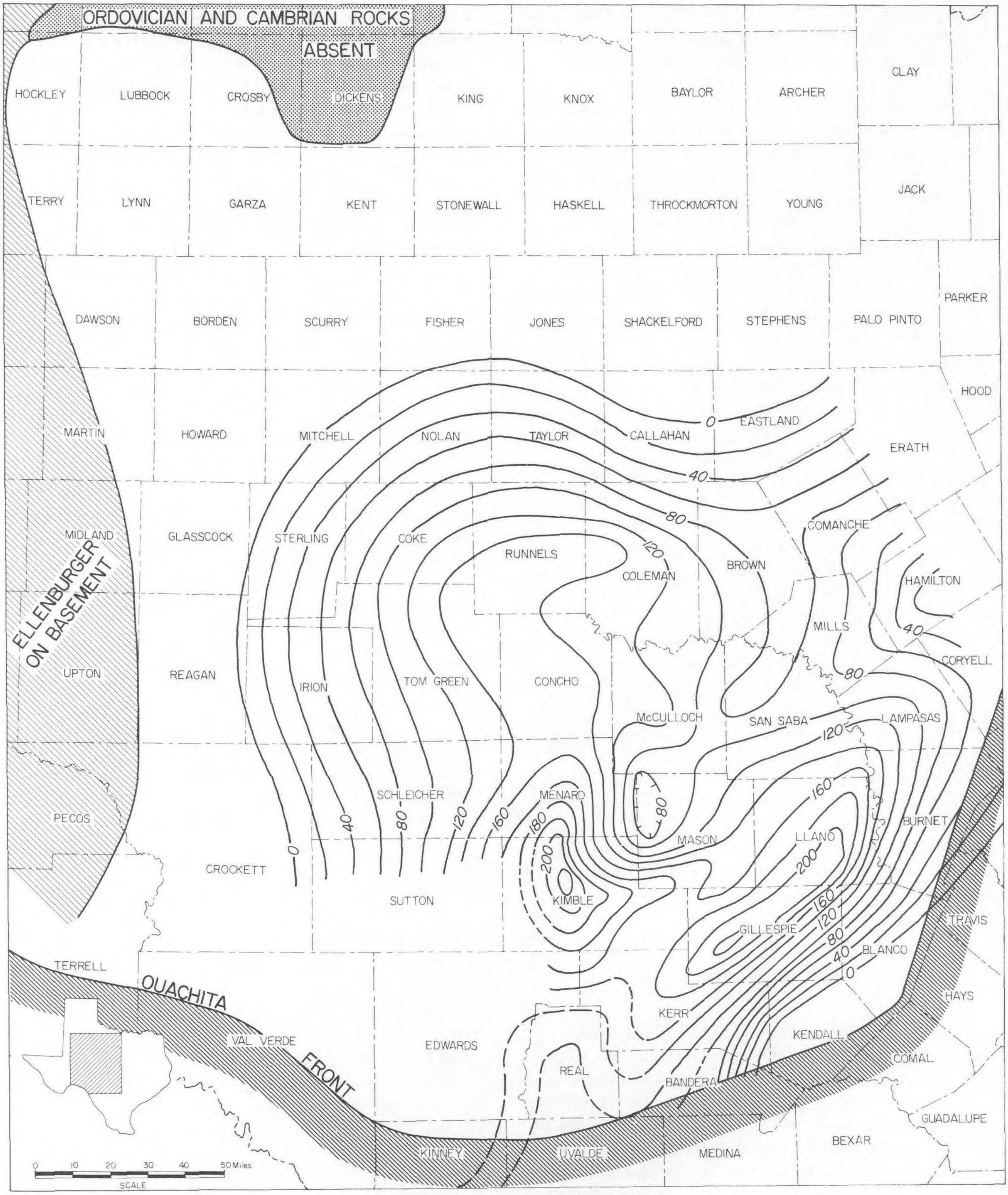



**Figure 10. Isopach map of Point Peak Member of Wilberns Formation, Central Texas.**

south to the Klett-Walker section. As the Point Peak Member thins, the San Saba Member correspondingly thickens, indicating a facies change in this direction.

The abruptness of transition from a dominantly terrigenous to a dominantly carbonate environment may have been enhanced by a barrier of stromatolite reefs extending in a northeast-southwest direction. This speculation is supported (Barnes, 1959, p. 31) by the presence of a thick sequence of aphanitic limestone at this position in Shell Oil Company No. 1 Purcell, Williamson County. Southwestward from this locality the rocks where exposed are generally dolomitized, and stromatolitic structure, if present, may not have been recognized. Some evidence is seen that at least part of the massive, coarse-grained dolomite originally may have been reef-like. In thin section, most dolomite of this type has composite structure; little of it contains ghost structures, and most of those present are angular, breccia-like forms.

Barnes (1959, pl. 1) found that southeastward from the Llano region the Point Peak Member is not recognized; southward its existence is postulated on rather tenuous evidence; and in General Crude Oil Company No. 1 Anderson, Bandera County, an appreciable amount of siltstone is present. Considering the great thickening of the Wilberns Formation in this well, this silty interval could almost as well be assigned to the Morgan Creek Limestone, on the basis of the assignment of similar material in the Rowsey wells to the east.

Westward and northwestward from the Llano region, especially beyond where the carbonate rocks of the overlying and underlying units give way to terrigenous materials, the boundaries of the Point Peak Member are chosen with uncertainty on the basis of lithologic composition and have been assigned primarily from electrical and radioactivity characteristics where logs of these properties were available.

### San Saba Member

Bridge, Barnes, and Cloud (1947, p. 117) reviewed the nomenclature of the San Saba Member as follows: “The name San Saba was originally used as a series term by Comstock (1890, p. 301–305) who applied it either to these beds or to some part of them. Dake and Bridge (1932) called these beds ”Post Wilberns,“ correlated them with the Fort Sill and Signal Mountain Formations of the Arbuckle and Wichita Mountains, and suggested that Comstock’s name San Saba might well be revived for a part of them.” Barnes (1944, p. 37), Romberg and Barnes (1944), and Howell and others (1944) first mentioned the San Saba Limestone Member with scant definition, and Bridge, Barnes, and Cloud (1947, p. 117) stated: “The San Saba Limestone Member of the Wilberns Formation is named by Bridge from exposures along and near San Saba River, northwest of Camp San Saba, McCulloch County. The type section, about 280 feet thick, is exposed along both sides of the Mason-Brady highway, beginning at the bridge across the San Saba River and extending northward for 0.7 mile, at which place it is in collapse contact with the limestones of the Threadgill Member of the Tanyard Formation.” Laterally equivalent dolomite was named the Pedernales Dolomite Member.

Barnes and Bell (1954b, p. 35) dropped the name Pedernales Dolomite Member, placing all dolomite so named with the San Saba and changing the name San Saba Limestone to San Saba Member. This brought the nomenclature of the upper part of the Wilberns Formation into conformity with that of the overlying Tanyard Formation of the Ellenburger Group.

Plummer (1943) described quartz sand in the “Cambrian” of western Mason County which he termed the Erna Sand. In view of the varied number and local character of the sandy zones in the San Saba Member of this area, Bridge, Barnes, and Cloud (1947, p. 121) thought it undesirable that any of them be formally named.

The San Saba Member, composed mostly of dolomite and limestone in the Llano region, varies considerably both laterally and vertically. The calcitic facies, mostly medium and fine grained, glauconitic, thinly to thickly bedded, various shades of gray, yellowish gray, light olive gray, and greenish gray to the west, becomes finer grained eastward to localities where the remaining small amount of limestone is aphanitic, white, and nonglauconitic. The basal beds in the central part of the area contain small limestone spheres known as girvanella.

The dolomitic facies is in part fine grained, medium bedded, and various shades of gray, yellowish gray, and pinkish gray, characteristically mottled pale red and purple, and in part medium to coarse grained, massive to thickly bedded, and light yellowish gray. Typically, the western portion is largely limestone, the eastern portion mostly dolomite with rare eyes or islands of limestone; in the area between, limestone overlies dolomite. However, in the extreme northwestern part of the region dolomite preserving stromatolitic structure predominates and is overlain by clean, calcareous sandstone followed by limestone. From 55 to 70 feet of sandstone has been measured; most of the grains are of medium size and well rounded.

In measured sections, calcitic San Saba Member is overlain by calcitic Threadgill Member, and dolomitic San Saba is overlain by dolomitic Threadgill. The predominantly granular, glauconitic, calcitic San Saba contrasts with the predominantly aphanitic, nonglauconitic, calcitic Threadgill. Boundaries between these rock types are everywhere gradational through a few feet of section, and there is no evidence to indicate any interruption in sedimentation. Dolomitic San Saba typically is fine grained and varicolored, commonly mottled pale reddish purple; dolomitic Threadgill typically is medium to coarse grained and mostly very light gray to white. Locally, in the eastern part of the Llano region the upper part of the San Saba Member is coarse-grained dolomite entirely similar to that in the overlying Threadgill Member, and in these places no boundary can be mapped.

Stromatolitic bioherms similar to those in the Point Peak Member characterize parts of the San Saba Member; where present they exist essentially toward the base. Some chert in the eastern dolomitic facies has a structure which suggests that it replaced the granular rock that normally forms septae between stromatolitic heads and probably was formed prior to or during dolomitization. The thickest stromatolitic sequence seen is in northwestern Mason County (Barnes and Bell, 1954a, fig. 7). It almost reaches the top of the San Saba Member, is almost completely dolomitized, appears to have served as a barrier cutting off eastward movement of sand, and sharply bounds the western edge of the extensive sandstone body in the San Saba Member.

In southwestern Mason County along James River, sandstone is equally abundant in the same stratigraphic-position, but to the east along Threadgill Creek none is present. To the south in the subsurface Barnes (1959, p. 33) found 300 feet of sandstone in Forest Oil Corporation No. 1 Stapp, Kimble County, but to the east, sandstone and even sand are completely absent at this level in L. U. Rowntree No. 1 Richard Kott, Gillespie County. Still farther south, there is a 500–foot sandstone and sandy dolomite zone in General Crude Oil Company No. 1 Anderson, Bandera County, whereas no sandstone or sand is present at this level in wells to the east. It seems likely that the extensive sandstone body of the San Saba Member is sharply terminated by a north-south-oriented barrier reef exposed, so far as is known, only in northwestern Mason County.

Figure 11 is an isopach map of the San Saba Member. The thickness of the San Saba Member in the Camp San Saba section (pl. 2) is 299 feet, which is slightly more than the 280 feet measured by Cloud (in Bridge, Barnes, and Cloud, 1947, p. 117) in the type section along the highway. Elsewhere in the Llano region the thickness of the San Saba generally ranges from a measured 281 feet in the Threadgill Creek section, Gillespie County, to a measured 324 feet in the Tanyard section, Burnet County, and to an estimated 450 feet in the Johnson City area, Blanco County. The values of 230 feet in the Everett Ranch section and 260 feet in the Dempsey Montgomery Oils No. 1 Yates are anomalous, and this thinness is not understood.

Barnes (1959, p. 33; pl. 1) found that the San Saba Member thickens markedly in the subsurface east of the postulated barrier reef south of the Llano region. Part of this thickening is at the expense of the Point Peak Member, and most of the rest appears to be at the expense of the Threadgill Member of the Tanyard Formation. The 600– to 800–foot thickness of San Saba found in wells in this area is exceeded only by the 880 feet in General Crude Oil Company No. 1 Anderson, Bandera County. Much of the lower half of the San Saba in this area is medium- to coarse-grained dolomite, and in Roland K. Blumberg No. 1 Wagner, Blanco County, medium- to coarse-grained dolomite extends to the top of the Threadgill Member. The lower boundary was chosen at a change in grain size, where lying on Morgan Creek Limestone, or at the first appearance downward of silty rocks, where lying on the Point Peak. Admittedly, this boundary in places is arbitrarily chosen.

To the east of the Llano region in Shell Oil Company No. 1 Purcell, Williamson County, the San Saba Member is similar in thickness to that measured in the nearest outcrop section. The lower half is stromatolitic, in part dolomitized, and the upper half is mostly coarse-grained dolomite. Coarse-grained dolomite continues upward high into the Tanyard Formation.

West of the postulated barrier reef the San Saba is sharply divided into two distinct units: a lower one, mostly Cambrian in age, dominantly sandstone, and an upper one, Ordovician in age, composed of slightly glauconitic, impure carbonate. Directly west of the Llano region granular limestone predominates in the upper unit and fine-grained dolomite is common. To the northwest the unit is primarily fine-grained dolomite. After an initial thickening it again thins to disappearance in a northwestward direction, except that in one well, Seaboard Oil Company No. 4 Upshaw, Stonewall County, the unit is exceptionally thick. The lower sandstone unit also thins northwestward and eventually feathers out on the Precambrian.

The upper boundary of the San Saba Member west of the postulated barrier reef does not hold a constant level, and two workers seldom choose the boundary at the same place in any one well; furthermore, a characteristic low S-P (spontaneous potential) value on electric-log curves seldom coincides with the lithologic boundary,

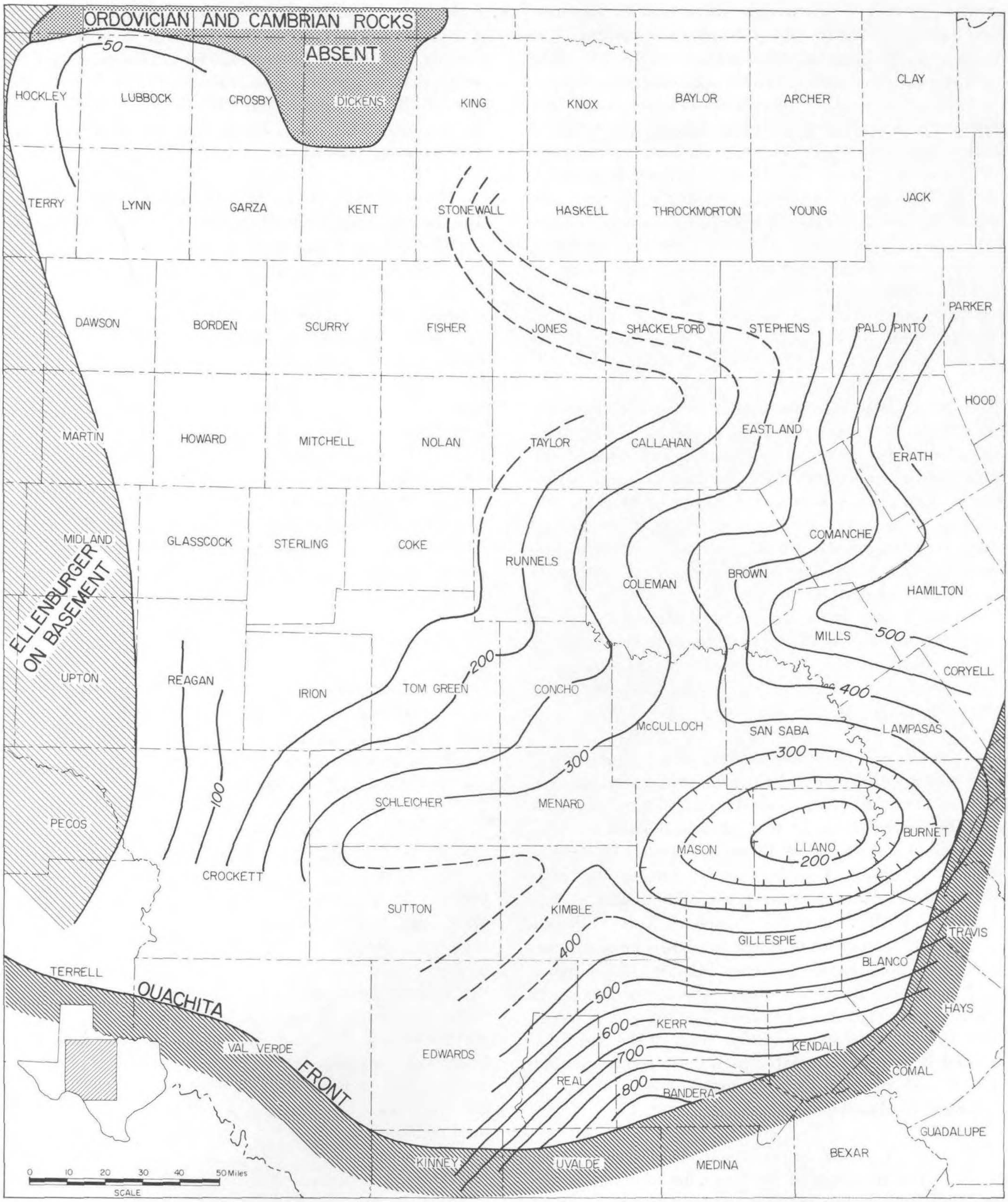



**Figure 11. Isopach map of San Saba Member of Wilberns Formation, Central Texas.**

most being above and a few below. The lower boundary of the San Saba, like the upper one, is not distinctive, and in this area electric logs were useful in deciding where to place it.

In the western part of the Llano region the upper 35 to 90 feet of calcitic San Saba contains a Lower Ordovician trilobite fauna. Similarity of rocks and lack of significant evidence of sedimentary hiatus indicate continuous deposition across the Cambrian-Ordovician boundary. The San Saba Member and the Threadgill Member are tangible rock units that differ lithologically, whereas the systemic boundary of necessity must be defined in paleontologic terms.

#### Pedernales Dolomite Member (discarded)

The name Pedernales Dolomite Member, first mentioned with scant definition (Barnes, 1944, p. 37; Romberg and Barnes, 1944; and Howell and others, 1944), was given by Barnes (in Bridge, Barnes, and Cloud, 1947, p. 121), to a sequence of dolomite, along Pedernales River northwest of Johnson City, laterally equivalent to the San Saba Limestone and most of the Point Peak Member of the western part of the Llano region. To bring the terminology of this part of the Wilberns into conformity with the terminology for the overlying Threadgill Member of the Tanyard Formation, Barnes and Bell (1954b, p. 35) discarded the name Pedernales Dolomite Member and included all dolomite so named as part of the San Saba Member.

## BEDS THAT OVERLIE THE MOORE HOLLOW GROUP

### Ellenburger Croup
### Tanyard Formation

*Threadgill Member.*—In the Llano region the lowest member of the Ellenburger Group, the Threadgill Member of the Tanyard Formation, rests on the highest member of the Moore Hollow Group, the San Saba Member of the Wilberns Formation. In the subsurface to the west, because of a facies change, the upper member of the Tanyard Formation, the Staendebach Member, rests on the San Saba Member.

The Threadgill Member, originally defined as the "Threadgill Limestone" (Bridge and Barnes, *in* Barnes, 1942; Barnes, 1944, p. 37), was revised to include equivalent dolomite as well (Cloud, Barnes, and Bridge, 1945, p. 143). The type section of the Threadgill Member is on Threadgill and Mormon Creeks, south of Lange's Mill, in northwestern Gillespie County (Cloud and Barnes, 1948, pl. 6; Barnes, 1952i). Cloud and Barnes (1948, p. 37) stated:

> At its type section the Threadgill Member measures 280 feet 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. 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.

Barnes (1952c, g; 1965b; 1967) in mapping the southeastern part of the Gold (Cave Creek School) quadrangle and the southwestern part of the North Grape Creek (Rocky Creek) quadrangle, found that the upper part of the Threadgill Member is thin-bedded, aphanitic limestone and fine-grained dolomite, whereas normally in this part of the Llano region, it is massive limestone grading laterally into coarse-grained dolomite similar to that in the lower part of the member. Another feature in this area, not seen before except in the San Saba Member in the southeastern part of the North Grape Creek quadrangle, is the lateral intergradation of fine-grained and coarse-grained dolomite.

In the subsurface to the west of a line circling the Llano region from eastern Bandera County to eastern Menard County, from there toward Brown County, Barnes (1959, pls. 1-3, 5) found that the Threadgill Member can no longer be identified with certainty. In Carpenter Exploration Company No. 1 Bradshaw, Mason County, at the edge of the outcrop area, the Threadgill is fine- and very fine-grained dolomite. A short distance west, because of upward transgression of Wilberns-type lithology, the upper part of the San Saba Member becomes laterally equivalent to the Threadgill Member. Therefore, in this western area the upper cherty member of the Tanyard Formation, the Staendebach Member, rests directly on the carbonate facies of the San Saba Member. In some wells a thin interval of very fine-grained to microgranular, noncherty dolomite is present between typical Staendebach and San Saba rocks; for convenience, this atypical rock is included with the Staendebach rather than showing it as a patchy, discontinuous part of the Threadgill Member.

*Staendebach Member.*—The Staendebach Member of the Tanyard Formation was named by Cloud, Barnes, and Bridge (1945, p. 144) after the Staendebach survey in the Cherokee area of southeastern San Saba County. In its type section (Cloud and Barnes, 1948, p. 37) it is 300 feet thick, and elsewhere in the Llano region it ranges from 229 feet in the west to 456 feet in the east. As a rule in the northeastern part of the region, the upper portion of the member is limestone, but elsewhere dolomite predominates and limestone is scarce to absent. The Staendebach characteristically contains an abundance of slightly dolomoldic, opaque, and translucent to semitranslucent chert, the latter commonly oolitic.

Barnes (1959, pls. 1–3, 5) found that in the subsurface where the Staendebach rests on the San Saba Member it is typically very fine-grained, microgranular, and fine-grained dolomite, in that order of abundance, and commonly cherty to the base of the member. As explained above, thin intervals of noncherty rock between typical Staendebach and typical San Saba are included with the Staendebach rather than showing them as a patchy, discontinuous part of the Threadgill Member.

### Canyon Croup

Barnes, Bell, and Pavlovic (1954, p. 33–34) found that in the northwestern part of the Llano region north of Hext, Menard-County, rocks identified by Harlton (1929) and mapped on the geologic map of Texas (Darton, Stephenson, and Gardner, 1937) as Canyon (Pennsylvanian) rest directly on sandstone and limestone of the San Saba Member (pl. 7, fig. 4). Part of this sandstone is of Ordovician age as shown by a collection of Ordovician trilobites obtained from limestone beneath the sandstone on the western side of the inlier 1.25 miles north of Hext.

This locality is important because it shows that the Cambrian-Ordovician boundary is not at the top of the sand sequence but is within the sand sequence of the San Saba. The top of the sandstone may hold a fairly constant level, as suggested by Barnes (1959), but it is not at the systemic boundary.

Many periods of emergence with erosion followed the deposition of the Moore Hollow and Ellenburger Groups, but the one, or ones, directly responsible for the erosional surface on which Canyon Group rocks were deposited occurred after deposition of Marble Falls—Smithwick rocks and after faulting which probably took place during Strawn time.

Pennsylvanian rocks of various ages in the subsurface rest from place to place on Moore Hollow rocks. These rocks have not been examined in detail during this project.

### Cretaceous Rocks

The Hensell Sand Member of the Shingle Hills Formation (upper Trinity of Lozo and Stricklin, 1956) is the Cretaceous unit generally found resting on Moore Hollow rocks. The Hensell Sand is the shoreward facies of the Glen Rose Limestone and is predominantly red, ranging from conglomerate to sand, silt, and calcareous clay.

Glen Rose Limestone rests directly on Moore Hollow Group rocks in places in the Blowout, Gold (Cave Creek School) and North Grape Creek (Rocky Creek) quadrangles (Barnes, 1952a, c, g; 1905b, 1907), and in the vicinity of Burnet. Comanche Peak Limestone in the Crabapple Creek and Palo Alto Creek quadrangles (Barnes, 1952b, h) and Edwards Limestone in the Palo Alto Creek quadrangle (Barnes, 1952h) also rest on Moore Hollow rocks. One hill of Cap Mountain Limestone in the Palo Alto Creek quadrangle reaches to about the 140-foot level in the Edwards Limestone and is the highest known point on the pre-Cretaceous surface in the Llano region.

# PETROLOGY

The discussion in this section on petrology is based mainly on the data in Part II, (on open file at the Bureau of Economic Geology), which, in addition to the field description of 23 stratigraphic sections, incorporates descriptions of more than 300 thin sections, the results of a binocular microscope examination of more than 1,300 crushed samples chipped from 5-foot intervals, binocular microscope examination of insoluble residues from these same intervals, petrographic microscope examination of representative samples of the insoluble residues, and examination of heavy minerals from about 112 samples from the chip-sampled intervals. The amount of insoluble residue and frequency counts for the heavy minerals for various stratigraphic sections are also given in Part II. Thin sections of well cores are described in Part III on open file at the Bureau of Economic Geology.

The following discussion is a summation of the thin-section, heavy-mineral, and insoluble-residue studies, followed by an overall interpretation of the sedimentary structures and history of the Moore Hollow Group of rocks.

## THIN-SECTION EXAMINATION

The following discussion and table 2 (in pocket) summarize the data on all of the thin-section descriptions. The mineralogy of the rock is discussed by individual minerals, and each mineral is discussed as to its form, distribution, and replacement history.

### Calcite

#### Matrix

The Moore Hollow Group of rocks of Central Texas is mainly limestone; consequently, calcite is the dominant mineral. Most fossils, fossil debris, ooids, intraclasts, and pellets are composed of calcite, and these objects exist in various types of calcite matrix. Listed in table 3 are the varieties of matrix, reference to illustrations of each, and the percentage of thin sections with the various types. Several types of matrix may be present in the same thin section.

Aphanitic calcite forms stromatolitic limestone (MH 30, pl. 14, fig. 3; TC 1,260–1,265, pl. 17, fig. 6) but rarely constitutes beds in the Moore Hollow Group except in the San Saba Member of the eastern part of the Llano region. However, it is the dominant calcite rock in the Ellenburger Group, Aphanitic calcite also forms girvanella (MH 170, pl. 14, fig. 5), intraclasts (KW 70, pl. 11, fig. 4; LL 874, pl. 14, fig. 1; MH 251, pl. 14, fig. 6; SS 278, pl. 16, fig. 2), fillings in fossils (LL 879, pl 14, fig. 2: TC 1,015–1,020, pl. 17, fig. 1; TC 1,145–1,150, pl. 17, fig. 3), and pellets (LL 860, pl. 13, fig. 6; MH 170, pl. 14, fig. 5).

Calcite completely replaces some fossil material with only ghost outlines remaining, and during the present weathering cycle much dolomite has been

**Table 3. Frequency of occurrence of calcite matrix varieties in thin sections of Moore Hollow Group rocks, Central Texas.**

| Matrix variety | Percent |
|---|---|
| 1. Granular, clear calcite in the form of a mosaic | |
| a. Coarse grained (SS 68a, pl. 15, fig. 6; SS 68b, pl. 16, fig. 1) | 19 |
| b. Medium grained (JRL 145–150b, pl. 10, fig. 5) in part twinned (KW 149a, pl. 12, fig. 3) | 27 |
| c. Fine grained (KW 70, pl. 11, fig. 4; LL 367, pl. 13, fig. 1) | 44 |
| d. Very fine grained (LL 573, pl. 13, fig. 4; MH 251, pl. 14, fig. 6) | 37 |
| e. Microgranular (MH 127, pl. 14, fig. 4; TC 1,135–1,140, pl. 17, fig. 2) | 40 |
| 2. Radial, clear calcite | |
| a. About fossil fragments (KW 93a, b, pl. 11, figs. 5, 6; TC 1,335–1,341, pl. 18, fig. 2) | 15 |
| b. About ooids and intraclasts (SS 302, pl. 16, fig. 3) | 5 |
| 3. Secondary calcite enlargement of pelmatozoan debris (KW 68, pl. 11, fig. 3) | 41 |
| 4. Aphanitic calcite (MH 170, pl. 14, fig. 5; TC 929–935, pl. 16, fig. 5; TC 1,175–1,180, pl. 17, fig. 4; TC 1,185–1,190, pl. 17, fig. 5) | 37 |

## PLATE 10

Photomicrographs of thin sections of Moore Hollow Group rocks,
Calf Creek (CC), upstream James River (JR), and downstream James River (JRL) sections,
Mason County, Texas

Fig. 1. CC-15–Calcite-filled vug in fine to medium grained, indistinctly zoned dolomite) flecks of hematite common; interstitial glauconite, upper right; ghost of a pelmatozoan fragment preserved in two dolomite rhombs, bottom center, ×30. Dolomitic facies, San Saba Member, Wilberns Formation.

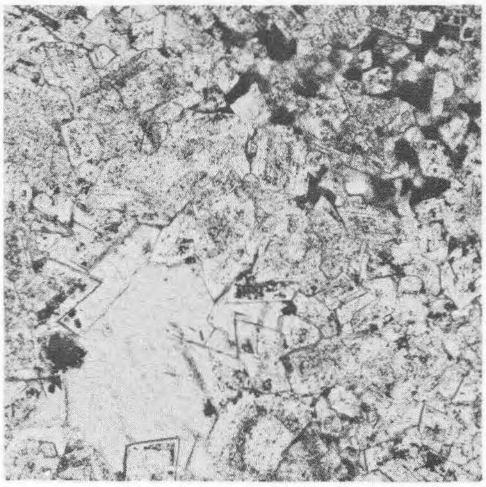
Fig. 2. JR 19.5a-Intermediate stage of weathering of greensand. Glauconite, medium gray, ragged from replacement by hematite, black; fossils replaced somewhat by hematite, ×30. Lion Mountain Sandstone Member, Riley Formation.

Fig. 3. JR 19.5b—Final stage of weathering of greensand. Hematite, black; one quartz grain, very light gray; quartz mosaics fill spaces left by removal of glauconite during weathering, ×30. Lion Mountain Sandstone Member, Riley Formation.

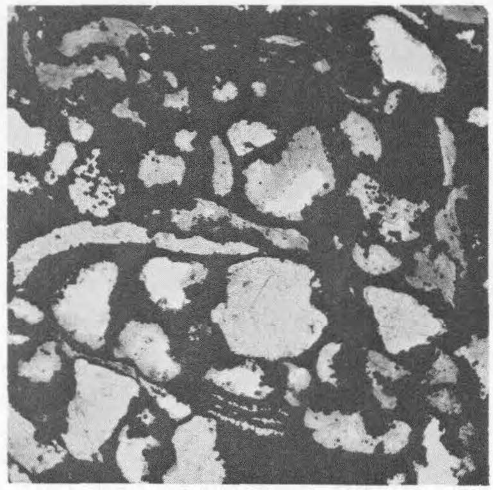
Fig. 4. JRL 145–150a—Chancelloria (?) and glauconite in fine grained, clear calcite matrix; aphanitic calcite and some silt fill cavities within fossils, ×28. Cap Mountain Limestone Member, Riley Formation.

Fig. 5. JRL 145–150b—Chancelloria (?) in medium-grained, clear, calcite mosaic; aphanitic calcite and some silt within fossil, ×28. Cap Mountain Limestone Member, Riley Formation.

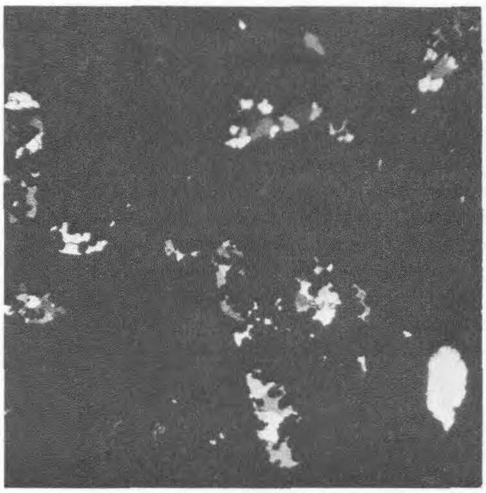
Fig. 6. JRL 185–190—Black opaque minerals concentrated at base of bed; glauconite common, medium gray; angular silt and very fine sand is composed of quartz, fresh to weathered feldspar, and fossil debris in a finely granular calcite matrix, ×30. Cap Mountain Limestone Member, Riley Formation.



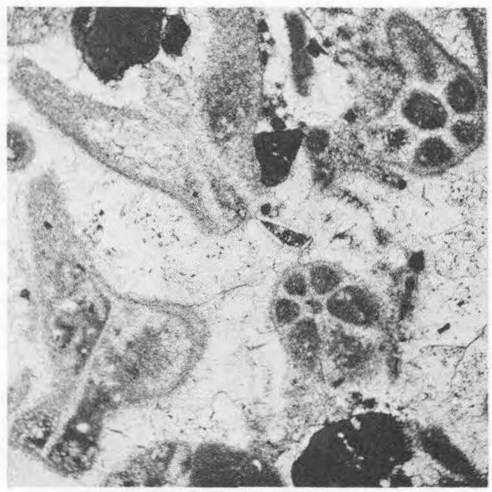
CC-15



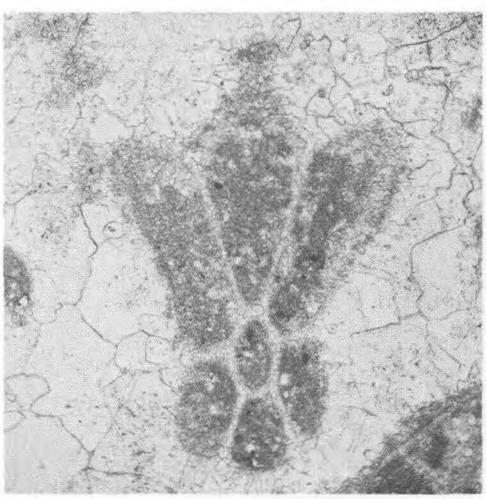
JR 19.5a



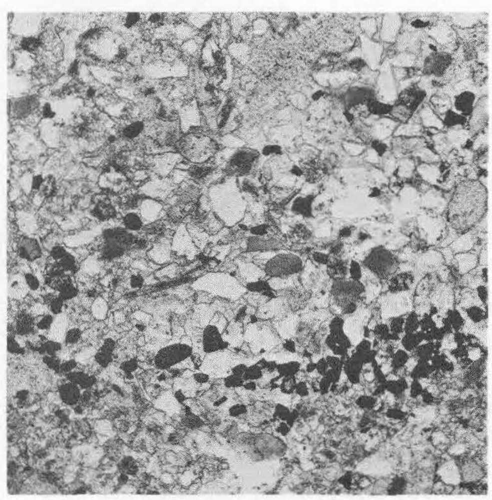
JR 19.5b



JRL 145-150a



JRL 145-150b



JRL 185-190

PLATE 11

Photomicrographs of thin sections of Moore Hollow Group rocks,
Klett-Walker section (KW) Blanco County, Texas

Fig. 1. KW 5–10—Ooids and veins replaced by fine-grained dolomite. The degree of cloudiness of the dolomite reflects the degree of cloudiness of the limestone it replaced, ×30. Cap Mountain Limestone Member, Riley Formation,

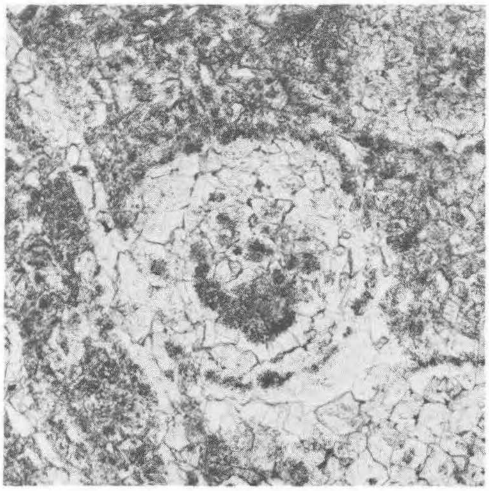
Fig. 2. KW 55–Pelmatozoan debris, cloudy, replaced by dolomite. The pelmatozoan debris is thought to have been enlarged by addition of optically continuous calcite before dolomitization took place. The black material is limonite, ×30. Cap Mountain Limestone Member, Riley Formation.

Fig. 3. KW 68c-Curved glauconite grains, dolomite ooid, dolomitic intraclast, enlarged pelmatozoan fragments, trilobite debris, and a few silt and sand grains in a coarse-grained, clear, calcite matrix, ×28. Cap Mountain Limestone Member, Riley Formation.

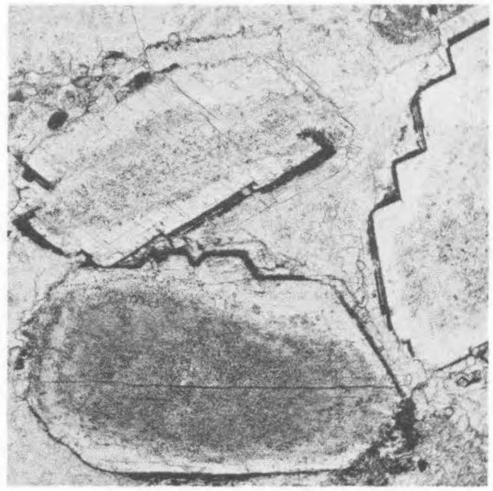
Fig. 4. KW 70—partly dolomitized ooids and intraclast in a fine-grained, clear, calcite matrix. Calcite ooids have distinct radial and indistinct concentric structure, ×30. Cap Mountain Limestone Member, Riley formation.

Fig. 5. KW 93a-Calcite radial to trilobite fragments, ×30. Cap Mountain Limestone Member, Riley Formation.

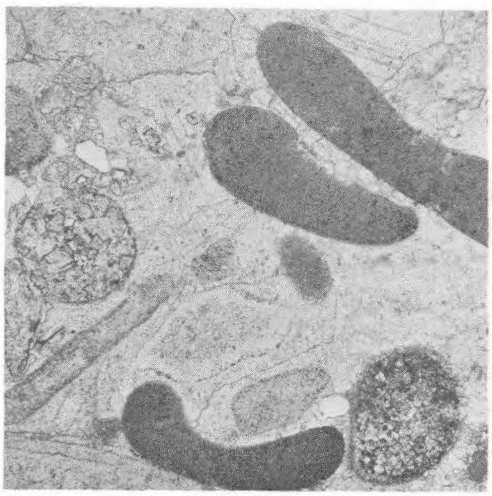
Fig. 6. KW 93b-Crossed-nicols view of figure 5.



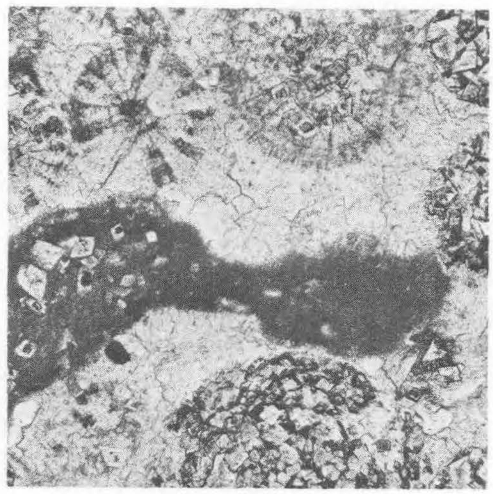
KW 5-10



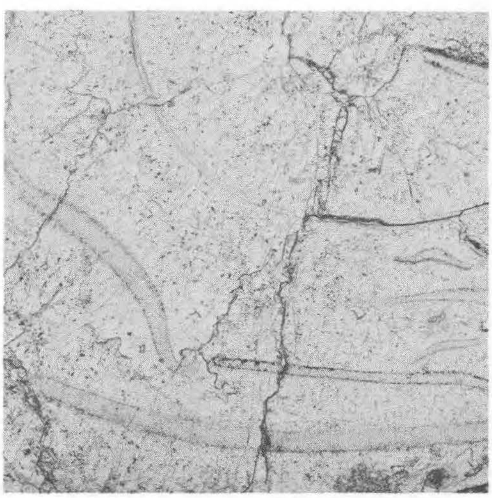
KW 55



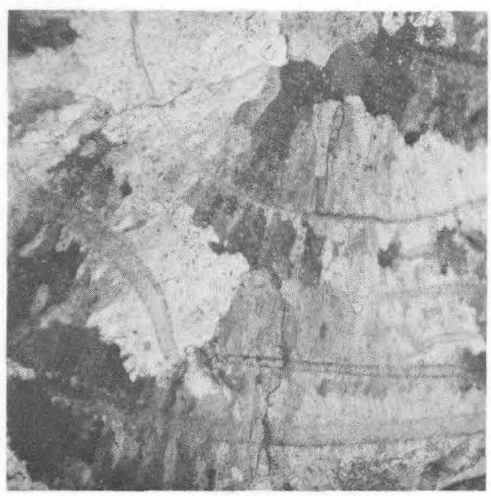
KW 68c



KW 70



KW 93a



KW 93b

PLATE 12

Photomicrographs of thin sections of Moore Hollow Croup rocks,
Klett-Walker section (KW), Blanco County and Little Llano River
section (LL) Llano County, Texas

Fig. 1. KW 144a— Pelmatozoan debris in part invaded by black threads of glauconite, right, replaced by fine to very coarse grained dolomite; black object, below center, is pelmatozoan fragment possibly replaced by glauconite then weathered to limonite; glauconite near center, medium gray, may be partly replaced by dolomite; quartz, very light gray, ×2S. Morgan Creek Limestone Member, Wilberns Formation.

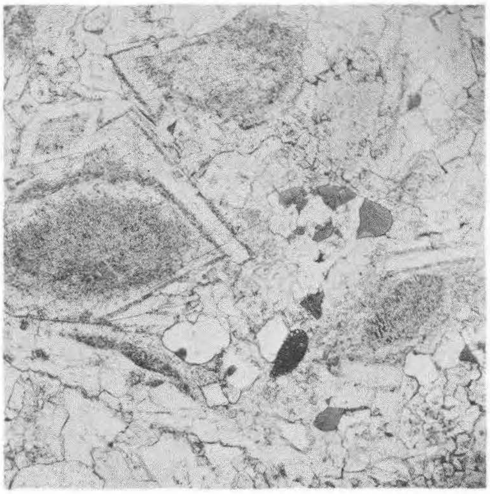
Fig. 2. KW 144b-Dolomite invading, disrupting, and possibly replacing glauconite, ×90. Morgan Creek Limestone Member, Wilberns Formation.

Fig. 3. KW 149a—Ooids replaced by dolomite in medium-grained, clear, calcite matrix; quartz, very light gray, ×30. Morgan Creek Limestone Member, Wilberns Formation.

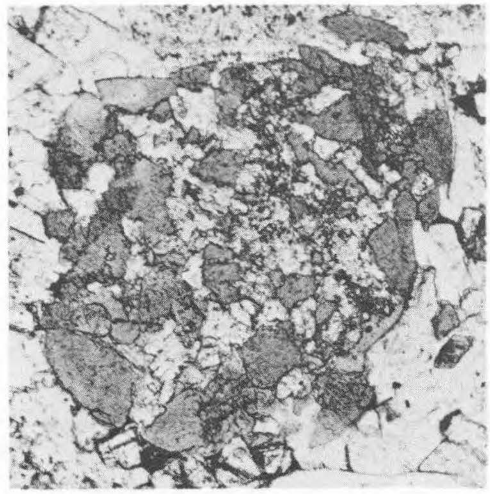
Fig. 4. KW 149b-Glauconite invading pelmatozoan debris, medium gray, and in turn replaced by limonite, black; quartz, very light gray; recrystallized ooid(?), top center, ×30. Morgan Creek Limestone Member, Wilberns Formation.

Fig. 5. LL 343a-Very coarse quartz grain derived from granite has microcline, plagioclase, and magnetite attached at lower right (grinding dust adheres to quartz but not to feldspar). Fossil fragments, mostly replaced by dolomite which in turn has been replaced by mosaic calcite and some limonite, lower edge center; cement, mostly medium to coarse, clear calcite, ×30. Hickory Sandstone Member, Riley Formation.

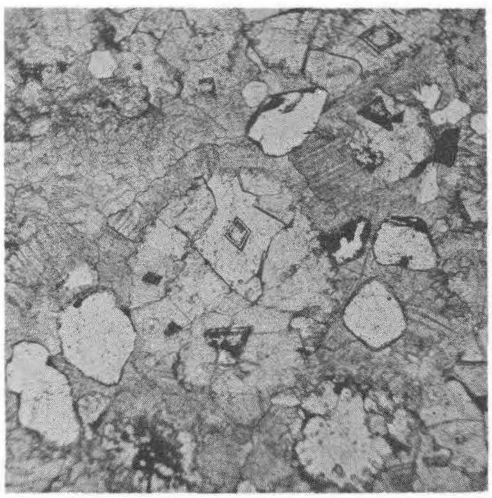
Fig. 6. LL 343b—Crossed-nicols view of figure 5.



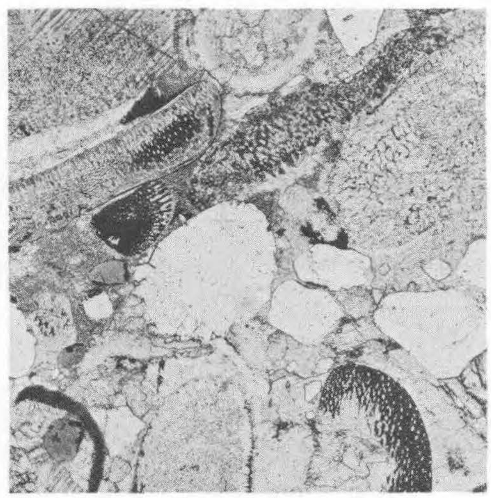
KW 144a



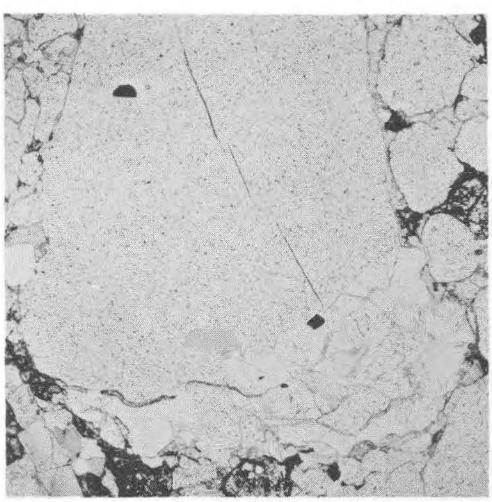
KW 144b



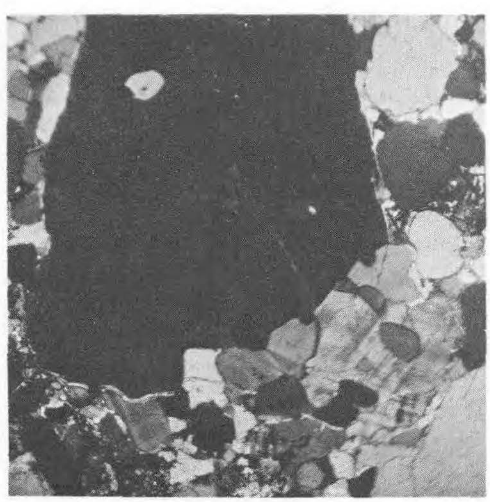
KW 149a



KW 149b



LL 343a



LL 343b

PLATE 13
Photomicrographs of thin sections of Moore Hollow Croup rocks,
Little Llano River section (LL) Llano County, Texas

Fig. 1. LL 367—Spicule type B showing septate structure; clear grains with similar structure as matrix are probably spicules in which septae have been destroyed. Pelmatozoan fragments, upper left, and intraclasts are partly replaced by dolomite which in turn has altered to calcite with limonitic staining, ×30. Cap Mountain Limestone Member, Riley Formation.

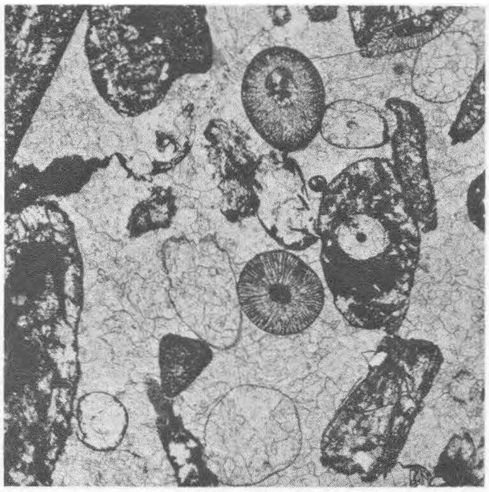
Fig. 2. LL 425—Crossed-nicols view of siltstone in part cemented by poikilitic calcite, right, and in part by silica, black, left; silt and very fine sand are mostly quartz and feldspar, ×30. Cap Mountain Limestone Member, Riley Formation.

Fig. 3. LL 464-Spicule type B replaced by limonite, some pelmatozoan debris in fine-grained, clear, calcite matrix, ×30. Cap Mountain Limestone Member, Riley Formation,

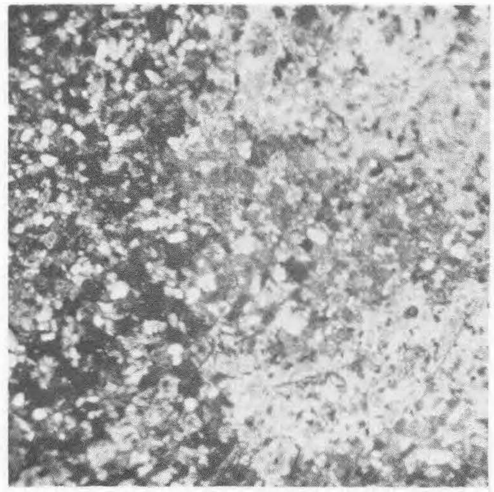
Fig. 4. LL 573—Pelmatozoan debris invaded by glauconite, medium dark gray, before secondary enlargement which engulfed silt particles; aphanitic to very fine grained calcite matrix contains some trilobite debris, ×30. Lion Mountain Sandstone Member, Riley Formation.

Fig. 5. LL 580—Two curved glauconite grains, one in upper left has a thin shell of ordered glauconite along left side; quartz sand, very light gray; laminated phosphatic brachiopod fragment, lower left; trilobite debris common; secondarily enlarged pelmatozoan fragment, bottom center; matrix very coarse grained, poikilitic, clear calcite, ×28, Lion Mountain Sandstone Member, Riley Formation.

Fig. 6. LL 860—Ooids mostly with distinct concentric and radial structure, one wedged in a trilobite spine without concentric structure; spine and two ooid are dissolved and offset along a stylolite; ooid at top has a pelmatozoan fragment for a nucleus, ×22, Point Peak Member, Wilberns Formation.

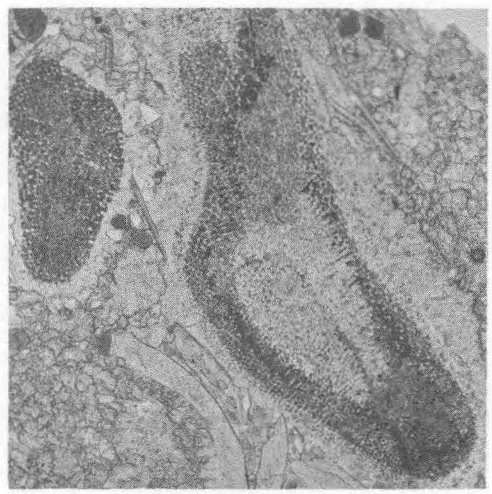


LL 367



LL 425

LL 464



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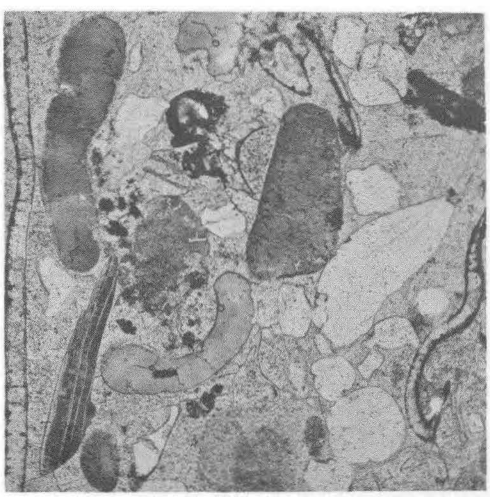

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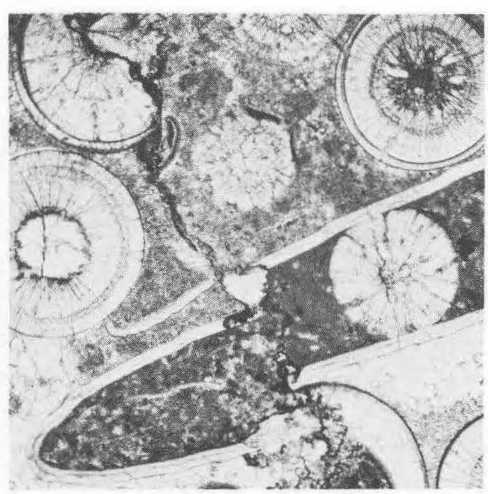


LL 860

PLATE 14

Photomicrographs of thin sections of Moore Hollow Group rocks,
Little Llano River (LL) and Moore Hollow (MH) sections,
Llano, County, Texas

Fig. 1. LL 874-Truncated ooid at surface of an intraclast having cloudy aphanitic matrix; fine-grained, clear calcite matrix surrounds interclast and contains similar ooids, ×30. Point Peak Member, Wilberns Foundation.

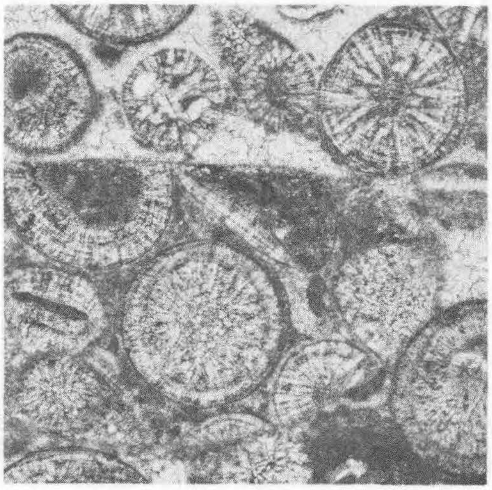
Fig. 2. LL 879b-Mixture of sharply bounded and hazy ooids; distinct ooids may have formed elsewhere and hazy ooids may have formed in place; matrix calcite, ranging from aphanitic, pelleted to clear, fine grained, ×30. Point Peak Member, Wilberns Formation.

Fig. 3. MH 30–Algal(?) structure represented by dendritic, fairly clear, microgranular calcite in a densely aphanitic matrix, ×30. Point Peak Member, Wilberns Formation.

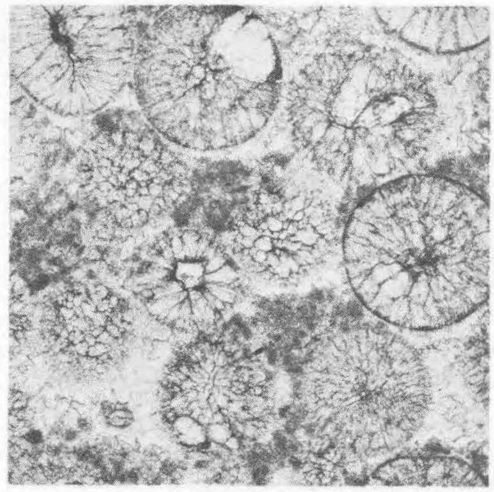
Fig. 4. MH 127—Microgranular, clear calcite contains pellets and a few shreds of fossil debris, ×30. Calcitic facies, San Saba Member, Wilberns Formation.

Fig. 5. MH 170—Girvanella, densely aphanitic and faintly pelleted, contains few spicules and a feldspar rhomb; pelleted matrix contains fossil debris, ×30. Calcitic facies, San Saba Member, Wilberns Formation.

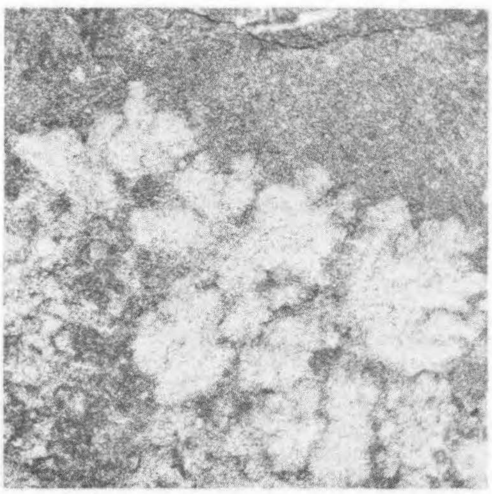
Fig. 6. MH 251—Aphanitic intraclast with uneroded ooid standing in relief; matrix of very fine-grained, clear calcite contains both sharply defined and hazy ooids, ×30. Calcitic facies, San Saba Member, Wilberns Formation.



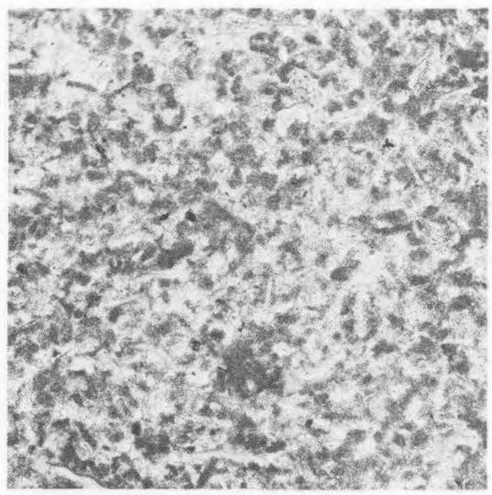
LL 874



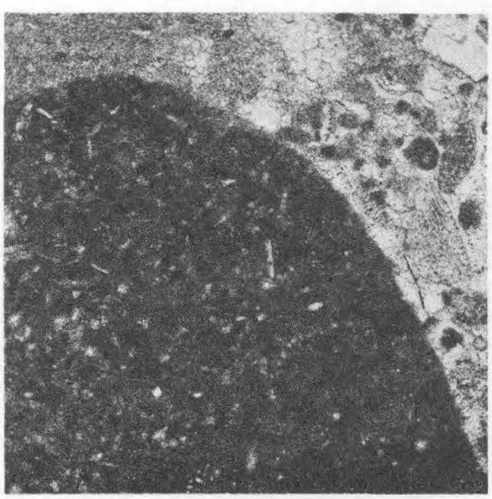
LL 879b



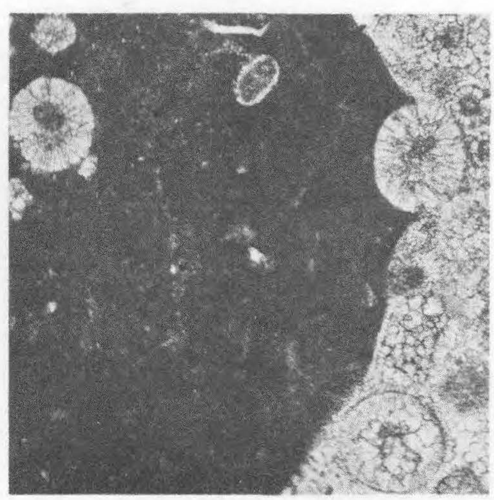
MH 30



MH 127



MH 170



MH 251

**PLATE 15**

**Photomicrographs of thin sections of Moore Hollow Group and Ellenburger Group rocks, Moore Hollow (MH) section, Llano County, and Camp San Saba section (SS) Mason County, Texas**

**Fig. 1. MH 292-Fine-grained, hypidiomorphic dolomite flecked by hematite; porosity in part may have developed during preparation of section, ×30. Dolomitic facies, San Saba Member, Wilberns Formation.**

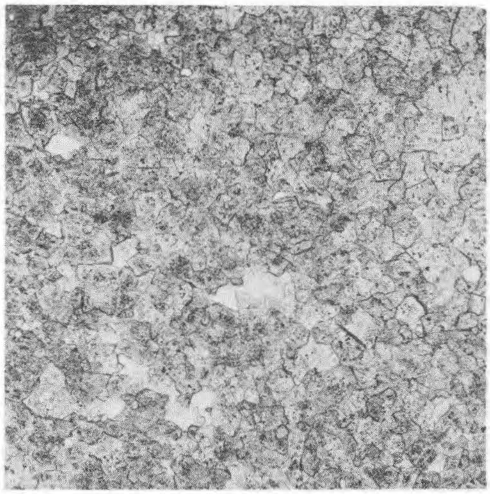
**Fig. 2. MH 312—Dolomite, hypidiomorphic, on boundary between microgranular and very fine grained; some rhomb centers are dark; flecked by hematite, ×30. Dolomitic facies, San Saba Member, Wilberns Formation.**

**Fig. 3. MH 340—Coarse-grained dolomite, indistinctly composite; ghost of large intraclast occupies lower left part of photograph; a vertical fracture left of center, ×28. Dolomitic facies, Threadgill Member, Tanyard Formation.**

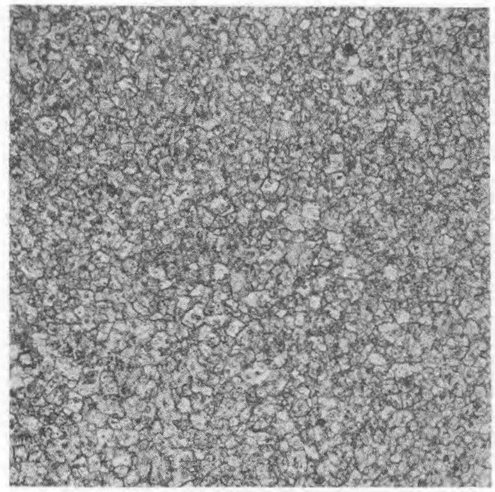
**Fig. 4. MH 475a—Coarse-grained, composite dolomite replacing pelleted, aphanitic limestone, × 30. Threadgill Member, Tanyard Formation.**

**Fig. 5. MH 475b—Crossed-nicols view of figure 4 showing undigested calcite in the dolomite.**

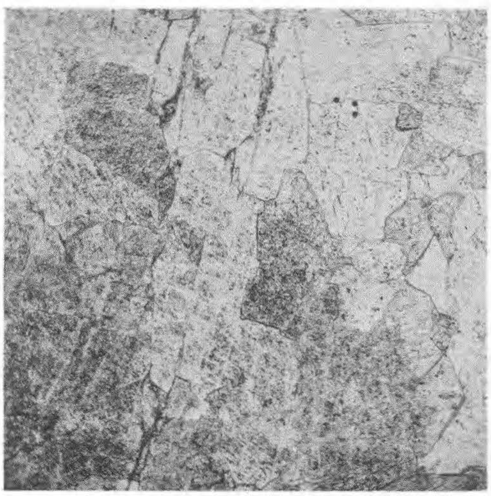
**Fig. 6. SS 68a—Trilobite fragments in coarse-grained, clear, calcite matrix; at lower right aphanitic calcite and one glauconite grain fills cavity in trilobite fragment, ×30. Morgan Creek Limestone Member, Wilberns Formation.**



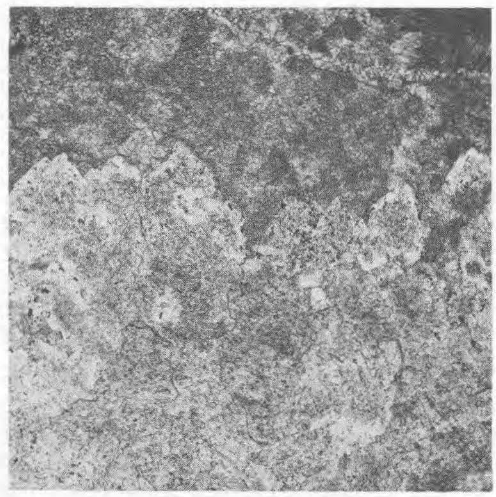
MH 292



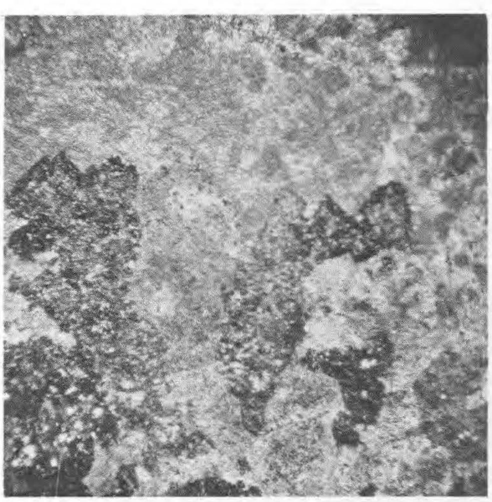
MH 312



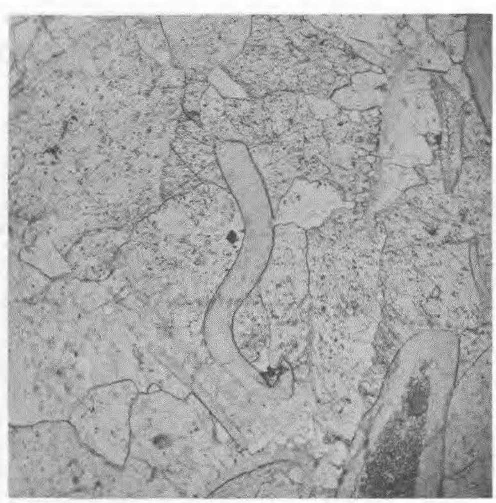
MH 340



MH 475a



MH 475b



SS 68a

PLATE 16

Photomicrographs of thin sections of Moore Hollow Group rocks,
Camp San Saba section (SS), Mason County, and Threadgill Creek section (TC),
Gillespie County, Texas

Fig. 1. SS 68b-Crossed-nicols view of figure 6, plate 15, showing a trilobite fragment partly enclosed by a coarse grain of clear calcite, black, ×30. Morgan Creek Limestone Member, Wilberns Formation.

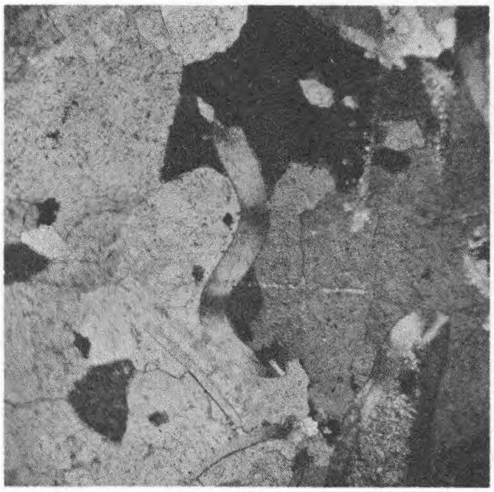
Fig. 2. SS 278-Densely aphanitic intraclasts in fine-grained, clear, calcite matrix, ×30. Calcitic facies, San Saba Member, Wilberns Formation.

Fig. 3. SS 302-Ooids, intraclasts, and fossil fragments all in part replaced by dolomite; rhombs in ooids in part truncated, in part projecting beyond periphery, both types of which formed earlier than the radial calcite which composes most of the matrix, ×28. Calcitic facies, San Saba Member, Wilberns Formation.

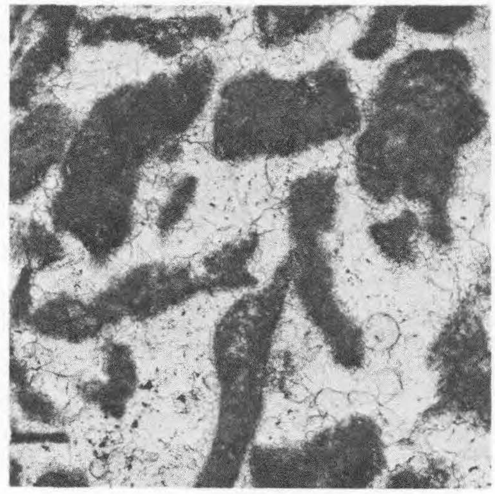
Fig. 4. TC 883–889—Ordered glauconite forming shells around pelmatozoan fragments which are impregnated by limonite which may have altered from glauconite; quartz grains near center are identified by coating of grinding dust; feldspar lower right is free of dust; dolomitized objects are ooids or intraclasts and one pelmatozoan fragment, upper left; a clear layer of dolomite surrounds these objects, ×30. Morgan Creek Limestone Member, Wilberns Formation.

Fig. 5. TC 929–935—Glauconite, medium dark gray, replacing brachiopod shell and in turn partly replaced by limonite; angular silt is fresh, detrital feldspar, ×28. Morgan Creek Limestone Member, Wilberns Formation.

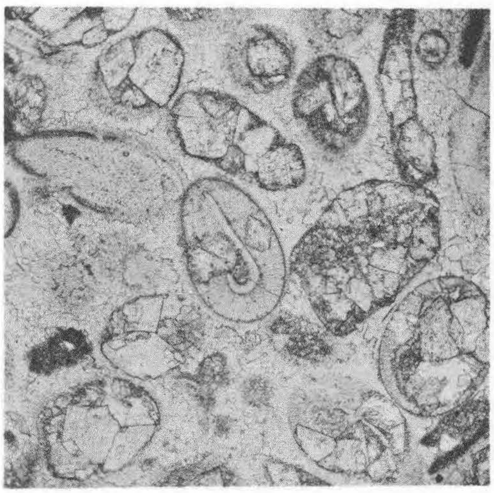
Fig. 6. TC 990–995–Curved grain is composed of ordinary glauconite between leaves of expanded hydrobiotite(?); a shell of ordered glauconite encompasses the grain; two grains of ordinary glauconite are admixed with calcite, lower right, left grain has ordered glauconite along its left side, ×78. Morgan Creek Limestone Member, Wilberns Formation.



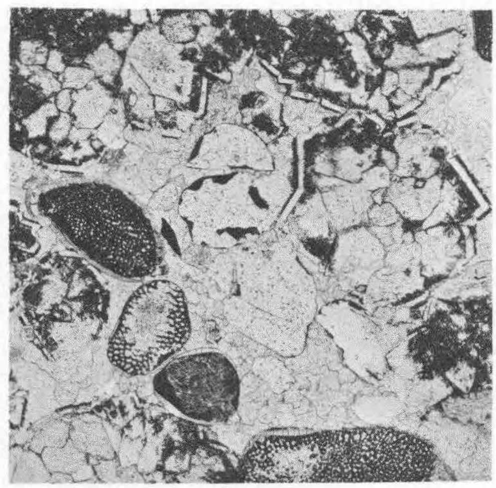
SS 68b



SS 278

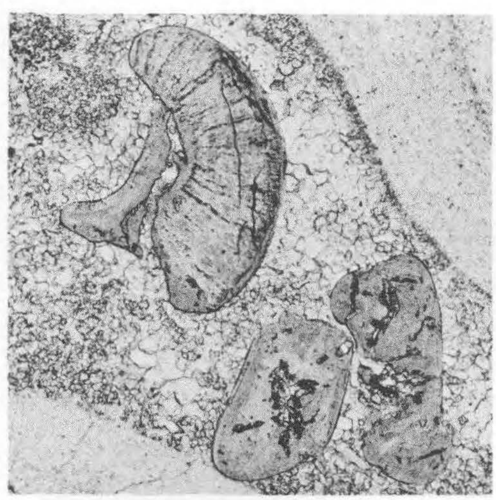


SS 302



TC 883-889

TC 929-935



TC 990-995

PLATE 17

Photomicrographs of thin sections of Moore Hollow Group rocks,
Threadgill Creek section (TC), Gillespie County, Texas

Fig. 1. TC 1,015–1,020—Ordered glauconite encompasses gastropod steinkern except where dolomite invades the steinkern; glauconite grain, top center, contains some finely admixed calcite and at one point is invaded by dolomite; calcite matrix is confined to upper left, ×60. Morgan Creek Limestone Member, Wilberns Formation.

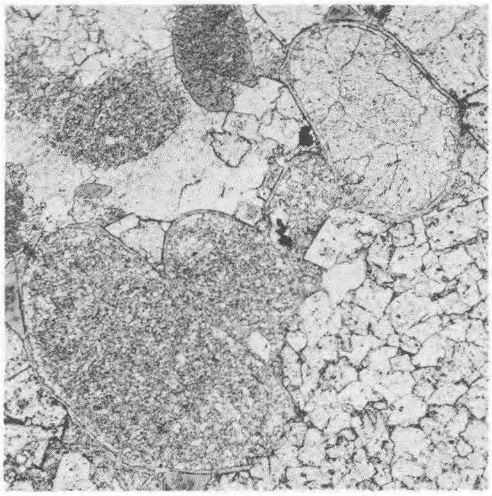
Fig. 2. TC 1,135–1,140—Crossed-nicols shows crytocrystalline nature of the silica composing a hexactinellid spicule; microgranular calcite matrix contains some silt-sized feldspar and glauconite, ×80. Point Peak Member, Wilberns Formation.

Fig. 3. TC 1,145–1,150–Aphanitic calcite fills brachiopod(?) shell which is partly replaced by glauconite; intraclast replaced by dolomite, upper left; fine- to coarse-grained, clear, calcite matrix contains much trilobite debris, ×28. Point Peak Member, Wilberns Formation.

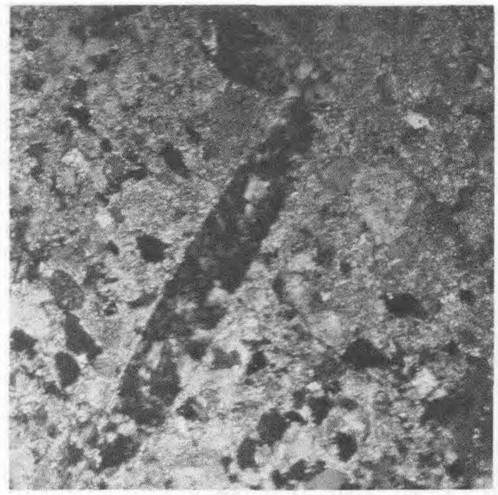
Fig. 4. TC 1,175–1,180–Glauconite interspersed with and surrounded by pelleted, aphanitic calcite; trilobite fragment at top; portion of ooid at lower right, ×70. Point Peak Member, Wilberns Formation.

Fig. 5. TC 1,185–1,190–Crossed-nicols showing hexactinellid spicule replaced by calcite; matrix aphanitic calcite, ×110. Calcitic facies, San Saba Member, Wilberns Formation.

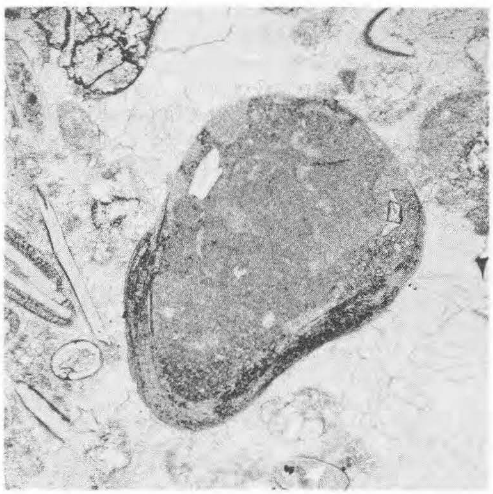
Fig. 6. TC 1,260–1,265—Densely aphanitic to microgranular, pelleted calcite occurring as wavy layers and mottles, outlines stromatolitic structure; silt is mostly rhombs of authigenic feldspar, ×42. Calcitic facies, San Saba Member, Wilberns Formation.



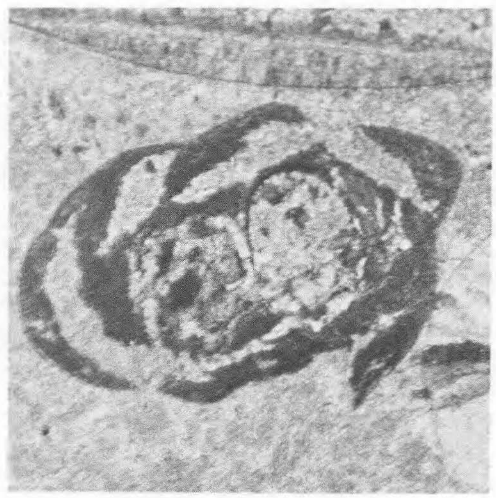
TC 1,015-1,020



TC 1,135-1,140

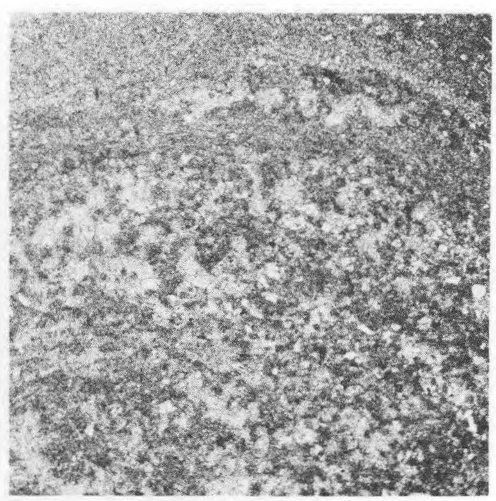


TC 1,145-1,150



TC 1,175-1,180

TC 1,185-1,190



TC 1,260-1,265

PLATE 18

Photomicrographs of thin sections and scatter mount of Moore Hollow Croup rocks, Threadgill Creek section (TC), Squaw Creek section, and Rowntree No. 1 Kott well, Gillespie County

Fig. 1. TC l,305–l,310–Salterella(?) composed of fine-grained, clear, calcite mosaic alternating with layers of aphanitic to fine-grained matrix; some dolomite in center, ×30. Calcitic facies, San Saba Member, Wilberns Formation.

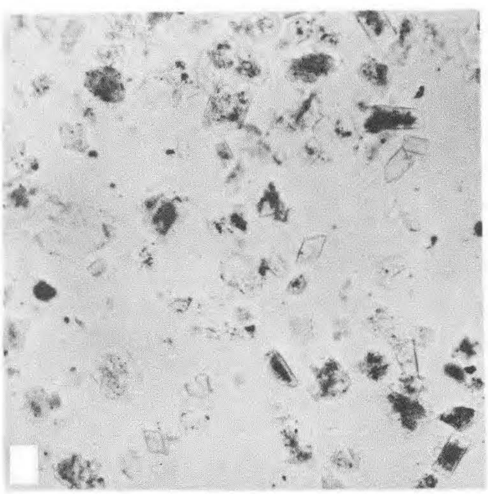
Fig. 2. TC 1,335–1,341–Dolomite formed in trilobite spines in part replaces shell material; matrix mostly radial calcite, ×28. Calcitic facies, San Saba Member, Wilberns Formation.

Fig. 3. SC 30–Calcite replacing glauconite. The delicate limonite membranes show the original shape of the glauconite grains. The calcite replacing the gray glauconite has optical continuity with the matrix, calcite between grains, about ×100. Lion Mountain Sandstone Member, Riley Formation. Photograph by T. R. Walker, Department Of Geology, University of Colorado.

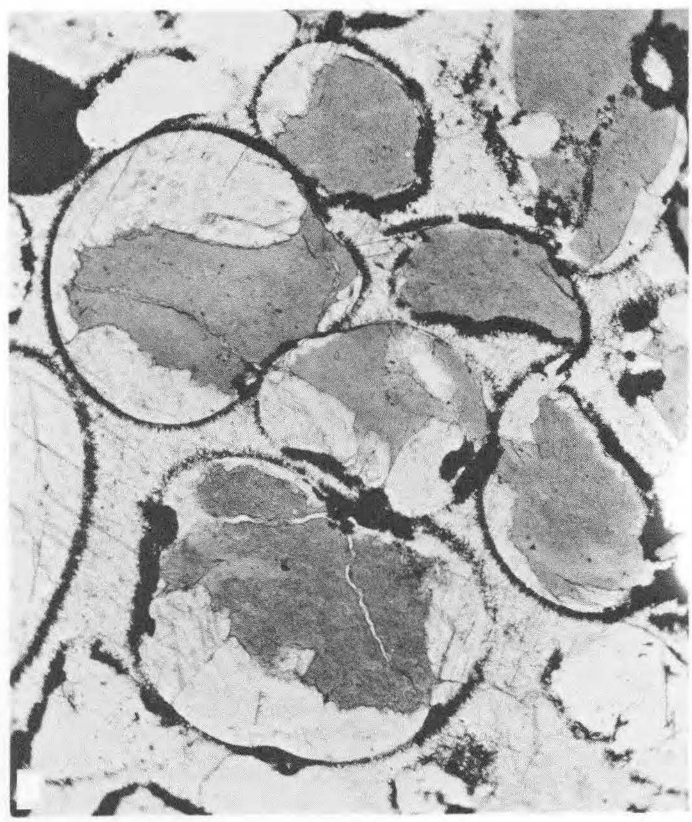
Fig. 4. Rowntree No. 1 Kott, 1,830–1,837–ScatteMnount of insoluble residue composed of feldspar, mostly clear authigenic with some detrital feldspar centers, ×50. Uppermost part of San Saba Member, calcitic facies, Wilberns Formation.

TC 1,305-1,310

TC 1,335-1,341



Rowntree No. 1 Kott
1,830-1,837



SC-30

replaced by calcite. Calcite forms veins (MH 475a, b, pl. 15, figs. 4, 5), occupies large voids such as vugs (CC -15, pl. 10, fig. 1), and in places is poikilitic (LL 425, pl. 13, fig. 2)

### Fossils and fossil debris

Complete fossils are scarce and those seen in thin section are usually smaller varieties such as *Chancelloria*(?) (JRL 145–150a, b, pl. 10, figs. 4, 5), *Salterella*(?) (TC 1,305–1,310, pl. 18, fig. 1), and spicule type B (LL 367, pl. 13, fig. 1; LL 464, pl. 13, fig. 3). The most abundant calcite fossil debris volumetrically is pelmatozoan fragments (LL 367, pl. 13, fig. 1; TC 883–889, pl. 16, fig. 4; TC 929–935, pl. 16, fig. 5), and in more than half of the thin sections, optically continuous, secondary calcite is added to the fragments (KW 149b, pl. 12, fig. 4; LL 573, pl. 13, fig. 4; LL 580, pl. 13, fig. 5), in part to the stage where all interstices are filled (KW 68, pl. 11, fig. 3). Many examples are cited in the thin-section descriptions (Part III on file at the Bureau of Economic Geology) of replacement or partial replacement of pelmatozoan debris by dolomite (KW 55, pl. 11, fig. 2; KW 144a, pl. 12, fig. 1; TC 883–889, pl. 16, fig. 4) and replacement or invasion by hematite and limonite (JR 19.5a, pl. 10, fig. 2; KW 149b, pl. 12, fig. 4; TC 883–889, pl. 16, fig. 4). Pelmatozoan debris is most abundant in the Morgan Creek Limestone, 89 percent of thin sections, and least abundant in the Lion Mountain Sandstone, 67 percent. Pelmatozoan and trilobite debris is present in 78 percent of the thin sections of Moore Hollow Group calcitic rocks examined.

Trilobite debris is next most abundant volumetrically (KW 68, pl. 11, fig. 3; KW 93a, b, pl. 11, figs. 5, 6; LL 573, pl. 13, fig. 4; LL 580, pl. 13, fig. 5; SS 68a, pl. 15, fig. 6; SS 68b, pl. 16, fig. 1; TC 1,145–1,150, pl. 17, fig. 3; TC 1,335–1,341, pl. 18, fig. 2) followed by phosphatic brachiopod debris (not calcite), 25 percent, and calcareous brachiopod debris (TC 929–935, pl. 16, fig. 5; TC 1,145–1,150?, pl. 17, fig. 3), 14 percent. Replacement of shell material by clear calcite with retention of ghost outlines is not illustrated but is mentioned in a number of thin-section descriptions (SS 630, Part II on open file at the Bureau of Economic Geology). Original gastropod shell material is almost entirely absent, and in its place is a very fine-grained mosaic of calcite (LL 879, pl. 14, fig. 2). Hexactinellid spicules commonly are replaced by calcite (TC 1,185–1,190, pl. 17, fig. 5) and tiny rodlike spicules (?) in girvanella are of calcite (MH 170, pl. 14, fig. 5). The finer grained rocks contain much finely shredded fossil debris (MH 127, pl. 14, fig. 4) which is not easily identified as to parent material.

Table 4 shows the percentage of thin sections of calcitic Moore Hollow rocks containing various fossils.

**Table 4. Frequency of occurrence of various fossils in thin sections of Moore Hollow Group rocks, Central Texas:**

| | Percent |
|---|---|
| Pelmatozoa | 78 |
| Trilobita | 78 |
| Phosphatic Brachiopoda | 25 |
| Calcitic Brachiopoda | 14 |
| Algae(?) | 11 |
| Gastropoda | 9 |
| Spicules type B | 4 |
| Hexactinellid | 3 |
| Straight | 3 |
| *Chancelloria*(?) | 2 |
| Girvanella (probably algal) | 2 |
| Hyolithides | 1 |
| *Salterella*(?) | 0.4 |

### Ooids

Ooids may be present almost anywhere in the calcitic rocks of the Moore Hollow Group and are especially abundant throughout the upper part of the Cap Mountain Limestone in the southern part of the region and in a few beds in the Morgan Creek Limestone, Point Peak and San Saba Members. They are present in about 17 percent of the thin sections examined of calcitic Moore Hollow rocks.

The ooids may have both distinct radial and concentric structure (LL 860, pl. 13, fig. 6; LL 874, pl. 14, fig. 1), distinct radial structure (KW 70, pl. 11, fig. 4; LL 879, pl. 14, fig. 2; MH 251, pl. 14, fig. 6; TC 1,175–1,180, pl. 17, fig. 4), or distinct concentric structure. Peripheral concentric structure in an ooid (KW 149b, pl. 12, fig. 4) surrounds a mosaic of twinned calcite without radial or concentric structure; this central part may be recrystallized. Structure in ooids may be obliterated during dolomitization (KW 149a, pl. 12, fig. 3; SS 302, pl. 16, fig. 3), partly obliterated (KW 70, pl. 11, fig. 4; SS 302, pl. 16, fig. 3), or ghosts of the structure may remain (KW 5–10, pl. 11, fig. 1).

Many ooids have nucleii—these may be calcite grains (LL 879, pl. 14, fig. 2), aphanitic limestone pellets or intraclasts (LL 860, pl. 13, fig. 6; LL 874, pl. 14, fig. 1), or fossil debris including trilobite fragments (SS 302, pl. 16, fig. 3) or pelmatozoan fragments (LL 860, pl. 13, fig. 6). Similar material included in the outer part of an ooid (LL 879, pl. 14, fig. 2) indicates that this ooid probably grew in place.

Ooids may be sharply defined (KW 68, pl. 11, fig. 3; KW 70, pl. 11, fig. 4; LL 860, pl. 13, fig. 6; LL 874, pl. 14, fig. 1) or hazy (LL 879, pl. 14, fig. 2; MH 251, pl. 14, fig. 6), the latter mixed with sharply defined ones. Hazy ooids merge with the matrix (LL 879, pl. 14, fig. 2) and the ooid just left of center appears to have invaded a patch of pelleted, aphanitic limestone. Such a relationship suggests that the ooid either grew in place or that enlargement continued after it was deposited.

Some aphanitic intraclasts contain ooids (LL 874, pl. 14, fig. 1; MH 251, pl. 14, fig. 6) and the degree of consolidation of such intraclasts at the time they were incorporated in the sediment is indicated by the degree of truncation or lack of truncation of the ooids. An ooid by the nature of its origin must have been of about the same hardness throughout its history, and if this is true the intraclasts must have been well indurated for the ooids to be truncated in the manner in which they are in LL 874, pl. 14, fig. 1. A distinct lowering of the surface of the matrix with the ooid left sitting on a slight pinnacle indicates that the matrix of the intraclast in MH 251, pl. 14, fig. 6), was much softer, but there must have been a fair degree of cohesiveness. Otherwise the ooid could not have remained in this precarious position as the intraclast was tumbled about.

The ooids in the intraclasts are exactly like the ooids in the matrix (LL 874, pl. 14, fig. 1; MH 251, pl. 14, fig. 6), suggesting that all the ooids formed in an aphanitic matrix. Many others in an aphanitic matrix, like those in LL 879, pl. 14, fig. 2, or with included aphanitic limestone were seen during thin-section examination of the Moore Hollow rocks. The thin section from which this illustration was taken has a distinct bedding surface separating a bed with closely packed ooids in a densely cloudy, pelleted, slightly glauconitic, aphanitic limestone from a bed with slightly fewer ooids floating in a less cloudy, aphanitic to microgranular matrix.

An examination of this contact shows that it is a micro-erosional contact with the ooids in the pelleted bed standing in relief; the pelleted bed is therefore the older. Moving downward in this bed a point is reached where some clear calcite is present mainly in crystal continuity with the crystals of the ooids and deposited along the bottom sides of the ooids (LL 879, pl. 14, fig. 2). A short distance downward no pelleted, aphanitic limestone remains — only clear, crystalline calcite. From this evidence, plus the fact that this 4-inch bed is in a siltstone sequence and has appreciable length along the outcrop, it is judged that the ooids formed under conditions exhibited in the immediately overlying bed; that is, that they grew in an aphanitic matrix. The lower bed was winnowed and in part thrown into suspension, thus accounting for the cleanly winnowed ooids beneath followed by an increased amount of fine material upward. That this explanation is true is shown by the accumulation of aphanitic matrix on the upper sides of ooids in the intermediate zone (LL 879, pl. 14, fig. 2), leaving space beneath which was later occupied by precipitated, clear calcite. As settling continued the amount of matrix fall-out became sufficient to embed the remaining ooids. After settling was complete and before deposition was renewed, currents swept the upper surface of the pelleted bed, eroding a little of the soft matrix, and leaving the hard ooids standing in relief.

The clear, granular calcite matrix in the lower part of the lower bed is not a product of recrystallization but of precipitation. Evidence for this statement is furnished by the presence of much undigested calcite in the ooids and very little in the matrix. The ooids, however, might be considered as products of recrystallization of a certain type, since they grew in place and now occupy space formerly occupied by aphanitic limestone. The growth of ooids of this type is visualized as starting from a center and progressing outward, the change taking place at an interface with one phase going into solution and another being created by precipitation. This is not the ordinary concept of recrystallization, such as that which takes place when a limestone is transformed into a marble.

Additional evidence that ooids grew in place in the rock from which thin section LL 860 was made is furnished by included glauconite grains in ooids, ooids tightly wedged in trilobite spines (LL 860, pl. 13, fig. 6), interfering ooids, included stringy patches of aphanitic limestone between the radial segments of ooids, and the presence throughout the crystalline calcite of the ooids of randomly oriented calcite dust interpreted as undigested calcite from the matrix in which the ooid grew. Many other such examples are mentioned in the thin section descriptions in Part II (on open file at the Bureau of Economic Geology).

In table 5 the various properties of ooids are listed, giving the percentage of thin sections in which each property occurs. Also an estimate is included concerning the place and conditions under which the ooids formed. In some thin sections evidence indicates that some ooids were reworked and that others grew in place.

#### Intraclasts

The intraclasts of the Moore Hollow Group calcitic-rocks are mostly aphanitic (LL 874, pl. 14, fig. 1), to densely aphanitic (KW 70, pl. 11, fig. 4; MH 251, pl. 14, fig. 6; SS 278, pl. 16, fig. 2) and microgranular limestone (KW 68, pl. 11, fig. 3). The intraclasts may contain ooids (MH 251, pl. 14, fig. 6; LL 874, pl. 14, fig. 1), fossil debris (LL 367, pl. 13, fig. 1) or any of the other objects, minerals and fossils recorded from these rocks. Many of the intraclasts are argillaceous and the amount of clay appears to be directly proportional to the density (light

**Table 5. Frequency of occurrence of various properties of ooids in thin sections of Moore Hollow Croup rocks, Central Texas.**

| | Percent |
|---|---|
| Ooids with radial structure | 97 |
| Ooids with concentric structure | 56 |
| Ooids with both radial and concentric structure | 53 |
| Ooids with sharp borders | 62 |
| Ooids with hazy borders | 65 |
| Ooids interfered with during growth | 18 |
| Ooids with stringy calcite inclusions | 41 |
| Ooids with calcite dust inclusions | 41 |
| Ooid nucleii—aphanitic calcite | 21 |
| granular calcite | 15 |
| intraclasts | 18 |
| trilobite debris | 21 |
| pelmatozoan debris | 18 |
| fossil debris unidentified | 35 |
| glauconite | 9 |
| sand | 6 |
| silt | 3 |
| pellets | 3 |
| Ooids which grew in situ | 50 |
| Ooids which grew in situ and then were reworked | 53 |
| Ooids which grew under conditions of agitation | 15 |

transmittance, controlled to some extent by grain size); that is, the greater the amount of clay the denser the intraclast.

Some intraclasts are in part replaced by dolomite (KW 70, pl. 11, fig. 4; SS 302, pl. 16, fig. 3), wholly replaced (LL 367, pl. 13, fig. 1; TC 1,145–1,150, pl. 17, fig. 3) or not replaced at all (LL 874, pl. 14, fig. 1; MH 251, pl. 14, fig. 6; SS 278, pl, 16, fig. 2). Where the entire rock is replaced by dolomite, ghosts of intraclasts may remain (MH 340, pl. 15, fig. 3). Some of the dolomitization took place before the intraclasts came to rest, as indicated by truncated rhombs (TC 1,145–1,150, pl. 17, fig. 3), and some afterward (MH 340, pl. 15, fig. 3); evidence for the time of dolomitization is generally not clear.

Many objects in thin section resembling intraclasts are not actually intraclasts but cavity fillings in fossils from which all shell material was removed. The origin of such objects may be suggested by their shape. In some cases their identity is made certain by finding whole fossils or parts of fossils surrounding identical material in the same thin section (LL 879, pl. 14, fig. 2; TC 1,015–1,020, pl. 17, fig. 1; TC 1,145–1,150, pl. 17, fig. 3).

Intraclasts of material other than limestone are common, including siltstone in the Point Peak Member and sandstone in the various sandstone units. Limestone intraclasts, however, are dominant in the Point Peak Member and many intraformational conglomerate beds are listed in this unit in the section descriptions (Part II, on open file at the Bureau of Economic Geology). Others may be found almost anywhere in the stratigraphic sequence. Thin-section examination shows that small intraclasts, not large enough to identify during field descriptions, are almost universally present.

Table 6 shows the percentage of thin sections of calcitic Moore Hollow rocks containing intraclasts having certain characteristics.

## Pellets

Ovoid to spherical objects averaging about 0.1 mm in diameter and composed of cloudy, aphanitic calcite are thought to be of excrementary origin. They merge imperceptibly with the slightly coarser grained, less cloudy matrix in which they lie and because of this they can be distinguished from sharp-bordered intraclasts of similar or larger size (SS 278, pl. 16, fig. 2). If these pellets were as fragile as they appear, it is believed that they could not have survived turbulent conditions. Therefore, when they are associated with ooids in the manner shown in LL 860, pl. 13, fig. 6, it is believed that the ooids grew in place. However, turbulent conditions are postulated for the occurrence shown in LL 879, pl. 14, fig. 2. Possibly in this case induration was sufficient so that clumps including ooids and pelleted limestone were formed and the pellets thus were preserved from destruction.

Pellets found in coarser grained, clear calcite matrix are included mostly in calcite that has been secondarily added to pelmatozoan debris (MH 170, pl. 14, fig. 5, center of right side). Pellets (MH 475a, pl. 15, fig. 4, upper part) may be very hazy and indistinct in completely aphanitic rocks such as those of the Ellenburger Group, and when replaced by dolomite, the ghosts of the

**Table 6. Frequency of occurrence of various properties of intraclasts in thin sections of Moore Hollow Group rocks, Central Texas.**

| | Percent |
|---|---|
| Intraclasts—aphanitic | 89 |
| microgranular | 20 |
| very fine grained | 8 |
| fine grained | 4 |
| Intraclasts probably derived from fossil fillings | 30 |
| Intraclasts replaced by dolomite | 37 |
| Intraclasts containing: fossil debris | 34 |
| ooids | 7 |
| pellets | 20 |
| intraclasts | 4 |
| silt | 48 |
| sand | 8 |
| glauconite | 33 |
| mica | 8 |
| hematite and limonite | 4 |

Table 7. Frequency of occurrence of pellets in various matrices of thin sections of Moore Hollow Group rocks, Central Texas.

| | Percent |
|---|---|
| Pellets in aphanitic matrix | 60 |
| Pellets in microgranular matrix | 61 |
| Pellets in very fine-grained matrix | 8 |
| Pellets in fine-grained matrix | 6 |
| Pellets in secondary calcite about pelmatozoan debris | 16 |

pellets are even less distinct (MH 475a, pl. 15, fig. 4, lower part). Very indistinct pelletlike objects are abundant in the girvanella (MH 170, pl. 14, fig. 5), and the origin of these is not easy to explain unless the so-called girvanella is actually an intraclast. Many other occurrences of pellets are noted in the thin section descriptions (Part II on open file at the Bureau of Economic Geology).

Table 7 shows the percentage of thin sections of calcitic Moore Hollow rocks containing pellets in different types of matrices.

## Dolomite

Dolomite is a minor constituent in many of the Moore Hollow Group rocks of Central Texas and in some areas constitutes entire units. To the east the San Saba Member is entirely dolomite, in the extreme northwest much of a thick, stromatolitic reef in the San Saba is dolomite, and in the subsurface to the southeast dolomite is even more widespread, constituting all but the lower 40 feet of the Wilberns Formation.

Where the rock is dominantly dolomite, the grain size ranges from near the upper limit of microgranular (MH 312, pl. 15, fig. 2), about 0.05 mm, to coarse grained (MH 340, pl. 15, fig. 3) and within this range, medium-grained dolomite (CC -15, pl. 10, fig. 1) is not well represented. Much of the finer grained dolomite is pinkish to purplish mottled from hematite specks (CC -15, pl. 10, fig. 1; MH 292, pl. 15, fig. 1; MH 312, pl. 15, fig. 2).

The finer grain sizes (MH 312, pl. 15, fig. 2; MH 292, pl. 15, fig. 1) in general do not preserve original rock textures, whereas coarser grain sizes (CC -15, pl. 10, fig. 1; MH 340, pl. 15, fig. 3) in general do. Illustrations of preserved textures include one of several pelmatozoan fragments and other fossil debris in fine- to very coarse-grained dolomite (KW 144a, pl. 12, fig. 1), one of a pelmatozoan fragment in medium-grained dolomite (CC -15, pl. 10, fig. 1), one of part of a very large, pelleted(?) intraclast in coarse-grained dolomite (MH 340, pl. 15, fig. 3), and one of ooids and veins in fine-grained dolomite (KW 5–10, pl. 11, fig. 1).

The latter example is believed to be entirely different from the others in that the dolomite is probably hypogene and formed in connection with sulfide mineralization that took place in the Cap Mountain Limestone near the base of the Klett-Walker section. The degree of cloudiness of the original limestone is preserved by the dolomite. Some of the ooids with distinct concentric structure are mostly clear; others are cloudy with clear veins; and the matrix, which was perhaps originally pelleted, is densely cloudy. The veins, as well as the rest of the rock, were probably originally calcite and during dolomitization dolomite formed across vein boundaries with many grains in part cloudy and in part clear. Missing parts of ooids along veins, not illustrated, indicate movement. Openings produced at this time were filled by calcite; then the whole was dolomitized, probably along with the introduction of sulfides. This sequence of events could have followed in rapid succession or have happened at widely separated times. The major period of structural deformation in the Llano region took place during mid-Pennsylvanian time and the fracturing in this rock probably happened at that time, thus substantiating the conclusion by Barnes (1956c) that the sulfide mineralization of the Cambrian rocks in Central Texas was mid-Pennsylvanian or later.

Selective dolomitization predominates in the slightly dolomitic rocks of the Moore Hollow Group with dolomite mostly replacing (in decreasing order) matrix, fossils, intraclasts, fossil fillings, and ooids. Table 2 shows that 72 percent of Moore Hollow calcitic rocks are dolomitic, and that the dolomite is dominantly very fine grained, with fine grained a little over half as abundant, followed in decreasing order by microgranular, medium, and coarse grained. Stratigraphically, dolomite is most abundant in the Cap Mountain and San Saba Members (84 and 79 percent respectively) and least abundant (33 percent) in the Lion Mountain. Regionally, dolomite in calcitic rocks is a little more abundant in the northern part (87 percent) than it is in the southern part (67 percent). From east to west there is no variation.

Some of the dolomitization, possibly much of it, took place before these objects reached their final resting place. Truncated rhombs at the margin of ooids (SS 302, pl. 16, fig. 3) suggest that such ooids may have been dolomitized, then reduced in size by abrasion before incorporation in the sediment. In the same illustration a few rhombs project beyond the borders of ooids, suggesting that these formed, or at least were secondarily enlarged, after the ooids were deposited. A completely dolomitized ooid (KW 149a, pl. 12, fig. 3) has a sutured boundary which suggests that it was dolomite and came to rest in an environment in which dolomite dissolved. Truncated rhombs in a dolomite intraclast (TC 1,145–1,150, pl. 17, fig. 3) appear to be sutured, indicating that some intraclasts likewise were dolomitized before arriving in their present environment.

Equidimensional, serrate objects of dolomite (TC 883–889, pl. 16, fig. 4) for the most part are completely surrounded by envelopes of clear dolomite; the time of formation of this clear dolomite is uncertain. A few of the projecting points composed of both types of dolomite, are missing as if they were removed by abrasion. The occurrences of such missing points are rather scarce, and in addition, as the outer clear dolomite did not form where marginal calcite is present within these objects, this evidence is inconclusive. A few ooids, intraclasts, and pelmatozoan fragments in this section are incipiently dolomitized. In each instance the rhombs are surrounded by envelopes of clear dolomite, whereas in the completely dolomitized examples the outer clear dolomite is confined to the peripheries of the objects only. The uniformity in thickness of these bands—whether surrounding large dolomite aggregates or individual rhombs inside ooids, intraclasts, and pelmatozoan fragments—indicates that the clear bands formed under uniform conditions. Such conditions probably are more apt to prevail in a sediment than under conditions of agitation on the sea bottom. If the sediment were already well lithified when invaded by magnesium-bearing solutions, then the rate of progress should have been about the same in the matrix as in the objects, thus accounting for the uniformity in thickness of the outer clear dolomite envelopes. However, this does not explain the absence of such dolomite between partially replaced pelmatozoan fragments and other objects and its absence at places on the periphery of the serrate objects.

A somewhat similar occurrence, where pelmatozoan fragments are replaced by dolomite (KW 55, pl. 11, fig. 2), appears to confirm the latter conclusion. The sequence of events in this case, in part derived by analogy with other observations, appears to be as follows:

1. Pelmatozoan fragments were secondarily enlarged by the addition of optically continuous calcite. A few tiny dolomite rhombs were included. (Calcite enlargement of pelmatozoan fragments is present in 41 percent of Moore Hollow Group thin sections.)

2. Each calcite unit was replaced by a dolomite unit; the tiny dolomite rhombs already present became inclusions in the newer dolomite.

3. The dolomite was superficially weathered and limonite stained. (Similar stained dolomite from weathering is found in 41 percent of Moore Hollow Group thin sections).

4. The dolomitized pelmatozoan debris was then transported with some loss of material by abrasion. (This change is better shown elsewhere in the slide than in the illustration (KW 55, pl. 11, fig. 2).)

5. After the objects came to rest, granular, clear, calcite cement filled the interstices.

6. Optically continuous dolomite was then added to that already present, enveloping the limonitic stain and replacing granular calcite matrix. Evidence of this replacement is the presence of a few undigested calcite inclusions, whereas such calcite inclusions are virtually absent in the earlier dolomite on the other side of the limonitic stain.

Other illustrations in which physical evidence for the time of dolomitization cannot be demonstrated include two of ooids and intraclasts (KW 68, pl. 11, fig. 3; KW 70, pl. 11, fig. 4), one of intraclasts (LL 367, pl. 13, fig. 1) and two of fossils and fossil fillings (TC 1,305–1,310, pl. 18, fig. 1; TC 1,335–1,341, pl. 18, fig. 2). The absence or near absence of dolomite in the matrix in these examples strongly suggests that dolomitization of these objects took place elsewhere.

Dolomite replacing matrix and barely nicking a gastropod (TC 1,015–1,020, pl. 17, fig. 1) was clearly formed within the sediment after it was deposited. Laterally grading dolomite, common in the San Saba Member in Blanco County, formed after the sediment accumulated to at least the full thickness of the member. Such gradation is well illustrated (MH 475a, b, pl. 15, figs. 4, 5) in the overlying unit, the Threadgill Member of the Tanyard Formation, in the Moore Hollow section. A thin section across the invasion front (MH 475b, pl. 15, fig. 5) shows the irregular character of the front and a large amount of undigested calcite in a 1 millimeter-wide band next to the front (30 mm in photograph).

Elsewhere in this thin section most calcite veins are encompassed by dolomite and in a few places may be replaced in part by dolomite, indicating, if true, that the veins were present when the dolomite formed. The veins are older than the stylolites against which they terminate, and in a hand sample the stylolites appear to be older than the dolomite along them. If the veining is related to the mid-Pennsylvanian period of structural deformation, then the dolomitization would be of about this age or younger. In another thin section (MH 340, pl. 15, fig. 3) from only a few feet away, dolomite grains are offset along fractures, showing that dolomitization took place before fracturing. More thin sections in selected areas are needed of these limestone-dolomite lateral transitions before definite conclusions can be reached.

Dolomite in some cases appears to replace glauconite (KW 144a, pl. 12, fig. 1) and in others appears to disrupt it, forcing it apart (KW 144b, pl. 12, fig. 2). The final result of the latter action is interstitial glauconite (CC-15, pl. 10, fig. 1).

After dolomitization, conditions favorable to calcitization can recur with deposition of calcite in pores (CC-15, pl. 10, fig. 1) or replacement of dolomite by calcite (LL 343b, pl. 12, fig. 6). The latter is definitely related to the present weathering cycle and the former may be. During the weathering of dolomite, limonitic stain forms and, when replacement occurs, one crystal of calcite may replace several dolomite rhombs and the intervening matrix, or a mosaic of calcite may form in one rhomb, or calcite crystals may cross rhomb boundaries. Some dolomite has weathered to calcite and admixed limonite in more than half of the 72 percent of Moore Hollow Group thin sections containing dolomite. Such alteration is slightly more prevalent in Riley Formation rocks than in Wilberns Formation rocks and much more prevalent in Moore Hollow Group rocks than in rocks of the Threadgill Member of the Ellenburger Group. By members, the greatest replacement is in the Cap Mountain Limestone (74 percent) and least in the Lion Mountain Sandstone (24 percent). Regionally such replacement is more prevalent to the north, and the variation found seems to be related to the depth of weathering—the steeper and fresher the section the less calcite alteration.

## Glauconite

Glauconite is present in 76 percent of the thin sections of Moore Hollow rocks (table 2), being somewhat more abundant in Riley Formation rocks than in Wilberns Formation rocks. All thin sections of Lion Mountain Sandstone rocks contain glauconite, and the least in any unit is 53 percent in the San Saba Member. Regionally, glauconite is most abundant to the south and least abundant to the northwest.

Fragmental glauconite (found in 88 percent of thin sections in which glauconite occurs) is twice as common as rounded, ellipsoidal, and lobate grains combined. These latter are somewhat more common in the Riley than in the Wilberns; the most (67 percent) are in the Lion Mountain and Morgan Creek Members, and the least (23 percent) are in the Point Peak followed closely by the San Saba (30 percent). Smooth, rounded, pellet-like forms and fragments of such forms are illustrated (JRL 145–150a, pl. 10, fig. 4; JRL 185–190, pl. 10, fig. 6). Curved forms slightly restricted in the middle are scarce (KW 68, pl. 11, fig. 3; LL 580, pl. 13, fig. 5), and a form seldom seen is a roughly concentric, discontinuous, interlayering of aphanitic limestone and glauconite (TC 1,175–1,180, pl. 17, fig. 4). The mode of formation of this type of grain is not apparent to the writer. Grains of glauconite commonly found in cavities of fossils (SS 68a, pl. 15, fig. 6) are usually associated with fossil debris and may have been washed into the cavities by currents.

Most of the glauconite contains calcite, in part peripheral (LL 580, pl. 13, fig. 5; TC 990–995, pl. 16, fig. 6), in part centrally located (TC 990–995, pl. 16, fig. 6) and in part uniformly distributed. In the thin section descriptions (Part II, on open file at the Bureau of Economic Geology) where calcite is described as admixed with glauconite, the two were not mixed mechanically but constitute a mixture with glauconite much the more abundant. Glauconite formed by the replacement of fecal pellets might very well contain admixed calcite. Peripheral calcite such as that shown in TC 990–995, pl. 16, fig. 6, appears to be continuous with the matrix, indicating that all such calcite may actually invade the glauconite either by replacement or perhaps by following cracks or openings made by organisms. That glauconite can be replaced by calcite is definitely shown in some thin sections.

Glauconite generally exhibits aggregate polarization between crossed nicols; however, there are many examples of "ordered" films around ordinary glauconite grains (TC 990–995, pl. 16, fig. 6), around elongate grains (LL 580, pl. 13, fig. 5), around grains formed from mica (TC 990–995, pl. 16, fig. 6), around partially glauconitized pelmatozoan debris and phosphatic brachiopod fragments (TC 883–889, pl. 16, fig. 4), and replacing shell material in a gastropod (TC 1,015–1,020, pl. 17, fig. 1). That the latter is a replacement of some layer within the shell seems certain, as shown by the manner in which the whorls come together and by the presence of mosaic calcite in gaps where the glauconite is missing entirely, similar to that replacing gastropod shells in other thin sections. That the "ordered" green material is glauconite is not proven; however, in every occurrence seen it is closely associated with normal-appearing glauconite except where replacing the gastropod (TC 1,015–1,020, pl. 17, fig. 1) and even here grains of normal glauconite are in contact with "ordered" glauconite in places. The "ordered" glauconite is fairly uniform in color with slight pleochroism. X is yellowish green and Z clear green. It has distinct cleavage perpendicular to the length of the film (TC 883–889, pl. 16, fig. 4) and extinction parallel or nearly parallel to the cleavage. Films are mostly curved and extinction follows around the film as the stage of the microscope is rotated, and for this reason it is not certain whether the extinction is exactly parallel to the cleavage or not. A few "ordered" films are free in the matrix and others are barely attached to pelmatozoan fragments, showing that the glauconite films formed before the fragments came to rest.

Similar glauconite may have been present in a sample of oolitic limestone collected by P. E. Cloud, Jr., from near the top of the Point Peak Member in the Everett Ranch section. The glauconite in this sample was examined by Jewell J. Glass and F. A. Hildebrand of the U.S. Geological Survey (unpublished laboratory note of July 17, 1952), who report that it is bright green in thin plates, micaceous, optically negative, 2V = 10°, refractive indices 1.610 and 1.630, and that X-ray analysis confirms its identity.

Several examples of glauconite forming from biotite or more commonly from hydrobiotite and alteration products of hydrobiotite are mentioned in the thin section descriptions (Part II on open file at the Bureau of Economic Geology). An exceptionally clear example is illustrated in TC 990–995, pl. 16, fig. 6. The curved grain is much altered hydrobiotite expanded and curved, the curvature perhaps being increased by the formation of more glauconite between the leaves on the convex side than on the concave side. The uniformly gray peripheral material is normal glauconite except for a very thin film of ordered glauconite on the right side.

A few notations in the thin section descriptions (Part II on open file at the Bureau of Economic Geology) of glauconite replacing feldspar are not certainly documented. Some of these examples consist of green material along feldspar cleavages, and others are based on the rhombic shape of glauconite grains similar to those of associated authigenic feldspar rhombs. It is possible that the latter examples cited are grains broken in such a manner as to show a rhombic cross-section in thin section.

Glauconite commonly invades fossils, mostly filling the interspaces of pelmatozoan debris (KW 144a, pl. 12, fig. 1; KW 149b, pl. 12, fig. 4; LL 573, pl. 13, fig. 4) and less commonly replacing brachiopod shell material (TC 929–935, pl. 16, fig. 5). It coats intraclastlike objects which may be fillings of fossil cavities. In such objects the glauconite may have either coated the inside of the shell, which was later removed, or replaced the shell (TC 1,145–1,150, pl. 17, fig. 3). In this example the tangential to concentric fibrous structure with areas of vague synchronous extinction indicates that a brachiopod shell has been replaced.

Glauconite is commonly replaced and disrupted by dolomite (KW 144a, b, pl. 12, figs. 1, 2; CC -15, pl. 10, fig. 1). In KW 144a, pl. 12, fig. 1, the relation of the dolomite to the fragmental glauconite grain strongly suggests that replacement is more important than disruption in this particular grain. In the same slide (KW 144b, pl. 12, fig. 2) dolomite appears to have crystallized within a glauconite grain, shoving it apart. The final stage of disruption of a glauconite grain is shown in CC -15, pl. 10, fig. 1, where the glauconite is relegated to the interstices between dolomite grains.

The replacement of glauconite by calcite is indicated by the admixture of calcite and glauconite discussed above. However, evidence that is much more convincing for such replacement is furnished by a photograph of material from the Squaw Creek section (pl. 18, fig. 4) received in a letter of March 27, 1959, from Dr. T. R. Walker, Department of Geology, University of Colorado. In this letter and subsequent correspondence Dr. Walker pointed out that the sparry calcite replacing the glauconite has optical continuity with the sparry calcite filling the space between glauconite grains. The delicate limonite membranes could not have remained in position if the glauconite had been removed prior to calcite deposition. Similar material from 30 feet in the Squaw Creek section is described in material on open file at the Bureau of Economic Geology.

Hematite nodules, so common in the soil derived from the Lion Mountain, are from concretionary masses formed along bedding planes and joints during the present weathering cycle. Alteration starts along an opening, bedding plane, or joint, and progresses outward. The iron presumably comes from the weathering of glauconite, and since the greensand contains only about one-quarter as much iron as the concretion, the iron must move laterally to the concretion. Such movement appears to take place in at least two different ways.

One manner in which these concretions form is illustrated in JR 19.5a, b, pl. 10, figs. 2, 3. Alteration is well advanced in JR 19.5a, pl. 10, fig. 2, with the glauconite pellets much reduced in size, and the remaining glauconite having ragged, embayed outlines from replacement by hematite. Fossil fragments are extensively replaced, and quartz with ragged outlines may also be partly replaced. The secondary quartz, filling voids (JR 19.5b, pl. 10, fig. 3), might be partly from this source and partly from altering glauconite.

Hand lens inspection of similar hematite concretions from the Squaw Creek section reveals that the glauconite, instead of being replaced, actually disappears, leaving voids in a zone around the concretion and that in the concretion the voids are filled by hematite.

Limonitic stain and replacement of glauconite by limonite is a common weathering phenomenon in the thin sections studied. Pelmatozoan debris invaded by glauconite, then weathered to limonite, is present in several thin sections (KW 149b, pl. 12, fig. 4; TC 883–889, pl. 16, fig. 4; TC 929–935, pl. 16, fig. 5; and perhaps KW 144a, pl. 12, fig. 1).

The glauconite in the Moore Hollow Group appears quite normal except possibly for the ordered glauconite films. Whether or not such films are described from other areas was not ascertained as only a limited number of references were consulted, including review articles such as those by Cloud (1955) and Burst (1958), textbooks on mineralogy and sedimentary petrography, and articles by Galliher (1935a, b, 1939), Takahashi (1939), and a few others. Crystals of glauconite and grains with radial structure mentioned in some of these references may be of similar material.

## Mica

Mica is abundant in the Point Peak and Morgan Creek Limestone Members, is much less abundant in the Cap Mountain Limestone Member, and is scarce in the rest of the Moore Hollow rocks. Much of the mica is extremely weathered, almost opaque, and deformed between other mineral grains. Another large, less altered, greenish portion with high birefringence is termed hydrobiotite and is an alteration product of biotite. Some chlorite that was not detected may be present. Fresh biotite is scarce, and colorless mica is even more scarce and usually appears as if it might have originated by bleaching of hydrobiotite. Some of the colorless mica may be true flakes of muscovite. Mica altered to glauconite is discussed on page 60.

Before alteration the mica of the Moore Hollow Group rocks was predominantly biotite, indicating a predominantly igneous source for this mineral. An impression, not based on statistical analysis, is that the mica in the Cap Mountain Limestone shows more alteration than that elsewhere in the Moore Hollow Group and that the mica in the Morgan Creek Limestone shows the least alteration. Presumably much of the weathering took place before the mica was incorporated in the sediment, and if this assumption is true a deeper mantle of weathering products must have existed during Cap Mountain time than later. Pointing up this difference even more strongly is the fact that the source of terrigenous sediments incorporated in the Cap Mountain was nearer than the source of those incorporated in the Morgan Creek and Point Peak Members. For the abundance of mica found in the younger members to survive through this greater distance of travel indicates that it must have been much fresher at the start.

## Hematite and Limonite

The red and brown iron oxide minerals are lumped without regard to their actual composition under the names hematite and limonite, using color to separate the two broad, ill-defined groups. Most of the iron oxide noted in the thin section descriptions (Part II on file at the Bureau of Economic Geology) is the product of weathering related to the present weathering cycle, but in one thin section (KW 55, pl. 11, fig. 2) it appears that the limonite formed before the grains were incorporated into the sediment. In some cases limonite has selectively replaced organic structures (LL 367, pl. 13, fig. 1; LL 464, pl. 13, fig. 3) and in others it replaces minerals such as glauconite which previously had invaded fossils (KW 149b, pl. 12, fig. 4; TC 883–889, pl. 16, fig. 4; TC 929–935, pl. 16, fig. 5). The formation of hematite concretions (JR 19.5a, pl. 10, fig. 2; JR 19.5b, pl. 10, fig. 3) in the Lion Mountain Sandstone Member is taking place during the present weathering cycle, and the limonite that forms when dolomite is replaced by calcite is discussed on page 58.

The hematite in red zones which persist into the subsurface is probably syngenetic. One of these zones is at the base of the Morgan Creek Limestone, and another transgresses laterally from the uppermost Hickory Sandstone in the northwestern part of the area into the Cap Mountain Limestone to the southeast. The hematitic Hickory Sandstone has been discussed in detail in a paper by Barnes and Schofield (1964); therefore, only a few of the more obvious relationships will be mentioned here. The hematite occurs as concentrically banded ooids, some with quartz, feldspar, or fossil nucleii; as thin coatings around sand grains and fossil fragments; as replacement of fossil debris; and as a matrix for sand grains and fossil fragments. The matrix hematite mostly formed after the sediment was deposited, and most of the ooids and coats on sand grains probably formed before the ooids and grains were incorporated into the sediment.

## Chert

Chert is common in a portion of the dolomitic facies of the San Saba Member, but otherwise is scarce except locally in the upper part of the Point Peak Member, where it commonly replaces brachiopods, pelmatozoan debris, and other objects. In one thin section (KW 291) thin chert films formed around pelmatozoan debris replaced by dolomite, and in another (KW 287) chert is present as wisps, stringers, and spherical bodies (see Part II on open file at the Bureau of Economic Geology).

In the calcitic facies of the San Saba Member chert rarely replaces pelmatozoan debris and brachiopod shells and otherwise is absent. Chert is common in a portion of the dolomitic facies of the San Saba Member, but of the few thin sections made of this part of the section, tiny patches of chert were present in only two.

### Quartz and Feldspar

Quartz and feldspar are the dominant minerals of the sand and silt fraction and are discussed under these fractions. Walker (1952) determined the relative percentages of feldspar and quartz in the fine sand and silt fraction for a few samples of Moore Hollow rocks, and these data are given in table 12.

Table 12 shows that feldspar is essentially absent in the fine sand and silt fraction of the Welge Sandstone Member and that it composes more than two-thirds of this fraction in the Point Peak Member. About a quarter of the fraction in the San Saba and Cap Mountain Limestone Members and about 17 percent in the Lion Mountain and Hickory Sandstone Members is feldspar.

Since these data are limited they probably do not give a true picture of the feldspar-quartz relationship for Moore Hollow rocks as a whole. From the thin-section examination it appears that the coarser the grain size, the smaller the amount of feldspar, and also that the feldspar-quartz ratio may be even higher for the San Saba Member as a whole than it is for the Point Peak Member. In the thin-section examination emphasis is on carbonate rocks, and the Hickory, Lion Mountain, and Welge Sandstone Members are not well represented,

### Sand

Quartz sand is the dominant constituent of the Welge and Hickory Sandstone Members and is also probably the dominant constituent of the Lion Mountain Sandstone. All other units contain sand; however, the very fine sand in the Point Peak Member verges on silt and is included with the silt because of its composition.

Eight percent of thin sections of the San Saba Member, all in the western part of the region, contain sand ranging in size from very fine to medium. Sand is in 51 percent of Morgan Creek Limestone thin sections (KW 144a, pl. 12, fig. 1; KW 149a, pl. 12, fig. 3; KW 149b, pl. 12, fig. 4) and the ratio of sandy to nonsandy thin sections is twice as great to the west; the coarsest and best-rounded sand, peculiarly, is to the southeast away from the source area. Sand is in 64 percent of Cap Mountain Limestone thin sections (JRL 185–190, pl. 10, fig. 6) with the ratio of sandy to nonsandy ones greatest to the east; the coarsest and best-rounded sand again is in the opposite direction. The sand in the Morgan Creek averages slightly coarser than that in the Cap Mountain, and that in the Lion Mountain is coarser than either.

In the three thin sections of Welge Sandstone examined, the sand is fine to coarse, mostly well rounded, and in part secondarily enlarged. Phosphatic brachiopod fragments are in two thin sections; glauconite in two, in one of which the grains are rounded and in the other fragmental; and fine-grained dolomite matrix in two, now weathered to calcite and admixed limonite.

Four thin sections of Hickory Sandstone were examined from the Little Llano River section; the sand is very poorly sorted, very fine to very coarse, angular to rounded, and composed mostly of quartz. Feldspar exists in three thin sections, rounded glauconite in one, very fine-grained dolomite matrix altered to calcite and admixed limonite in three, and some fine- to very fine-grained calcite matrix in two. Phosphatic brachiopod fragments are in three thin sections and pelmatozoan debris in one. Rock fragments (LL 343a, b, pl. 12, figs. 5, 6) may be present anywhere in the Hickory Sandstone, but only in a few places are they common. These are derived from local buried hills, whereas most of the sand in the Hickory Sandstone of the Llano region is derived from outside the region.

The only other thin sections of Hickory Sandstone examined are 12 from the highway material quarry on the H. Sell property, near Camp Air in the northwestern part of the region. The sand is mostly very fine to coarse; the very fine fraction and some of the fine is angular and the rest is exceptionally well rounded. Feldspar is very scarce, opaque minerals are common, and half the samples contain sandstone intraclasts, most with a limonitic matrix. Phosphatic brachiopod debris is abundant in all thin sections, pelmatozoan debris in 10, and trilobite debris in 8. Calcite cement is present in 11 thin sections, in part radial to fossils, in part as secondary enlargement of pelmatozoan debris, and it ranges from very fine to coarse grained. Limonite or hematite or both coat sand in every thin section, form ooids in 11, form matrix in 8, and replace pelmatozoan debris in 4. In one thin section dolomite replaces pelmatozoan and trilobite debris and in turn is replaced by calcite and admixed limonite.

The Hickory Sandstone has not been systematically thin sectioned but has been examined using a binocular microscope. The sand grains are usually rounded and in the upper part are extremely well rounded. Angular grains are more abundant toward the base and locally the sand is all angular, but in most places rounded grains are also present.

Most of the quartz sand grains throughout the Moore Hollow Group have straight or slightly undulatory extinction and bubble trains are common, indicating that much of the sand is from a granitic source. Grains with strong undulatory extinction and a few composite, sutured, lineated mosaics of quartz are from a metamorphic source and form only a minor fraction of the sand. Such grains are slightly more abundant downward.

Feldspar is common to very abundant in the very fine-grained sand fraction and is mostly detrital, in part with authigenic overgrowth. Completely authigenic rhombs are scarce. Most of the detrital feldspar in the very fine-grained fraction appears to be microcline and all the coarser grained feldspar appears to be microcline. Locally around granite knobs microcline is abundant as granules and small pebble-sized fragments.

In a few thin sections (LL 343a, b, pl. 12, figs. 5, 6; TC 883–889, pl. 16, fig. 4), apparently through some freak of preparation, feldspar and quartz can be distinguished at a glance in ordinary light. Grinding dust adheres to the quartz and not to the feldspar, as can be seen by comparing LL 343a, pl. 12, fig. 5, and LL 343b, pl. 12, fig. 6. This behavior is not consistent in the present set of thin sections, but in a set of metamorphic, igneous, and sedimentary rock thin sections prepared a number of years ago by another firm, all quartz was coated by dust and all feldspar, no matter what the composition, was free of dust.

### Silt

Data on silt in Moore Hollow calcitic rocks (table 2) show that it is present in about the same proportion of thin sections from the Wilberns and Riley Formations but is differently distributed among the members. It is most abundant in the Morgan Creek Limestone and Point Peak Members and least abundant in the Lion Mountain Sandstone and San Saba Members.

Quartz and feldspar (JRL 185–190, pl. 10, fig. 6) are the chief silt minerals, and silt constitutes much of the rock in the Point Peak Member, as well as in a zone in the Cap Mountain Limestone, and is plentiful elsewhere. The proportion of feldspar and quartz varies widely, with feldspar by far the more abundant in the San Saba Member and proportionately less downward, being exceed by quartz only in the Cap Mountain Limestone. Feldspar consists of detrital grains in part with authigenic overgrowth and in part as clear authigenic rhombs. Authigenic feldspar is dominant in the San Saba Member, about equal to detrital feldspar in the Point Peak Member, and downward becomes progressively less abundant. The detrital feldspar ranges from fresh to almost opaque from weathering, and the latter is most common in the Cap Mountain Limestone.

The siltstones of the Moore Hollow Group are almost entirely calcareous from calcite cement which may be poikilitic (LL 425, pl. 13, fig. 2) or very finely granular to somewhat coarser. Rarely is the siltstone cemented by silica (LL 425, pl. 13, fig. 2). Silt is widely scattered throughout the calcitic rocks of the Moore Hollow Group. In TC 929-935, pl. 16, fig. 5, it is mixed with shell debris, in JRL 185–190, pl. 10, fig. 6, it is mixed with sand, and it may occur in intraclasts, fossil fillings, ooids, stromatolites (TC 1,260–1,265, pl. 17, fig. 6), and in one case in a girvanella (MH 170, pl. 14, fig. 5). In the latter two examples the silt is authigenic feldspar which probably grew where it is found.

Silt was not seen in the 3 thin sections of Welge Sandstone or in the 12 thin sections of Hickory Sandstone from the highway material quarry on the H. Sell property. It is present in the four thin sections of the Hickory Sandstone from the Little Llano River section, where it is mostly detrital feldspar and quartz with a minor amount of detrital feldspar with authigenic overgrowth.

### Clay

Clay is one of the lesser constituents in Moore Hollow Group rocks and is most abundant in the Point Peak, Hickory Sandstone, and Lion Mountain Sandstone Members. In the Point Peak Member it forms a few thin beds and films, and much of the siltstone in this member is argillaceous. In the sandstone units clay is usually interstitial and less commonly occurs as thin beds and wisps.

A small amount of clay is present in all insoluble residues from the calcitic rocks; otherwise, clay is not often seen except along stylolites where it in part, at least, has accumulated as a residue from solution of carbonate. The limonitic material associated with the weathering of dolomite appears to be argillaceous, and clay is probably an important constituent of the very dense, almost opaque intraclasts and fossil fillings.

The small amount of clay in Moore Hollow rocks seems to be out of proportion to the amount of terrigenous sand and silt. One explanation is that the clay has been winnowed out and deposited elsewhere. However, in view of the large amount of authigenic feldspar in Moore Hollow rocks it seems likely that clay was originally present but has been converted to authigenic feldspar in the manner suggested by Berg (1952) for a unit in the Franconian of the Upper Mississippi River valley.

## HEAVY-MINERAL EXAMINATION[3]

### Detrital and Authigenic Minerals

Each 5-foot interval of most of the various stratigraphic sections of Moore Hollow rocks was chip sampled;

[3]Abridged from Walker (1952) with additions by Barnes.

however, for the heavy-mineral study, only about 1 out of every 4 to 10 samples of the sandy and silty units in the following sections was examined for heavy minerals: Calf Creek, Bluff Creek, upstream James River, Little Llano River, Morgan Creek, Pontotoc, Squaw Creek, Threadgill Creek, and White Creek.

Preparation of samples for heavy-mineral examination included crushing in a jaw crusher, splitting to obtain a sample of about 90 grams, treating in a 3:1 solution of hot hydrochloric acid until effervescence stopped, treating in 1:1 hydrochloric acid with stannous chloride added to remove iron oxide and phosphatic shell fragments, disaggregating clumps using a rubber mortar and pestle, and washing and decanting of clay-sized fraction. Approximately 10 grams of the minus–70–mesh fraction was centrifuged in acetylene tetrabromethane, specific gravity not less than 2.90. The heavy fraction from this operation was split with an Otto Microsplit, a portion mounted in Canada balsam, and the remainder kept for immersion work and reference.

Heavy-mineral frequency counts including all minerals were based on a count of 300 grains. Another heavy-mineral frequency count, excluding titanium minerals and black opaque minerals, was based on a count of at least 100 grains. The results of these counts for each stratigraphic section are given in Part II, on open file at the Bureau of Economic Geology. The results are tabulated by stratigraphic units in tables 8 and 9 and are shown graphically in plate 6.

Minerals in Moore Hollow rocks with a specific gravity greater than 2.90 include anatase, apatite, barite, black opaque minerals (ilmenite, hematite, and magnetite), epidote, garnet, altered ilmenite, leucoxene, pyrite, rutile, tourmaline, and zircon.

#### Anatase

Basal tabular crystals of anatase common in many samples are probably mostly authigenic. Most crystals are yellow and a few are blue. Euhedral crystals of anatase commonly project from grains of leucoxene, and the two minerals form a gradational series which causes some uncertainty as to category in which to record intermediate grains. Anatase included in quartz grains, described later, is definitely not authigenic.

#### Apatite

Apatite is common but was destroyed, for the most part, during hydrochloric acid treatment; consequently, that which remained is not included in grain counts. In check samples, where the carbonate was removed by use of acetic acid, apatite is present, ranges from prismatic to irregular grains, almost always contains minute inclusions, and is colorless.

#### Barite

Colorless cleavage fragments of barite found in a few samples may be authigenic.

#### Black opaque minerals

Polished sections of eight samples were made and examined by Dr. E. N. Cameron, who reports that the black opaque grains are mostly ilmenite, hematite is common in the lower part of the Riley Formation, and magnetite is very scarce. The hematite grains are subangular to well rounded, detrital, and a few grains show exsolution intergrowths of ilmenite. With this exception ilmenite is homogeneous and without exsolution patterns.

#### Epidote

Subangular grains of epidote, present in very few samples, are weakly pleochroic from colorless to yellow and very scarce.

#### Garnet

Garnet, uniformly distributed, seldom exceeds 2 or 3 percent of the heavy fraction and usually contains small inclusions. It is in subangular, mostly etched grains and two varieties are distinguishable. The most common type is colorless and included with it are grains without etching; this may be a variety of spinel or other isotropic mineral of high refractive index. The other variety is pink to reddish brown.

#### Ilmenite, altered

Only those grains of ilmenite showing some alteration to leucoxene are distinguishable; the remainder is included with the black opaque minerals. Ilmenite and leucoxene form a gradational series, which causes some uncertainty as to the category in which to record intermediate grains. Ilmenite of this type is common and in many samples forms more than 50 percent of the heavy fraction.

#### Leucoxene

Leucoxene occurs as earthy, dull white to light brown, opaque grains. It is present in all samples except those in the vicinity of the Riley-Wilberns boundary. Leucoxene grades to anatase and ilmenite, a fact which causes some uncertainty as to category in which to record intermediate grains. If any ilmenite was detected, the grain was classified as ilmenite.

Table 8. Heavy-mineral frequency counts* for Moore Hollow Group rocks, Central Texas.

| Section and Sample | Zircon Total | Zircon Clear | Zircon Zoned | Zircon Dusty | Zircon Malacon | Tourmaline Total | Tourmaline Brown | Tourmaline Green | Tourmaline Blue | Tourmaline Black | Garnet Total | Garnet Colorless | Garnet Pink | Rutile Total | Rutile Amber | Rutile Foxy red | Anatase | Altered ilmenite | Leucoxene | Black opaques | Epidote | Barite | Pyrite | Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAN SABA MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| CC 5–10 | 46 | 33 | 2 | 11 | 0 | 5 | 2 | 3 | x** | 0 | 3 | 2 | x | 4 | 4 | x | 16 | 3 | 22 | x | 0 | 0 | 0 | 0 |
| CC 40–45 | 73 | 68 | 0 | 5 | 0 | 7 | 4 | 3 | 0 | 0 | 3 | 2 | x | 1 | 1 | x | 3 | x | 10 | 2 | 0 | 0 | 0 | 0 |
| CC 85–90 | 25 | 23 | x | 2 | 0 | 3 | 2 | 2 | 0 | 0 | 5 | 2 | 2 | 3 | 2 | x | 9 | 25 | 27 | 4 | 0 | 0 | 0 | 0 |
| BC 85–90 | 64 | 43 | 7 | 13 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 3 | 3 | 0 | 4 | 8 | 17 | 0 | 0 | 0 | 0 | 0 |
| BC 120–125 | 25 | 20 | 1 | 5 | 0 | 5 | 1 | 5 | 0 | 0 | 2 | 2 | 0 | 3 | 3 | 0 | 9 | 28 | 28 | 0 | 0 | 0 | 0 | 0 |
| BC 165–170 | 21 | 19 | x | 2 | 0 | x | 0 | x | 0 | 0 | 1 | 1 | x | 1 | 1 | x | 3 | 15 | 52 | 6 | 0 | 0 | 0 | 0 |
| JR 630–635 | 13 | 13 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | x | 6 | 6 | 0 | x | 0 | x | 0 | 7 | 71 | 1 | 0 | 0 | 0 | 0 |
| JR 590–595 | 33 | 30 | 0 | 3 | 0 | 1 | 1 | x | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 23 | 12 | 31 | 0 | 0 | 0 | 0 | 0 |
| JR 565–570 | 24 | 21 | x | 3 | 0 | 5 | 1 | 3 | 0 | 0 | 2 | 2 | 0 | 1 | 1 | 0 | 21 | 6 | 40 | 1 | 0 | 0 | x | 0 |
| JR 505–510 | 34 | 29 | 3 | 3 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 28 | 6 | 27 | x | 0 | 0 | 0 | 0 |
| JR 445–450 | 45 | 30 | 3 | 12 | 0 | 6 | 2 | 4 | 0 | 0 | 3 | 2 | 1 | 7 | 7 | 0 | 11 | 2 | 25 | 1 | 0 | 0 | 0 | 0 |
| JR 415–420 | 14 | 8 | 1 | 4 | 1 | 2 | 2 | x | 0 | 0 | 1 | 1 | x | 2 | 2 | 0 | 12 | 32 | 28 | 5 | 0 | 3 | 0 | 0 |
| POINT PEAK MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| JR 290–300 | 8 | 6 | 1 | 1 | 0 | 3 | 0 | 3 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | x | 8 | 19 | 45 | 14 | 0 | 0 | 0 | 0 |
| JR 250–260 | 3 | 2 | x | x | x | 2 | x | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 25 | 8 | 33 | 29 | 0 | 0 | 0 | 0 |
| JR 220–230 | 7 | 4 | 2 | 1 | 0 | 1 | 1 | x | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 14 | 12 | 44 | 21 | 0 | 0 | 0 | 0 |
| WC 1,000–1,005 | 5 | 3 | 0 | 1 | 0 | 4 | 2 | 2 | 0 | 0 | 2 | 2 | 0 | 4 | 4 | 0 | 3 | 46 | 11 | 26 | 0 | 0 | 0 | 0 |
| WC 980–985 | 20 | 14 | 1 | 3 | 3 | x | x | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 20 | 11 | 43 | 4 | 0 | 0 | 0 | 0 |
| WC 930–935 | 43 | 30 | 3 | 7 | 2 | 1 | x | 1 | 0 | 0 | 1 | x | 1 | 6 | 6 | 0 | 4 | 8 | 33 | 4 | 0 | 0 | 0 | 0 |
| WELGE SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| JR 65–70 | 7 | 5 | 0 | 2 | 0 | x | x | 0 | 0 | 0 | x | x | 0 | x | x | 0 | 3 | 73 | 5 | 4 | 0 | 0 | 7 | 0 |
| TC 870–875 | 5 | 3 | 1 | 1 | 0 | x | 0 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 56 | 2 | 3 | 0 | 0 | 0 | 0 |
| SC 100–105 | 11 | 10 | 0 | 1 | 0 | 1 | 0 | x | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 1 | 53 | 0 | 33 | 0 | 0 | 0 | 0 |
| SC 85–90 | 11 | 9 | x | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 31 | 1 | 55 | 0 | 0 | x | 0 |
| WC 820–825 | 8 | 8 | 0 | 0 | 0 | x | 0 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 74 | 0 | 0 | 0 | 0 |
| MC 595–600 | 12 | 10 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 1 | 43 | 0 | 0 | x | 0 |
| LL 605–610 | 27 | 19 | 2 | 6 | 0 | 1 | 0 | 1 | x | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 12 | 52 | 7 | 1 | 0 | 0 | 0 | 0 |
| P 695–700 | 9 | 6 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 40 | 1 | 47 | 0 | 0 | 0 | 0 |
| LION MOUNTAIN SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| JR 40–45 | 5 | 4 | 0 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | x | 79 | 0 | 0 | 0 | 0 |
| JR 5–10 | 5 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | x | 86 | 0 | 0 | 2 | 0 |
| TC 835–840 | 7 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 0 | 50 | 0 | 0 | 0 | 0 |
| TC 795–800 | 12 | 9 | x | 3 | 0 | x | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 32 | 1 | 53 | 0 | 0 | 0 | 0 |
| SC 60–65 | 4 | 3 | 0 | 1 | 0 | 1 | x | 0 | x | 0 | 0 | 0 | 0 | x | 0 | x | x | 24 | x | 71 | 0 | 0 | 0 | 0 |
| SC 20–25 | 3 | 2 | 0 | 1 | 0 | x | 0 | x | 0 | 0 | x | x | 0 | 0 | 0 | 0 | 3 | 12 | 3 | 78 | 0 | 0 | 0 | 0 |

* Percentages based on a count of 300 grains.
** X, one grain present.

(Table 8 continued.)

| Section and Sample | Zircon Total | Zircon Clear | Zircon Zoned | Zircon Dusty | Zircon Malacon | Tourmaline Total | Tourmaline Brown | Tourmaline Green | Tourmaline Blue | Tourmaline Black | Garnet Total | Garnet Colorless | Garnet Pink | Rutile Total | Rutile Amber | Rutile Foxy red | Anatase | Altered ilmenite | Leucoxene | Black opaques | Epidote | Barite | Pyrite | Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WC 800–805 | 2 | 1 | 0 | 1 | 0 | x | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | x | 76 | 0 | 0 | 0 | 0 |
| MC 558–563 | 6 | 5 | 0 | 1 | 0 | x | 0 | x | 0 | 0 | x | 0 | x | x | x | 0 | 0 | 12 | 0 | 74 | 0 | 0 | 6 | 0 |
| LL 585–590 | 6 | 3 | x | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 2 | 63 | 0 | 0 | 0 | 0 |
| LL 540–545 | 4 | 3 | x | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 4 | 43 | 3 | 45 | 0 | 0 | 0 | 0 |
| P 680–685 | 5 | 4 | x | 1 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | x | x | 0 | 0 | 45 | 1 | 49 | 0 | 0 | 0 | 0 |
| CAP MOUNTAIN LIMESTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 640–645 | 11 | 7 | 1 | 2 | 1 | 1 | 0 | x | 0 | x | 0 | 0 | 0 | x | x | 0 | 23 | 30 | 34 | 2 | 0 | 0 | 0 | 0 |
| TC 600–605 | 7 | 6 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 18 | 26 | 44 | 2 | 0 | 0 | 0 | 0 |
| TC 545–550 | 29 | 18 | 1 | 10 | 1 | 1 | x | x | 0 | 0 | x | x | 0 | 1 | 1 | 0 | 2 | 49 | 10 | 8 | 0 | 0 | 0 | 0 |
| TC 500–505 | 31 | 21 | 1 | 9 | 0 | 1 | x | x | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 46 | 4 | 15 | 0 | 0 | 0 | 0 |
| TC 445–450 | 16 | 11 | 0 | 5 | 0 | x | 0 | x | 0 | 0 | x | x | 0 | 0 | 0 | 0 | 2 | 49 | 9 | 23 | 0 | 0 | 0 | 0 |
| TC 375–380 | 23 | 15 | 1 | 7 | 0 | 1 | x | x | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 7 | 43 | 5 | 22 | 0 | 0 | 0 | 0 |
| WC 760–765 | 7 | 4 | 1 | 2 | 0 | x | 0 | 0 | x | 0 | x | x | 0 | x | x | 0 | 1 | 43 | 3 | 45 | 0 | 0 | 0 | 0 |
| WC 645–650 | 4 | 3 | 0 | 1 | 0 | 1 | x | x | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 75 | 10 | 8 | 0 | 0 | 0 | 0 |
| WC 620–625 | 13 | 10 | x | 3 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 1 | 1 | 0 | 16 | 3 | 67 | x | 0 | 0 | 0 | 0 |
| WC 595–600 | 3 | 3 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 8 | 33 | 50 | 2 | 0 | 0 | 0 | 0 |
| WC 570–575 | 15 | 11 | 1 | 3 | 0 | 1 | x | 1 | 0 | 0 | x | x | 0 | 2 | 2 | 0 | 3 | 35 | 37 | 4 | 0 | 0 | 0 | 0 |
| WC 520–525 | 42 | 27 | 4 | 11 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 1 | 47 | 6 | 2 | 0 | 0 | 0 | 0 |
| WC 490–495 | 24 | 15 | 1 | 6 | 2 | 1 | x | 1 | 0 | 0 | x | x | 0 | 1 | 1 | 0 | 5 | 43 | 23 | 3 | 0 | 0 | 0 | 0 |
| WC 465–470 | 15 | 10 | 0 | 4 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 3 | 47 | 10 | 21 | 0 | 0 | 0 | 0 |
| WC 435–440 | 47 | 31 | 1 | 12 | 3 | 1 | 1 | x | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 16 | 9 | 23 | 2 | 0 | 0 | 0 | 0 |
| WC 415–420 | 28 | 19 | 1 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 46 | 5 | 19 | 0 | 0 | 0 | 0 |
| WC 395–400 | 26 | 14 | 1 | 10 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 5 | 18 | 21 | 26 | 0 | 0 | 0 | 0 |
| WC 370–375 | 10 | 7 | 0 | 2 | x | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 4 | 33 | 18 | 32 | 0 | 0 | 0 | 0 |
| WC 345–350 | 22 | 14 | 1 | 6 | 1 | 2 | 1 | 1 | 0 | 0 | x | x | 0 | 2 | 2 | 0 | 0 | 33 | x | 41 | 0 | 0 | 0 | 0 |
| WC 320–325 | 10 | 6 | x | 3 | 1 | 2 | 1 | 1 | 0 | x | x | x | 0 | 1 | 1 | 0 | 2 | 44 | 11 | 29 | 0 | 0 | 0 | 0 |
| WC 295–300 | 75 | 49 | 4 | 18 | 4 | 4 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 6 | 5 | 1 | 2 | 7 | 8 | x | 0 | 0 | 0 | 0 |
| MC 515–520 | 10 | 5 | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | x | 13 | 1 | 76 | 0 | 0 | 0 | 0 |
| MC 440–445 | 7 | 5 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 10 | 14 | 58 | 9 | 0 | 0 | 0 | 0 |
| MC 395–400 | 13 | 9 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 12 | 43 | 13 | 19 | 0 | 0 | 0 | 0 |
| MC 350–355 | 20 | 15 | 1 | 4 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | x | 0 | 43 | 1 | 33 | 0 | 0 | 0 | 0 |
| LL 450–455 | 7 | 5 | x | 2 | x | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 61 | 12 | 9 | 0 | 0 | 0 | 0 |
| LL 395–400 | 19 | 10 | 3 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 14 | 54 | 8 | 3 | 0 | 0 | 0 | 0 |
| P 595–600 | 4 | 3 | x | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 4 | 47 | 18 | 26 | 0 | 0 | 0 | 0 |
| P 545–550 | 5 | 3 | 0 | 2 | 0 | x | x | 0 | 0 | 0 | 0 | 0 | 0 | x | x | 0 | 21 | 4 | 69 | 1 | 0 | 0 | 0 | 0 |
| P 495–500 | 15 | 11 | 1 | 4 | 0 | 1 | 0 | 1 | 0 | 0 | x | x | 0 | 0 | 0 | 0 | 28 | 27 | 24 | 4 | 0 | 0 | 0 | 0 |
| HICKORY SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | | |
| TC 345–350 | 14 | 7 | x | 7 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | x | 0 | 0 | 0 | 10 | 38 | 15 | 22 | 0 | 0 | 0 | 0 |
| TC 295–300 | 50 | 33 | 1 | 16 | 0 | 3 | 1 | 2 | x | 0 | 1 | 1 | 0 | x | x | 0 | 0 | 33 | 3 | 8 | 0 | 0 | 0 | 0 |
| TC 245–250 | 39 | 27 | 3 | 9 | 0 | 3 | 1 | 2 | 0 | 0 | 3 | 3 | 0 | 3 | 2 | x | 4 | 29 | 15 | 4 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TC | 195–200 | 49 | 31 | 4 | 14 | 0 | 7 | 4 | 3 | x | x | 0 | 0 | 0 | 3 | 3 | x | 3 | 32 | 6 | x | 0 | 0 | 0 | 0 |
| TC | 145–150 | 21 | 16 | 1 | 4 | 0 | 2 | 1 | 1 | 0 | 0 | x | x | 0 | x | x | 0 | 8 | 55 | 13 | 1 | 0 | 0 | 0 | 0 |
| TC | 95–100 | 16 | 9 | 1 | 6 | x | 5 | 3 | 2 | x | 0 | 1 | x | x | 2 | 2 | 0 | 2 | 65 | 7 | 2 | 0 | 0 | 0 | 0 |
| TC | 45–50 | 15 | 9 | 1 | 4 | 0 | 3 | 1 | 1 | 0 | 0 | x | x | 0 | 1 | x | x | x | 78 | 1 | 3 | 0 | 0 | 0 | 0 |
| TC | 0–5 | 10 | 6 | 1 | 3 | 0 | x | 0 | 0 | x | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 34 | 9 | 0 | 6 | 36 | 0 | 2 |
| WC | 270–275 | 15 | 9 | 1 | 5 | 0 | 3 | x | 2 | 0 | 0 | x | 0 | x | 3 | 2 | x | 0 | 37 | 5 | 37 | 0 | 0 | 0 | 0 |
| WC | 250–255 | 36 | 22 | 2 | 11 | x | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | x | x | 26 | 20 | 10 | 0 | 0 | 0 | 0 |
| WC | 220–225 | 12 | 6 | 1 | 4 | 0 | 2 | 1 | 1 | x | 0 | 1 | 1 | 0 | 7 | 5 | 2 | x | 35 | 4 | 39 | 0 | 0 | 0 | 0 |
| WC | 180–185 | 32 | 15 | 3 | 13 | 1 | 17 | 12 | 4 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 0 | 29 | 9 | 10 | 0 | 0 | 0 | 0 |
| WC | 165–170 | 26 | 18 | 1 | 7 | x | 9 | 7 | 3 | 0 | 0 | 1 | 1 | x | 4 | 2 | 2 | 1 | 28 | 29 | 2 | 0 | 0 | 0 | 0 |
| WC | 140–145 | 22 | 14 | 1 | 6 | 1 | 5 | 3 | 2 | 0 | 0 | 1 | 1 | x | 4 | 3 | 1 | 3 | 52 | 12 | 1 | 0 | 0 | 0 | 0 |
| WC | 120–125 | 26 | 15 | 1 | 8 | 1 | 5 | 2 | 2 | 0 | x | 3 | 3 | 0 | 4 | 4 | 0 | 2 | 24 | 32 | 3 | 0 | 0 | 0 | 0 |
| WC | 95–100 | 24 | 15 | 1 | 6 | 1 | 4 | 1 | 2 | 0 | 1 | x | 0 | x | 1 | 1 | 0 | x | 62 | 6 | 3 | 0 | 0 | 0 | 0 |
| WC | 70–75 | 21 | 13 | x | 7 | x | 1 | x | 1 | 0 | 0 | x | x | 0 | x | 0 | x | x | 64 | 11 | 1 | 0 | 0 | 1 | 0 |
| WC | 45–50 | 23 | 15 | 2 | 6 | x | 8 | 4 | 4 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 62 | 4 | x | 0 | 0 | 0 | 0 |
| WC | 25–30 | 28 | 17 | 2 | 9 | 1 | 7 | 4 | 2 | 0 | 1 | x | 0 | x | 1 | 1 | x | 2 | 39 | 21 | 1 | 0 | 0 | 0 | 0 |
| WC | 5–10 | 19 | 11 | 1 | 7 | x | 3 | 1 | 3 | 0 | 0 | 1 | x | 1 | 2 | 1 | x | 1 | 64 | 7 | 3 | 0 | 0 | 0 | 0 |
| MC | 300–305 | 9 | 7 | x | 1 | 0 | 1 | 1 | 0 | x | 0 | x | x | 0 | x | x | 0 | 0 | 72 | 1 | 16 | 0 | 0 | 0 | 0 |
| MC | 250–255 | 14 | 9 | 2 | 3 | 0 | 3 | 1 | 2 | 0 | 0 | 2 | 1 | x | 2 | 1 | 1 | 2 | 45 | 5 | 28 | 0 | 0 | 0 | 0 |
| MC | 200–205 | 7 | 5 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | x | 1 | 1 | x | 0 | 24 | 2 | 63 | 0 | 0 | 0 | 0 |
| MC | 150–155 | 17 | 12 | 1 | 4 | x | 4 | 2 | 2 | 0 | 0 | 1 | x | 1 | 4 | 2 | 2 | 2 | 34 | 5 | 32 | 0 | 0 | 0 | 0 |
| MC | 100–105 | 47 | 24 | 6 | 17 | 0 | 4 | 1 | 3 | 0 | 0 | 2 | 1 | x | 3 | 1 | 2 | 17 | 3 | 24 | 1 | 0 | 0 | 0 | 0 |
| MC | 50–55 | 30 | 15 | 2 | 13 | 0 | 12 | 7 | 4 | 0 | x | 2 | x | 2 | 3 | 1 | 1 | 22 | 7 | 24 | 1 | 0 | 0 | 0 | 0 |
| MC | 5–10 | 29 | 13 | 3 | 12 | 1 | 3 | 2 | x | 0 | 0 | 1 | 1 | 0 | x | x | 0 | x | 44 | 5 | 18 | 0 | 0 | 0 | 0 |
| LL | 350–355 | 23 | 15 | 1 | 7 | x | 1 | 1 | 1 | 0 | 0 | 3 | 2 | 1 | 1 | 1 | x | 1 | 37 | 2 | 31 | 0 | 0 | 0 | 0 |
| LL | 295–300 | 14 | 9 | 1 | 3 | 0 | 2 | 1 | x | 0 | x | 2 | 2 | x | 1 | 1 | x | 1 | 48 | 1 | 31 | 0 | 0 | 0 | 0 |
| LL | 245–250 | 25 | 14 | 2 | 9 | 0 | 3 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 5 | 3 | 2 | 0 | 39 | 3 | 23 | 0 | 0 | 0 | 0 |
| LL | 180–185 | 41 | 25 | 2 | 14 | x | 7 | 6 | 1 | 0 | 0 | 1 | x | x | 3 | 2 | 1 | 19 | 5 | 21 | 3 | 0 | 0 | 0 | 0 |
| LL | 145–150 | 31 | 17 | 3 | 11 | 0 | 8 | 4 | 3 | x | 0 | 1 | 1 | x | 4 | 3 | 1 | 15 | 5 | 35 | 1 | 0 | 0 | 0 | 0 |
| LL | 95–100 | 30 | 17 | 2 | 11 | x | 9 | 5 | 4 | 0 | 1 | x | x | 0 | 4 | 2 | 2 | 2 | 43 | 10 | x | 0 | 0 | 0 | 0 |
| LL | 45–50 | 32 | 19 | 2 | 10 | 1 | 7 | 4 | 3 | 0 | 0 | x | 0 | x | 4 | 1 | 2 | 18 | 20 | 18 | 1 | 0 | 0 | 0 | 0 |
| LL | 0–5 | 6 | 4 | 1 | 2 | 0 | 3 | 1 | 2 | 0 | 0 | 2 | 2 | 0 | x | x | 0 | x | 36 | 7 | 45 | x | 0 | 0 | 0 |
| P | 445–450 | 42 | 25 | x | 17 | 0 | x | 0 | x | 0 | 0 | x | x | 0 | x | x | 0 | 0 | 29 | 2 | 26 | 0 | 0 | 0 | 0 |
| P | 295–400 | 34 | 21 | 1 | 13 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | x | 58 | 1 | 4 | 0 | 0 | 0 | 0 |
| P | 345–350 | 25 | 16 | 0 | 10 | 0 | 1 | 1 | x | 0 | 0 | 1 | 1 | x | 0 | 0 | 0 | 1 | 42 | 5 | 24 | 0 | 0 | 0 | 0 |
| P | 295–300 | 24 | 16 | x | 7 | 1 | 2 | 1 | 1 | 0 | x | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 38 | 5 | 28 | 0 | 0 | 0 | 0 |
| P | 245–250 | 27 | 15 | 0 | 11 | 1 | 4 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | x | 0 | 51 | 9 | 7 | 0 | 0 | 0 | 0 |
| P | 190–195 | 36 | 19 | 1 | 16 | 0 | 6 | 1 | 5 | 0 | 0 | 4 | 4 | 1 | 2 | 2 | 0 | 1 | 36 | 9 | 4 | 0 | 0 | 0 | 0 |
| P | 145–150 | 38 | 24 | 1 | 11 | 1 | 6 | 3 | 3 | 0 | 0 | 3 | 2 | 1 | 2 | 2 | 0 | 2 | 26 | 22 | 0 | 0 | 0 | 0 | 0 |
| P | 95–100 | 29 | 16 | 2 | 11 | 0 | 10 | 5 | 5 | 0 | 0 | 1 | 1 | x | 6 | 4 | 2 | 6 | 31 | 14 | 2 | 0 | 0 | 0 | 0 |
| P | 45–50 | 28 | 17 | 3 | 8 | 0 | 3 | 1 | 2 | 0 | 0 | 2 | 2 | 0 | 3 | 2 | x | 9 | 10 | 43 | 2 | 0 | 0 | 0 | 0 |
| P | 0–5 | 15 | 9 | x | 6 | x | 1 | x | 1 | 0 | 0 | 4 | 3 | 1 | 1 | 1 | 0 | 1 | 36 | 24 | 17 | 0 | 0 | 0 | 0 |

Table 9. Heavy-mineral frequency counts*, exclusive of opaque and titanium minerals, for Moore Hollow Group rocks, Central Texas.

| | Zircon | | | | | Tourmaline | | | | | Garnet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Section and Sample | Total | Clear | Zoned | Dusty | Malacon | Total | Brown | Green | Blue | Black | Total | Colorless | Pink | Epidote | Barite | Unknown |
| **SAN SABA MEMBER** | | | | | | | | | | | | | | | | |
| CC 5–10 | 85 | 60 | 4 | 21 | 0 | 10 | 4 | 5 | 1 | 0 | 6 | 4 | 1 | 0 | 0 | 0 |
| CC 40–45 | 88 | 82 | 0 | 6 | 0 | 8 | 5 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 0 |
| CC 85–90 | 78 | 68 | 1 | 7 | 0 | 10 | 5 | 5 | 0 | 0 | 14 | 7 | 7 | 0 | 0 | 0 |
| BC 85–90 | 95 | 64 | 10 | 21 | 0 | 3 | 1 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| BC 120–125 | 79 | 61 | 2 | 16 | 0 | 16 | 2 | 13 | 1 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| BC 165–170 | 92 | 84 | 1 | 7 | 0 | 3 | 1 | 2 | 0 | 0 | 5 | 4 | 1 | 0 | 0 | 0 |
| JR 630–635 | 62 | 59 | 0 | 3 | 0 | 7 | 3 | 3 | 1 | 0 | 31 | 26 | 5 | 0 | 0 | 0 |
| JR 590–595 | 96 | 88 | 0 | 8 | 0 | 4 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JR 565–570 | 79 | 68 | 1 | 10 | 0 | 15 | 4 | 11 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 |
| JR 505–510 | 95 | 79 | 7 | 8 | 0 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JR 445–450 | 83 | 56 | 6 | 22 | 0 | 12 | 4 | 7 | 0 | 0 | 6 | 4 | 1 | 0 | 0 | 0 |
| JR 415–420 | 70 | 42 | 5 | 20 | 3 | 13 | 8 | 5 | 0 | 0 | 7 | 6 | 1 | 0 | 7 | 3 |
| **POINT PEAK MEMBER** | | | | | | | | | | | | | | | | |
| JR 290–300 | 75 | 53 | 4 | 16 | 2 | 18 | 18 | 0 | 0 | 0 | 7 | 7 | 0 | 0 | 0 | 0 |
| JR 250–260 | 60 | 39 | 2 | 18 | 1 | 33 | 19 | 14 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| JR 220–230 | 81 | 44 | 8 | 25 | 4 | 10 | 5 | 5 | 0 | 0 | 9 | 9 | 0 | 0 | 0 | 0 |
| WC 1,000–1,005 | 55 | 39 | 2 | 14 | 0 | 21 | 11 | 10 | 0 | 0 | 24 | 24 | 0 | 0 | 0 | 0 |
| WC 980–985 | 90 | 61 | 3 | 15 | 11 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| WC 930–935 | 95 | 69 | 7 | 16 | 3 | 2 | 1 | 1 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 0 |
| **WELGE SANDSTONE MEMBER** | | | | | | | | | | | | | | | | |
| JR 65–70 | 94 | 68 | 1 | 25 | 0 | 3 | 1 | 2 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| TC 870–875 | 95 | 71 | 7 | 17 | 0 | 2 | 0 | 2 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| SC 100–105 | 95 | 75 | 5 | 15 | 0 | 4 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| SC 85–90 | 97 | 73 | 4 | 20 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC 820–825 | 99 | 93 | 4 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MC 595–600 | 97 | 72 | 2 | 23 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| LL 605–610 | 97 | 69 | 9 | 19 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P 695–700 | 100 | 73 | 5 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **LION MOUNTAIN SANDSTONE MEMBER** | | | | | | | | | | | | | | | | |
| JR 40–45 | 97 | 67 | 2 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 |
| JR 5–10 | 99 | 50 | 7 | 40 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TC 835–840 | 97 | 64 | 5 | 28 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| TC 795–800 | 97 | 60 | 3 | 34 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| SC 60–65 | 97 | 66 | 3 | 28 | 0 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SC 20–25 | 94 | 50 | 6 | 38 | 0 | 4 | 3 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC 800–805 | 94 | 66 | 4 | 20 | 4 | 3 | 3 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 |
| MC 558–563 | 95 | 63 | 6 | 25 | 1 | 2 | 0 | 2 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| LL 585–590 | 97 | 55 | 11 | 31 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| LL 540–545 | 93 | 68 | 10 | 14 | 1 | 6 | 6 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| P 680–685 | 98 | 62 | 4 | 30 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |

* Percentages based on a count of a minimum of 100 grains.

(Table 9 continued.)

| Section and Sample | | Zircon Total | Zircon Clear | Zircon Zoned | Zircon Dusty | Zircon Malacon | Tourmaline Total | Tourmaline Brown | Tourmaline Green | Tourmaline Blue | Tourmaline Black | Garnet Total | Garnet Colorless | Garnet Pink | Epidote | Barite | Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | CAP MOUNTAIN LIMESTONE MEMBER | | | | | | | | |
| TC | 640–645 | 96 | 59 | 12 | 22 | 3 | 3 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| TC | 600–605 | 86 | 61 | 3 | 22 | 0 | 11 | 5 | 6 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| TC | 545–550 | 97 | 61 | 3 | 31 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| TC | 500–505 | 96 | 64 | 4 | 28 | 0 | 2 | 1 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| TC | 445–450 | 95 | 64 | 5 | 25 | 1 | 1 | 0 | 1 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 |
| TC | 375–380 | 95 | 62 | 4 | 29 | 0 | 5 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC | 760–765 | 97 | 57 | 15 | 25 | 0 | 2 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| WC | 645–650 | 93 | 66 | 4 | 20 | 3 | 4 | 2 | 2 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| WC | 620–625 | 97 | 63 | 4 | 26 | 4 | 1 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 595–600 | 90 | 55 | 4 | 30 | 1 | 7 | 2 | 5 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| WC | 570–575 | 94 | 60 | 5 | 26 | 3 | 4 | 1 | 3 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 520–525 | 99 | 62 | 9 | 26 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 490–495 | 94 | 61 | 5 | 23 | 5 | 3 | 1 | 2 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| WC | 465–470 | 79 | 53 | 0 | 22 | 4 | 9 | 8 | 1 | 0 | 0 | 12 | 10 | 2 | 0 | 0 | 0 |
| WC | 435–440 | 98 | 65 | 2 | 24 | 7 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC | 415–420 | 92 | 60 | 3 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 3 | 0 | 0 | 0 |
| WC | 395–400 | 91 | 50 | 3 | 31 | 7 | 5 | 2 | 3 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 |
| WC | 370–375 | 83 | 51 | 3 | 26 | 3 | 15 | 13 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 345–350 | 92 | 58 | 6 | 26 | 2 | 8 | 4 | 4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| WC | 320–325 | 85 | 49 | 4 | 30 | 2 | 13 | 8 | 4 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 295–300 | 95 | 62 | 5 | 23 | 5 | 5 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MC | 515–520 | 100 | 54 | 6 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MC | 440–445 | 97 | 64 | 7 | 25 | 1 | 3 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MC | 395–400 | 98 | 64 | 10 | 24 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| MC | 350–355 | 93 | 70 | 5 | 18 | 0 | 4 | 2 | 2 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 0 |
| LL | 450–455 | 96 | 63 | 10 | 20 | 3 | 4 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LL | 395–400 | 100 | 53 | 12 | 34 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P | 595–600 | 97 | 68 | 9 | 20 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| P | 545–550 | 96 | 60 | 12 | 21 | 3 | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| P | 495–500 | 87 | 62 | 4 | 20 | 1 | 9 | 2 | 7 | 0 | 0 | 4 | 3 | 1 | 0 | 0 | 0 |
| | | | | | | | | | HICKORY SANDSTONE MEMBER | | | | | | | | |
| TC | 345–350 | 86 | 47 | 4 | 35 | 0 | 6 | 3 | 3 | 0 | 0 | 8 | 7 | 1 | 0 | 0 | 0 |
| TC | 295–300 | 93 | 61 | 2 | 30 | 0 | 6 | 3 | 3 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| TC | 245–250 | 86 | 60 | 6 | 20 | 0 | 7 | 2 | 5 | 0 | 0 | 7 | 7 | 0 | 0 | 0 | 0 |
| TC | 195–200 | 87 | 55 | 8 | 24 | 0 | 13 | 7 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| TC | 145–150 | 91 | 61 | 8 | 20 | 2 | 8 | 5 | 3 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| TC | 95–100 | 78 | 39 | 12 | 26 | 1 | 18 | 10 | 7 | 1 | 0 | 4 | 4 | 0 | 0 | 0 | 0 |
| TC | 45–50 | 83 | 54 | 10 | 19 | 0 | 14 | 9 | 5 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| TC | 0–5 | 20 | 12 | 2 | 6 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 11 | 65 | 4 |
| WC | 270–275 | 88 | 48 | 9 | 31 | 0 | 10 | 3 | 6 | 0 | 0 | 2 | E | 1 | 0 | 0 | 0 |
| WC | 250–255 | 93 | 57 | 6 | 29 | 1 | 7 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WC | 220–225 | 84 | 43 | 5 | 35 | 1 | 11 | 5 | 5 | 1 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| WC | 180–185 | 63 | 30 | 6 | 26 | 1 | 34 | 23 | 9 | 0 | 3 | 3 | 1 | 1 | 0 | 0 | 0 |
| WC | 165–170 | 72 | 49 | 3 | 19 | 1 | 26 | 18 | 7 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| WC | 140–145 | 78 | 46 | 5 | 25 | 2 | 19 | 12 | 7 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| WC | 120–125 | 78 | 45 | 4 | 25 | 4 | 14 | 7 | 6 | 0 | 1 | 9 | 9 | 0 | 0 | 0 | 0 |
| WC | 95–100 | 83 | 53 | 3 | 23 | 4 | 16 | 6 | 8 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 |
| WC | 70–75 | 84 | 52 | 3 | 28 | 1 | 15 | 11 | 4 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| WC | 45–50 | 73 | 48 | 5 | 19 | 1 | 25 | 13 | 12 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| WC | 25–30 | 80 | 48 | 5 | 26 | 2 | 19 | 10 | 6 | 0 | 3 | 1 | 0 | 1 | 0 | 0 | 0 |
| WC | 5–10 | 78 | 46 | 4 | 25 | 3 | 17 | 8 | 9 | 0 | 0 | 5 | 4 | 1 | 0 | 0 | 0 |
| MC | 300–305 | 85 | 61 | 3 | 21 | 0 | 7 | 4 | 2 | 1 | 0 | 8 | 7 | 1 | 0 | 0 | 0 |
| MC | 250–255 | 78 | 54 | 7 | 17 | 0 | 11 | 5 | 6 | 0 | 0 | 11 | 9 | 2 | 0 | 0 | 0 |
| MC | 200–205 | 76 | 47 | 6 | 23 | 0 | 13 | 10 | 3 | 0 | 0 | 11 | 6 | 5 | 0 | 0 | 0 |
| MC | 150–155 | 70 | 47 | 2 | 20 | 1 | 20 | 12 | 8 | 0 | 0 | 10 | 6 | 4 | 0 | 0 | 0 |

(Table 9 continued.)

| Section and Sample | | Zircon | | | | | Tourmaline | | | | | Garnet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Total | Clear | Zoned | Dusty | Malacon | Total | Brown | Green | Blue | Black | Total | Colorless | Pink | Epidote | Barite | Unknown |
| MC | 100–105 | 89 | 47 | 11 | 32 | 0 | 8 | 2 | 6 | 0 | 0 | 3 | 3 | 1 | 0 | 0 | 0 |
| MC | 50–55 | 69 | 35 | 5 | 30 | 0 | 27 | 17 | 9 | 0 | 1 | 5 | 1 | 4 | 0 | 0 | 0 |
| MC | 5–10 | 90 | 41 | 10 | 35 | 4 | 8 | 7 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| LL | 350–355 | 88 | 55 | 5 | 27 | 1 | 4 | 2 | 2 | 0 | 0 | 8 | 7 | 1 | 0 | 0 | 0 |
| LL | 295–300 | 73 | 52 | 6 | 15 | 0 | 12 | 10 | 1 | 0 | 1 | 15 | 10 | 5 | 0 | 0 | 0 |
| LL | 245–250 | 85 | 47 | 6 | 32 | 0 | 12 | 7 | 5 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| LL | 180–185 | 85 | 52 | 5 | 27 | 1 | 14 | 12 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| LL | 145–150 | 78 | 42 | 8 | 28 | 0 | 19 | 10 | 8 | 1 | 0 | 3 | 2 | 1 | 0 | 0 | 0 |
| LL | 95–100 | 76 | 42 | 5 | 28 | 1 | 23 | 12 | 10 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 |
| LL | 45–50 | 82 | 49 | 6 | 25 | 2 | 17 | 10 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LL | 0–5 | 63 | 35 | 11 | 17 | 0 | 15 | 7 | 8 | 0 | 0 | 21 | 10 | 11 | 1 | 0 | 0 |
| P | 445–450 | 99 | 58 | 1 | 40 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| P | 395–400 | 96 | 59 | 2 | 26 | 0 | 2 | 0 | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 |
| P | 345–350 | 92 | 57 | 2 | 33 | 0 | 3 | 2 | 1 | 0 | 0 | 5 | 4 | 1 | 0 | 0 | 0 |
| P | 295–300 | 90 | 55 | 3 | 30 | 2 | 7 | 3 | 3 | 0 | 1 | 3 | 3 | 0 | 0 | 0 | 0 |
| P | 245–250 | 85 | 47 | 0 | 34 | 4 | 11 | 4 | 7 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 |
| P | 190–195 | 79 | 41 | 3 | 35 | 0 | 12 | 3 | 9 | 0 | 0 | 9 | 8 | 1 | 0 | 0 | 0 |
| P | 145–150 | 82 | 53 | 2 | 24 | 3 | 13 | 6 | 6 | 0 | 0 | 6 | 4 | 2 | 0 | 0 | 0 |
| P | 95–100 | 72 | 39 | 5 | 28 | 0 | 25 | 13 | 12 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| P | 45–50 | 84 | 52 | 10 | 23 | 0 | 10 | 3 | 7 | 0 | 0 | 6 | 6 | 0 | 0 | 0 | 0 |
| P | 0–5 | 79 | 37 | 2 | 39 | 1 | 4 | 2 | 2 | 0 | 0 | 17 | 11 | 6 | 0 | 0 | 0 |

### Pyrite

Where present, pyrite commonly exists in unaltered, yellow, irregular aggregates that are probably authigenic.

### Rutile

Rutile in a foxy-red variety and a more abundant amber variety is widely distributed and constitutes only a small part of the heavy fraction. The grains are subangular to subrounded and a few show geniculate twinning.

### Tourmaline

Tourmaline is commonly present in angular fragments to rounded, flattened grains, in amounts of less than 1 percent of the heavy fraction. Of the four varieties recognized, brown is most abundant, green is common, and blue and black are scarce. The brown variety includes grains that are pleochroic from colorless to yellow, yellow to brown, brown to black, and light brown to dark brown. The green variety includes grains that are pleochroic from colorless to green, yellow to green, brown to green, green to black, and light to dark green. The blue grains are generally pleochroic from blue to black, and the black grains remain black in all positions, light being transmitted through thin edges only. Many grains contain inclusions of unoriented needles, crystals, or colorless masses.

### Zircon

Zircon generally constitutes at least 75 percent and in some cases as much as 90 percent of the nonopaque minerals, exclusive of the nonopaque titanium minerals. Normal zircon is most abundant, malacon seldom exceeds 10 percent, and hyacinth zircon was not seen. Malacon grades in birefringence toward that of normal zircon, a fact which causes some uncertainty as to the category in which to record intermediate grains. Normal zircon is divided into clear, zoned, and dusty varieties, the latter usually caused by abundant small inclusions and, to a lesser extent, alteration. Altered zircon has a snowy appearance in reflected light. Fluid and crystalline inclusions are common and most are randomly oriented except that in some zoned crystals they are parallel to the zoning. Subangular to subround grains are most abundant and euhedral and well-rounded grains are common, all of which may occur in the same sample. Euhedral grains are perfect prisms which may have rounded terminations or be terminated by prisms some of which are capped by small basal pinacoids.

## Mineral Inclusions in Quartz

Nine samples were pulverized and treated in the manner outlined by Tyler (1936, p. 72–73) to release the included minerals from the quartz. The minerals found are anatase, apatite, biotite, black opaque minerals, garnet, hornblende, altered ilmenite, leucoxene, pyrite, rutile, tourmaline, and zircon. Frequency counts of included minerals in 100 grains of quartz for each of 9 samples are given in table 10.

### Anatase

Anatase forms euhedral grains, in part zoned, mostly cloudy (probably from leucoxene), and a few grains contain clear inclusions.

### Apatite

Apatite is in subangular to subrounded grains in part irregularly etched and in prismatic crystals very often with rounded terminations. Many grains contain clear crystalline or black inclusions.

### Biotite

Biotite, mostly with black inclusions, occurs in elliptical to discoidal flakes, many of which are hexagonal.

### Black opaque minerals

The various black opaque minerals were not separately identified.

### Garnet

Garnet, present in a few samples, is scarce, colorless, and in part etched; colorless inclusions are common.

### Hornblende

Prismatic fragments of hornblende are mostly green, a few are brown, most are strongly pleochroic, and a few contain inclusions which are either black or colorless.

### Ilmenite, altered

Except where ilmenite could be identified from its crystal form, its identification depended on the presence of leucoxene alteration. Most of the ilmenite is probably included with the black opaque minerals. The grains are mostly rounded to irregular.

### Leucoxene

Leucoxene forms earthy to very porous, white to light brown grains.

### Pyrite

Pyrite is scarce and occurs mostly in cubes and irregular masses.

**Table 10. Relative frequency of heavy-mineral inclusions in quartz grains* of Moore Hollow Group rocks, Central Texas.**

| | Zircon | | | | | Tourmaline | | | | Garnet | | | Rutile | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Section and Sample | Total | Clear | Zoned | Dusty | Malacon | Total | Brown | Green | Black | Total | Colorless | Pink | Total | Amber | Foxy red | Anatase | Altered ilmenite | Leucoxene | Black opaques | Pyrite | Biotite | Hornblende | Apatite |
| SAN SABA MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| BC 165–170 | 61 | 40 | 1 | 16 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 6 | 2 | 11 | 0 | 11 | 3 | 4 |
| BC 85–90 | 49 | 39 | 3 | 7 | 0 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 0 | 9 | 6 | 30 | 0 | 0 | 1 | 0 | 0 |
| JR 565–570 | 41 | 24 | 2 | 12 | 3 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 26 | 3 | 3 | 4 | 0 | 5 | 5 | 11 |
| POINT PEAK MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| WC 1,000–1,005 | 4 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 1 | 1 | 0 | 7 | 15 | 26 | 19 | 0 | 8 | 0 | 16 |
| WELGE SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| WC 820–825 | 34 | 16 | 4 | 14 | 0 | 1 | 0 | 0 | 1 | 2 | 2 | 0 | 2 | 0 | 2 | 0 | 6 | 8 | 25 | 0 | 5 | 11 | 6 |
| LION MOUNTAIN SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| WC 800–805 | 34 | 11 | 2 | 15 | 6 | 1 | 0 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 41 | 2 | 4 | 1 | 7 |
| CAP MOUNTAIN LIMESTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| WC 345–350 | 28 | 14 | 5 | 7 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 1 | 10 | 5 | 50 | 0 | 0 | 1 | 0 |
| HICKORY SANDSTONE MEMBER | | | | | | | | | | | | | | | | | | | | | | | |
| WC 140–145 | 51 | 20 | 2 | 27 | 2 | 3 | 3 | 0 | 0 | 1 | 1 | 0 | 3 | 1 | 2 | 11 | 5 | 7 | 10 | 0 | 7 | 1 | 1 |
| WC 5–10 | 49 | 25 | 2 | 21 | 1 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 4 | 3 | 1 | 11 | 2 | 6 | 8 | 0 | 9 | 3 | 4 |

* Stated as percentage of total number of heavy-mineral inclusions in 100 grains of quartz.

### Rutile

Foxy-red and amber varieties of rutile form euhedral and subangular to subrounded grains; the latter appear to be euhedral grains with rounded terminations. A few grains are striated and many contain black inclusions.

### Tourmaline

Subrounded and prismatic tourmaline grains are mostly brown, many are green, and black ones are very scarce. Green grains are pleochroic from green to black and colorless to green, and brown ones are pleochroic from colorless to yellow, brown to black, yellow to black, and light brown to dark brown. Most grains contain inclusions which are either black or colorless, mostly randomly oriented, and rarely aligned parallel to the principal axis.

### Zircon

Both normal and malacon varieties of zircon are present; however, malacon makes up only a small percentage of the heavy fraction. Normal zircon is either clear, zoned, or dusty; each variety may be euhedral or rounded; and many prismatic grains have rounded terminations and basal pinacoids. The malacon is either clear or dusty from abundant inclusions or, in some cases, alteration. Most grains contain randomly-oriented liquid or crystalline inclusions, some of which are black.

## Heavy Minerals in Precambrian Rocks of the Llano Region

Walker (1952) examined eight samples of sand from present streams wholly within Precambrian outcrop areas of the Llano region to see if similar rocks might have been the source of the Moore Hollow sands. He stated: "Unfortunately the results of this study were not conclusive. This was due to the lack of distinctive characteristics of grains both in the Cambrian samples and in the stream samples." No data are given.

This rather ambiguous statement, if taken at face value, indicates that both the Cambrian and Precambrian samples are alike. The unfortunate thing about this phase of the work is that Walker does not give data; hence one cannot judge for himself whether the results are inconclusive.

Wills (1951) examined heavy minerals obtained by panning from 35 localities in the Spring Creek drainage basin of Burnet County. Some samples are from small drainage areas limited to one rock type, others were from drainage areas tributary to two rock types, and a few samples included material from large portions of almost all of the Spring Creek drainage basin. Rocks represented include Valley Spring Gneiss, Packsaddle Schist, various small intrusive bodies, Cambrian rocks, possibly Ordovician rocks, and Cretaceous rocks.

From the Precambrian rocks Wills lists apatite, biotite, black opaque minerals, diopside, epidote, fluorite, garnet, hornblende, monazite, rutile, tourmaline, sphene, and zircon. From two samples (nos. 3 and 20) which appear to be predominantly from the Cambrian he lists apatite, black opaque minerals, epidote, garnet, hematite, hornblende, leucoxene, limonite, rutile, tourmaline, and zircon.

In view of Walker's findings, the presence of from 15 to 30 percent of hornblende, as well as the presence of tremolite, fluorite, and sphene, in the Cambrian rocks is anomalous. It seems likely that these minerals are all windblown from the adjacent Precambrian to the west. These findings suggest that caution must be used in interpreting the results of heavy-mineral counts made from samples concentrated from stream materials. Within the Precambrian areas modification of percentages may not be important, but in the case of the Cambrian, composed mostly of carbonate minerals, small additions

**Table 11. Relative frequency of inclusions in quartz grains* of Moore Hollow Group rocks of Central Texas classified according to Mackie (1896).**

| Section and sample | Regular | Acicular | Irregular |
|---|---|---|---|
| | SAN SABA MEMBER | | |
| JR 630–635 | 90 | 10 | 0 |
| JR 565–570 | 83 | 17 | 0 |
| JR 445–450 | 92 | 6 | 2 |
| | POINT PEAK MEMBER | | |
| WC 980–985 | 83 | 1 | 16 |
| | WELGE SANDSTONE MEMBER | | |
| WC 820–825 | 83 | 17 | 0 |
| | LION MOUNTAIN SANDSTONE MEMBER | | |
| WC 800–805 | 85 | 11 | 4 |
| | CAP MOUNTAIN LIMESTONE MEMBER | | |
| WC 520–525 | 93 | 4 | 3 |
| WC 435–440 | 96 | 1 | 3 |
| WC 345–350 | 92 | 5 | 3 |
| | HICKORY SANDSTONE MEMBER | | |
| WC 250–255 | 88 | 9 | 3 |
| WC 140–145 | 85 | 11 | 4 |
| WC 5–10 | 84 | 12 | 4 |

* Stated as percentage of total number of heavy-mineral inclusions in 100 grains of quartz.

from the Precambrian might seriously contaminate the heavy-mineral suite.

The heavy minerals found in the Cambrian by Walker are very similar to the more stable ones from the Precambrian found by Wills in the Spring Creek drainage basin. In view of the rather simple suite of minerals in the Cambrian, it is not surprising to find that this very local area is representative of the source area of the Cambrian as a whole.

### Relative-AbundanceData

The relative abundance of the entire suite of heavy minerals in Moore Hollow rocks is given in table 8. In table 9 the opaque and titanium minerals are excluded so that the relative abundance of the remaining heavy minerals will be shown more sharply. The relative frequency of heavy-mineral inclusions in quartz grains is given in table 10, and in table 11 the inclusions in quartz grains are classified as to shape. The relative abundance of quartz and feldspar in the fine sand and silt fractions is given in table 12.

### Conclusions from Heavy-Mineral Examination

In the section of his thesis entitled "Facts revealed by the investigation," Walker (1952) enumerates significant facts established by the investigation. A somewhat abridged and rearranged statement of these facts is given herein, followed by an interpretation of their meaning. Two facts dealing with the light fraction are also included. The interpretation is modified by the writer to conform with information obtained since Walker did his work.

1. *The heavy-mineral suite is the same throughout the Moore Hollow Group of rocks* (table 8; pl. 6). This evidence indicates a fairly uniform range of rock composition throughout the source area.

2. *The relative percentages of the heavy minerals vary somewhat* (table 8; pl. 6). This variation may be caused by selective sorting because of differences in size of the various heavy-mineral species, or possibly by intrastratal solution removing some species. In the case of the titanium minerals, differences may be caused by diagenetic changes which should be proportionally greater in fine-grained minerals than in coarse-grained minerals.

3. *The less resistant heavy minerals are absent.* Weathering must have destroyed them, as they are present within quartz grains. Walker also suggests that intrastratal solution may have been effective in removing such minerals.

4. *Black opaque minerals are relatively more abundant in the vicinity of the Riley-Wilberns formational boundary* (table 8; pl. 6). As the chief black opaque mineral appears to be ilmenite and ilmenite tends to alter to leucoxene, it seems likely that leucoxene has been abraded from the course ilmenite grains in the coarse-grained units, whereas the leucoxene has survived on the fine-grained ilmenite in the finer grained units. Walker suggests that some beds favored intrastratal changes while others did not. This suggestion is doubtful because the more permeable the bed, the less the change.

**Table 11 Relative abundance of quartz and feldspar in fine sand and silt fractions*, Moore Hollow Group rocks, Central Texas.**

| Section and Sample | Quartz | Feldspar |
|---|---|---|
| **SAN SABA MEMBER** | | |
| BC 120-125 | 61 | 39 |
| JR 630-635 | 85 | 15 |
| JR 590-595 | 96 | 4 |
| JR 565-570 | 72 | 28 |
| JR 445-450 | 48 | 52 |
| **POINT PEAK MEMBER** | | |
| WC 980-985 | 23 | 77 |
| JR 250-260 | 34 | 66 |
| **WELGE SANDSTONE MEMBER** | | |
| JR 85-90 | 100 | 0 |
| WC 820-825 | 100 | 0 |
| MC 595-600 | 100 | 0 |
| P 695-700 | 97 | 3 |
| **LION MOUNTAIN SANDSTONE MEMBER** | | |
| JR 5-10 | 88 | 12 |
| JR 20-25 | 82 | 18 |
| WC 800-805 | 99 | 1 |
| LL 540-545 | 64 | 36 |
| **CAP MOUNTAIN LIMESTONE MEMBER** | | |
| TC 640-645 | 43 | 57 |
| TC 500-505 | 81 | 19 |
| WC 620-625 | 60 | 40 |
| WC 520-525 | 88 | 12 |
| WC 435-440 | 60 | 40 |
| WC 345-350 | 80 | 20 |
| MC 558-563 | 98 | 2 |
| MC 395-400 | 61 | 39 |
| MC 350-355 | 97 | 3 |
| **HICKORY SANDSTONE MEMBER** | | |
| WC 250-255 | 65 | 35 |
| WC 140-145 | 72 | 28 |
| WC 5-10 | 85 | 15 |
| LL 350-355 | 96 | 4 |
| P 395-400 | 98 | 2 |

* Based on a count of 100 grains.

5. *Zircon is relatively more abundant in the upper part of the Riley Formation and in the lower part of the Wilberns Formation* (table 9; pl. 6). As diagenetic changes are not involved, this may be accounted for by sorting.

6. *The species of detrital minerals are the same as the species included in quartz grains except that quartz grains also contain the less resistant mineral hornblende* (table 10). A comparison of samples in table 8 with corresponding samples in table 10 shows differences in the relative amounts of the inclusion and detrital suites from corresponding samples, but such differences are not consistent from sample to sample. These limited data indicate little change in the relative amounts of the resistant minerals of the detrital suite during transportation and weathering.

7. *Regular inclusions predominate in the quartz grains of the nine samples examined* (table 11). According to Walker, who follows Mackie (1896), this concept indicates the derivation of the quartz grains from a predominantly metamorphic source. This conclusion is not substantiated by the thin-section examination or the rest of the evidence furnished by the heavy-mineral examination. Thin sections from the parts of the particular sections from which Walker studied inclusion suites were not available; however, a few equivalent stratigraphic levels in other sections were examined. Before accepting Walker's conclusion, many more samples of inclusion suites should be examined.

8. *The coarser zircon grains are somewhat more rounded upward in the Moore Hollow Group.* This fact indicates an increase in the distance of transportation as the sediments accumulated.

9. *The coarser sand grains in the Moore Hollow Group above the Hickory Sandstone Member show a relatively high degree of rounding.* The red zone in the upper part of the Hickory Sandstone Member should also have been included in this group. Walker attributes the rounding, as well as the absence of the less resistant heavy minerals (item 3 above), in part to the derivation of the sand from pre-existing sandstone. Flawn's basement rock studies (1956) show that Precambrian sandstone is absent in the likely source area for these rocks. This writer believes that quartz grains from igneous and metamorphic sources were well rounded by wind action and eventually were deposited by water action.

10. *Detrital feldspar, mostly in the finer grain sizes, occurs in significant amounts in all sandy units except in the upper part of the Lion Mountain sandstone and all of the Welge Sandstone* (table 12). In order to have a source of quartz grains, weathering must have been active, perhaps about as it is in the Llano area at present. Under present conditions plagioclase and hornblende alter to clay, and the biotite becomes crinkly and lighter colored. Without a vegetation cover, wind could act, microcline because of its cleavage would become finely ground, and both the finely ground microcline and clay would be blown away. Perhaps similar conditions existed during the deposition of Moore Hollow rocks, with the finer materials carried by wind beyond where the coarser material would ordinarily have been deposited. Much of the clay may have formed authigenic feldspar and authigenic overgrowths on detrital feldspar, accounting for the noticeable deficiency of clay in Moore Hollow rocks.

### Comparison of Heavy-Mineral Suites from Texas and Wisconsin

In table 13, the ranges in amounts are given for the heavy minerals commonly present in the sandy and silty Moore Hollow rocks of Central Texas and the Cambrian and Ordovician sandstones of Wisconsin. The most noticeable difference between the two groups is the greater abundance of tourmaline and garnet and the lesser abundance of the titanium minerals in the Wisconsin rocks. The relative amounts of zircon and rutile are about the same.

The garnet and perhaps the tourmaline in the Wisconsin rocks indicate that the ultimate source area contained more metamorphic rocks than did the source area from which the Moore Hollow rocks came. The lesser relative abundance of titanium minerals in Wisconsin rocks could mean either that fewer titanium minerals were present in the source area or that the minerals had been partly eliminated by wear in a greater distance of transportation. That the latter explanation may be true is indicated by the fact that much of the Wisconsin sand has passed through two or more cycles (Tyler, 1936), whereas the sand in the Moore Hollow Group must be predominantly first-generation sand.

That metamorphic rocks made up only a small part of the ultimate terrane from which the sand of the St. Peter and some of the Cambrian units was derived is indicated by Tyler's (1936) study of heavy minerals included in quartz grains. Using the same criteria for the Moore Hollow rocks, their source area must have contained even fewer metamorphic rocks.

## INSOLUBLE-RESIDUE EXAMINATION

Insoluble residues were prepared for all chip-sampled intervals from the various sections; the amount present in each is stated after the appropriate section description in Part II (on open file at the Bureau of Economic Geology) and shown graphically in plate 6.

**Table 13. Comparison of the heavy minerals* of Moore Hollow Croup rocks of Central Texas with those listed by Tyler (1036, p. 78) in Cambrian and Ordovician sandstones of Wisconsin.**

| Stratigraphic unit | Zircon | Tourmaline | Garnet | Rutile | Anatase | Ilmenite and other black opaque minerals | Leucoxene |
|---|---|---|---|---|---|---|---|
| **TEXAS** | | | | | | | |
| San Saba Member | 13–73 | 0–7 | 0–6 | 0–7 | 0–28 | 2–37 | 10–71 |
| Point Peak Member | 3–43 | 0–4 | 0–2 | 0–6 | 3–25 | 12–72 | 11–45 |
| Welge Sandstone Member | 5–27 | 0–1 | 0 | 0–1 | 0–33 | 53–91 | 0–7 |
| Lion Mountain Sandstone Member | 2–12 | 0–1 | 0 | 0 | 0–4 | 85–97 | 0–3 |
| Cap Mountain Limestone Member | 3–75 | 0–4 | 0–2 | 0–6 | 0–28 | 28–71 | 0–69 |
| Hickory Sandstone Member | 6–50 | 0–17 | 0–4 | 0–7 | 0–22 | 4–88 | 1–43 |
| **WISCONSIN** | | | | | | | |
| St. Peter Sandstone | 61 | 15 | x | x | 1 | 5 | 16 |
| Madison Sandstone | 64 | 17 | 2 | 2 | 3 | x | 11 |
| Jordan Sandstone | 10–25 | 5–10 | 75–100 | | | x | x |
| Franconia Sandstone | 4 | 15 | 80 | x | x | x | x |
| Galesville Sandstone | 25–50 | 10–25 | 0–10 | | x | 5–10 | 1–5 |
| Eau Claire Sandstone | 29 | 4 | 22 | 1 | 2 | 30 | 11 |
| Mount Simon Sandstone | 18 | 10 | 2 | x | x | 50 | 21 |

* Stated as range of percentages of heavy-mineral inclusions.

Most descriptions of insoluble residues are incorporated with the description of the rocks in the various stratigraphic sections (Part II). Most of the insoluble constituents are described in the section Thin-Section Examination and the rest under Heavy-Mineral Examination.

Seals (1939) studied the insoluble residues of the "Cap Mountain Formation" and basal part of the Wilberns Formation (Cap Mountain Limestone, Lion Mountain Sandstone, Welge Sandstone, and lower part of Morgan Creek Limestone of this report) in the Cap Mountain, Lion Mountain, and Morgan Creek areas. He concluded that the insoluble residues of the limestone of the Cap Mountain and Morgan Creek are almost identical and that they both differ somewhat from those of the sandstones. The minerals observed by Seals in the limestone of the Cap Mountain and Morgan Creek are chiefly quartz, glauconite, limonite, magnetite, leucoxene, microcline, plagioclase, and zircon, with tourmaline scarce; and in the sandstone, chiefly quartz, glauconite, and limonite. Quartz grains in the limestone of the Cap Mountain and Morgan Creek, according to Seals, are subrounded and mostly 1/256 to 1/2 mm in size, and those from the sandstone are rounded and mostly from 1/2 to 2 mm, with some from 2 to 4 mm, and some below 1/2 mm in size. He concluded that acidic igneous rocks constituted most of the source area for the insoluble residues of the "Cap Mountain Formation."

Gardner (1940) studied the insoluble residues from the "Wilberns Formation" (Morgan Creek Limestone and Point Peak Members of this report) in the Camp San Saba and Morgan Creek areas. He found the same general suite throughout this portion of the Wilberns and some variation in relative abundance. The most common minerals identified by Gardner are quartz, glauconite, microcline, plagioclase, mica, magnetite, and zircon; less common minerals are garnet, hornblende, tourmaline, pyrite, and leucoxene. He found a zone with an abundance of feldspar approximately 20 to 60 feet above the base of the "formation," and also noticed a definite decrease in grain size at a point about 115 feet above its base, but otherwise found no characteristics that might be used in correlating the two areas or with Gallagher and Lawson No. 1 Terry in Comanche County. Gardner also concluded that acidic igneous rocks constituted most of the source area for the insoluble residues in this part of the Wilberns Formation.

Barnes and Bell (1954a, fig. 2) graphically portrayed the amount of insoluble residue in the Klett-Walker, Morgan Creek, Carnp San Saba, and Calf Creek sections and showed that the amount of insoluble residue increases northwestward. The sandstone units and the Point Peak Member furnish the most insoluble residue, followed by the Cap Mountain Limestone, Morgan Creek Limestone, and San Saba Members, in that order.

All the insoluble residue data for Moore Hollow Group rocks shown graphically in plate 6 do not appreciably change the conclusions just cited. However, minor variations are brought out, such as the insoluble-residue peak produced by the silty zone in the Cap Mountain Limestone.

The kind of insoluble residue in Moore Hollow rocks is roughly the same throughout the group and is mostly distinct from the insoluble residues of Ellenburger rocks. Except for an occasional tiny grain, glauconite is confined to Moore Hollow rocks. Feldspar, found mostly in Moore Hollow rocks, is also present in the lower few hundred feet of Ellenburger in the western area.

For the insoluble residues of Moore Hollow rocks, amount is the most noticeable variation, but there are also some other distinctive differences. The thin zone of red-stained sand at the base of the Morgan Creek Limestone is fairly distinctive in the Llano region, but this zone cannot be traced far in the subsurface. This sand is similar to that in a thicker zone in the Cap Mountain Limestone in the southeastern part of the Llano region. This zone of sand passes laterally northwestward into the Hickory Sandstone, and to the north and west in the subsurface this zone of the Hickory Sandstone is very distinctive.

The abundance of black opaque minerals serves to distinguish the Lion Mountain and Welge Sandstones from the Hickory Sandstone beneath and the sandstone in the San Saba Member above. No attempt has been made to see if this zone of black opaque minerals can be traced into the subsurface. Abundance of glauconite combined with abundance of sand distinguishes the Lion Mountain Sandstone Member, and at the surface iron nodules formed by the weathering of glauconite are very useful in tracing the Lion Mountain in poorly exposed areas.

## SEDIMENTARY STRUCTURES

Sedimentary structures included in this discussion are features produced in sediments during sedimentation and at a later date, but excluding those features formed through tectonic deformation. In addition to structures produced by the action of sedimentation there are structures caused by biological activity, penecontemporaneous deformation, and diagenesis. Among the features produced during diagenesis are mottling from selective dolomitization, stylolites, concretions, and collapse structures (at least those formed before diagenesis was complete). Collapse structures produced during the present cycle of erosion are excluded. Penecontemporaneous deformation appears to be exceedingly scarce in the Moore Hollow Group rocks of the Llano region and was observed with uncertainty in a few places in steeply dipping beds around buried hills.

Stratification is an almost ubiquitous property of sedimentary rocks. Moore Hollow rocks, because of the diversity of rock types, have a wide range of stratification features. Major bedding surfaces, so far as the eye can tell, are mostly parallel, or nearly so, and may be widely spaced, closely spaced, of some intermediate spacing, or alternations of various spacings. Bedding surfaces may be essentially plane, irregular, or ripple marked, or they may bear impressions of raindrops, ice crystals(?), flow markings and lebensspuren, such as burrows, trails, or excavations for resting or nesting. Between the major bedding surfaces the rock may be homogeneous, ranging from aphanitic to coarsely particulate, or be composed of intraformational conglomerate, or be alternations of lithic types, laminated, crossbedded, burrowed, mottled, fossiliferous, or stromatolitic.

In the descriptions of stratigraphic sections (Part II, on open file at the Bureau of Economic Geology), bedding features are described in general terms; no attempt was made to make a systematic study of current directions or to detect markings on the underside of beds. Now that the broader aspects of the various units in the Moore Hollow Group and the general direction from which the sediments were derived are known, detailed studies should perhaps be made to see how well the details conform to the overall picture. Such studies should go far in determining the degree of confidence one can have in local observations as the basis for making broad generalizations about shelf-type deposits.

The various units of the Moore Hollow Group vary considerably in their sedimentary and solutional structures and for this reason each unit is discussed separately.

### RILEY FORMATION

#### Hickory Sandstone Member

The Hickory Sandstone is composed of poorly sorted sand, granules, finer materials, and some pebbles, some of which at the base of the member are wind-abraded. Beds may be thick and massive, especially near the base of the member in some areas, or they may be medium to thin. In some parts of the Hickory, beds of various thicknesses alternate with argillaceous, sandy, thinly bedded siltstone zones. The surfaces of beds range from smooth where fine grained, and silty to rough where bearing cuneiform markings. Trails and burrows are common in the middle and upper parts and crossbedding is abundant throughout.

Climactichnites(?) trails 4 inches wide are exposed in the bed of Threadgill Creek (between 237 and 239 feet in line of section); such trails have not been seen elsewhere in the Llano region.

Depressions preserved as casts (*Cruziarui*) on the underside of beds may be resting places for merostomes or trilobites. No other traces of the organisms which made them have been recognized. Such forms were noted 500 feet beneath the top of the Riley Formation in the Morgan Creek section, about 650 feet below in the Pontotoc section, and in an intermediate position in the Threadgill Creek section where they were noted through about 25 feet of section. As mentioned above, the bottom sides of beds were not systematically searched for these forms, and the figures given very likely do not represent the range of these forms.

Cuneiform markings interpreted by the writer (Barnes, 1958) as ice crystal casts, but possibly representing some type of burrow instead, are noted in the various stratigraphic sections. They range from 420 to 590 feet beneath the top of the Riley Formation in the Morgan Creek section, 500 to 650 feet beneath in the Pontotoc section, and 590 to 780 feet beneath in the Threadgill Creek section. The top of this zone in reference to the top of the Riley drops about 170 feet between the Morgan Creek area to the northeast and the Threadgill Creek area to the southwest. Whether the top of this zone approximates a time plane is unknown. If it does, then a greater thickness of sediment accumulated in the same time interval in the southwestern area than in the northeast area.

Intraformational conglomerate and ripple marks are common; in fact, all features of the Hickory Sandstone indicate its deposition in shallow water, and if the cuneiform markings are ice crystal casts then portions of it must have been barely awash.

### Cap Mountain Limestone Member

The middle silty unit of the Cap Mountain Limestone is characterized by small-scale, wavy to irregular bedding probably from minute crossbeds primarily, and in part from solution along minute stylolites and disturbance by organisms. This unit appears massive in bluffs and along water courses but on weathered slopes forms thin slabs.

Wavy to irregular bedding prominent in the upper calcitic part of the Cap Mountain was probably caused mainly by solution along low-amplitude stylolites and to a lesser extent by original depositional irregularities and disturbance by organisms.

The Cap Mountain Limestone increases in thickness southward influenced by the distance from shore, and in this area it is massive, bluff forming, and the beds in general are thicker and more distinct in the upper and lower parts. In the lower unit crossbeds are common in the sandy beds, and ripple marks essentially confined to this part of the Cap Mountain are scarce.

Mottles and specks from selective dolomitization of filled burrows, ooids, and other objects are very common, especially in the more calcareous portions of the member. The scarcity of intraformational conglomerate and ripple marks and the scale of the bedding irregularities indicate that the Cap Mountain Limestone was deposited in slightly deeper water than the Hickory Sandstone. Southward the upper limestone unit becomes increasingly oolitic, as does the lower limestone unit after it appears. The widespread occurrence of the silty member, rather than indicating a regressive-transgressive cycle, may indicate a climatic cycle during which mechanical disintegration was at a maximum, winds were strong, and the fine materials were blown far to sea.

### Lion Mountain Sandstone Member

Crossbedding is probably the dominant sedimentary feature of the heterogeneous Lion Mountain Sandstone Member and is present in all lithic types. Even the fairly continuous limestone beds in the lower part of the member are crossbedded, and the most striking display is furnished by the crossbeds of white trilobite coquinite scattered throughout the deep green greensand. To form such trilobite accumulations, it seems likely that moulting took place periodically, and that the moults were swept by currents to the foreset face of developing crossbeds. Between moultings sand deposition continued.

Current ripple marks are common in the lower part of the Lion Mountain Sandstone Member, and burrows and trails are well preserved in the more argillaceous portions. Hematite concretions along the bedding and vertical tabular masses along joints are forming during the present weathering cycle.

Lion Mountain sediments appear to have been deposited in shallower water than those of the Cap Mountain Limestone; in fact, a period of emergence ended Lion Mountain deposition over most if not all of the Llano region. However, south from the region in

Magnolia Petroleum Company No. 1 Below, sedimentation appears to have been continuous across the Riley-Wilberns boundary.

## WILBERNS FORMATION

### Welge Sandstone Member

The Welge Sandstone characteristically is massive, thick bedded, and in some exceptionally well-exposed outcrops, such as those in the bed of James River, crossbedding is excellently displayed. However, in some outcrops crossbedding was not recorded and if present must have been subdued. Thin shale beds interspersed with the thick sandstone beds, especially in the southwestern part of the Llano region, are well displayed in the type section of the Welge Sandstone. A section of bluff at this locality toppled and turned upside down, exposing the bottom sides of the sandstone beds and two types of lebensspuren. These, originally excavations in the clay, are preserved as sand casts.

One of these types, preserved as blocky individuals, is in geometrical patterns (triangles, squares, pentagons, and hexagons, as well as individuals and pairs) and is difficult to explain, unless the animals that made them behaved much as elephants at a circus, forming a circle and grasping in their trunks the tail of the next one in line. Whether these are resting or nesting burrows or excavations for some other purpose is unknown. Similar excavations may be seen by examining the underside of beds in the bluff exposure of Welge Sandstone along James River.

The other type of excavation, preserved as molds that look like coprolites, has essentially random distribution and its function, too, can be only speculated on. How such excavations can be so well preserved in a presumably soft clay mud is also difficult to understand unless the mud was exposed to the air and dried before the sand was heaped on it. but if this happened mud cracks should be present and none were noted. Another mode of formation may be more logical: the clay is undisturbed except in its uppermost part, suggesting that as the clay accumulated, the bottom was rendered unfavorable for organisms of the type which made the excavations and that it did not become favorable until sand accumulated. Then perhaps the organisms burrowed through the sand and into the upper surface of the clay and as the animals left the excavation, sand filled in behind them. No conclusive evidence that this is true could be seen in the collected specimens; however, the sandstone does appear to have been traversed by organisms and irregular, discontinuous films of clay are interspersed throughout the sandstone.

### Morgan Creek Limestone Member

The lower part of the Morgan Creek Limestone is thickly bedded, grading upward from the massive Welge Sandstone beneath. Upward it is less thickly bedded, and about the middle, or slightly lower, bedding characteristics change to an alternation of medium to thin beds of coarsely granular limestone and beds of silty, argillaceous, darker colored, wavy bedded, finely granular limestone.

The finely granular limestone is mostly reworked by organisms, nodular, and indistinctly bedded. The coarse-grained limestone may be crossbedded but mostly is stylolitic, producing a wavy appearance along the bedding. There is little reworking by organisms. The Morgan Creek Limestone is somewhat thicker bedded again toward the top and in this portion stromatolites are common. The stromatolites may be distributed as widely spaced, isolated individuals, or they may coalesce to form continuous beds with only narrow septae of granular limestone in between.

In the lower part of the Morgan Creek, structures designated as mudballs(?) are irregular in shape and much finer grained than the matrix in which they rest. They are composed of impure carbonate material and from their color appear to be above average in iron content. In view of the granularity of the matrix and the irregular lobate shape of these objects, they may be of algal origin rather than mudballs.

Dolomitization of ooids and fossil fragments is common, producing a speckled to mottled appearance in some beds.

In most of the Llano region Wilberns sedimentation followed transgression, and the water probably continued to deepen after the Welge Sandstone was deposited. The water was deep enough to eliminate most of the effects of turbulence but shallow enough for great fields of cystoids to grow and crossbedding to develop.

During the deposition of the upper part of the Morgan Creek Limestone, either shallowing or climatic cycles, or possibly both, occurred, causing an alternation of lithic types. Coarse pelmatozoan beds formed probably during quiescent periods and fine-grained silty beds formed probably during turbulent periods.

The upper few feet of the Morgan Creek in the northeastern part of the region is reddish. Whether or not this color resulted from local emergence is unknown; however, there is a sharp change at this point from the massive pelmatozoan limestone of the Morgan Creek to the siltstone of the Point Peak.

### Point Peak Member

The lower 30 feet of the Point Peak is chiefly siltstone, calcareous, thinly to very thinly bedded, and most bedding surfaces are smooth; a few are marked by trails, raindrop(?) impressions, mud flowage marks(?), and minute ripples of the type that can form only in a film of water 1 mm or so deep.

Beds of intraformational conglomerate, scarce in the lower 30 feet, become increasingly abundant upward except in the uppermost part where granular limestone becomes prominent. Some of these limestones are ripple marked, and crossbedding is common. In some areas the upper half of the Point Peak Member is a massive stromatolitic reef, and beds of stromatolites may be found anywhere within the Point Peak. The stromatolites range from rather smooth forms to those which are crenulated with intraformational conglomerate in the furrows. Larger masses are composed of smaller stromatolites on the order of 2 feet in diameter and these in turn may be composed of still smaller masses.

The Point Peak Member accumulated in water ranging from shallow to extremely shallow as indicated by the minute ripples in its lower part in the western area of the Llano region. The water was shallow at all times, and probably intertidal most of the time, since intraformational conglomerate is thought to form only in the intertidal zone where lithification can readily take place. A similar depth of water may also be optimum for the growth of stromatolites.

### San Saba Member

Lithologically the San Saba Member varies greatly both locally and from area to area. Stromatolites form widely distributed thick zones in the western part of the Llano region; some started growth during Point Peak deposition and grew through most of San Saba time. In the eastern area where the San Saba is predominantly dolomite, evidence of stromatolites is furnished by chert films which either follow the structure of the stromatolites or replace the septae between stromatolites. Where chert is absent the portion of the San Saba that is stromatolitic cannot always be determined; obviously, however, the abundant, uniformly bedded dolomite is not stromatolitic.

The stromatolitic origin of the coarse-grained dolomite in the eastern area has not been ruled out, but it seems unlikely in view of the fine-grained dolomite forming the very thick stromatolitic reef in western Mason County and the fine-grained dolomite associated with the stromatolitic chert in the eastern area. In the Sudduth area there are stromatolitic structures in noncherty dolomite and here too the dolomite is fine grained.

In the westernmost part of the Llano region massive, crossbedded sandstone is common in the upper part of the San Saba Member. In the central and western part of the Llano region, most of the San Saba is distinctly bedded limestone. The beds are mostly medium, some are thick, and others are thin. Large-scale ripple marks are present in the lower part and crossbedding, burrowed beds, trails, and stylolites producing wavy-appearing bedding are common throughout.

On the underside of a bed at 477 feet in the upstream James River section, circular 1/4-inch grooves, 4 to 5 inches in diameter, 2 of which are concentric, are present. These grooves were probably formed by a mud-burrowing animal of some type.

Many beds are speckled and mottled from replacement of various objects by dolomite. Where overlain by calcitic Threadgill rocks many beds in the upper part of the San Saba are small-pebble, intraformational conglomerates with aphanitic pebbles in a granular matrix. Similar intraformational conglomerate in the overlying Threadgill Member differs in having a mostly aphanitic matrix.

In the western area as Point Peak sedimentation gave way to San Saba sedimentation, water depth increased slightly but not enough to inhibit the flourishing growth of stromatolites. Toward the end of San Saba deposition, shallowing again occurred, intraformational conglomerate indicative of intratidal conditions developed, and these conditions persisted well into deposition of the Threadgill.

In the eastern area where both the San Saba and Threadgill Members are mostly dolomite, sedimentary structures are not well preserved. However, the limestone in both is aphanitic and of a type that should form on banks beneath the level of the intertidal zone.

## COMPARISON OF RECENT SEDIMENTS AND MOORE HOLLOW GROUP ROCKS

The influence of wind on the source materials for sediments during early Paleozoic time must have been much greater than it is now because of the absence of vegetation. Absence of vegetation should result in wind action over a much wider range of moisture conditions than is possible at present. It is visualized that the minerals susceptible to weathering decayed and released the more resistant ones, such as quartz and microcline, to be moved about by wind and water.

The source area for the terrigenous material in the Moore Hollow Group was a granitic cratonic area of fairly low relief in which microcline is abundant. The microcline because of its cleavage was soon reduced to silt, and the silt-sized quartz and microcline, as well as the clay from weathering, were blown away, much of it directly into the sea. Such a process could account for the silty unit of the Cap Mountain and the siltstone of the Point Peak.

The quartz that remained, constantly subjected to wind action, developed a high degree of rounding, and this well-rounded sand was flushed into the sea to be redistributed by marine currents. In succeeding periods, after vegetation reached a certain degree of development, it is unlikely that similar sedimentary source materials could have developed in quantities sufficient to produce deposits of the volume present in the terrigenous units of the Moore Hollow Group. It is unlikely that comparable marine terrigenous deposits are forming now.

The limestones also are different from those forming now. In discussing the thin-section data (p. 54), it was shown that a high percentage of thin sections contain pelmatozoan debris. It was also shown that the proportion of thin sections with pelmatozoan debris is highest for the Morgan Creek Limestone and lowest for the limestone in the Lion Mountain Member. The lower half of the Morgan Creek Limestone and most of the coarse-grained limestone in the rest of the Moore Hollow Group, except in the Lion Mountain, is composed predominantly of pelmatozoan debris.

The type of animal that furnished this vast amount of debris is unknown; however, cystoid calyxes were found at one level in the Point Peak Member, and a fossil of unknown affinities, apparently in symbiotic association with aphrosalpingoids and stromatolites, found near the top of the Morgan Creek Limestone, could have yielded similar debris. Trilobites furnished appreciable debris to the limestone of the Moore Hollow, and calcareous brachiopods were important in the upper half of the Morgan Creek Limestone. Of the chief kinds of animals that made up these limestones, only brachiopods are alive today and at present they are not known to be important limestone producers. Of the Pelmatozoa the only survivor is the Crinoidea and they first appeared in the Ordovician. Now crinoids live in colonies on some parts of the sea floor, but the nature of the deposits they form is unknown to the writer.

The stromatolitic limestones of the Moore Hollow Group are volumetrically important, but again I am unaware of similar limestone being formed today.

The aphanitic limestone in the San Saba Member of the eastern part of the Llano region appears to be the only rock in the Moore Hollow Group that has a counterpart in modern sedimentation. The origin of this type rock is treated by Cloud and Barnes (1948, p. 79–89) and the reader is referred to that publication.

## DEPOSITIONAL HISTORY

The first Paleozoic sea to invade Central Texas entered a region of about 800 feet maximum local relief, which is not far from the relief of the present surface of the Precambrian in this area. The climate also was probably similar to that of the present or slightly cooler, with enough moisture to weather plagioclase feldspar and biotite and release microcline and quartz to be moved about by wind and water. The action of wind is documented (Barnes and Parkinson, 1940) by a pavement of wind-abraded quartz pebbles which in at least one locality are undisturbed, indicating that they were protected by a covering of sand when the sea invaded. If eolian sandstone is preserved it must be of very local extent as none was identified in the various measured sections. However, all of the extremely well-rounded sand in the Hickory Sandstone and some of the less well-rounded sand was probably wind-abraded before being flushed or blown into the sea to be water deposited.

If the cuneiform markings in the lower part of the Hickory are ice crystal casts rather than some special type of burrow, then at times the lower part of the Hickory must have been barely awash and freezing was more severe than in this region now. From this time to the end of the Wilberns the climate probably warmed.

Subsidence continued at about the rate of sedimentation until the start of deposition of the Cap Mountain Limestone, at which time subsidence may have exceeded sedimentation, allowing the water to deepen. The silty zone of the Cap Mountain may have accumulated when the water was deepest, possibly as the result of a period of intense wind activity during which fine detritus was blown far to sea. Because of the widespread and uniform nature of this unit and its sterility, such an interpretation appeals to the writer more than one based on regression and transgression.

During or after the deposition of the silty unit, the rate of subsidence may have slowed, allowing sedimentation to decrease the depth of water, and conditions for trilobite growth progressively improved. Subsidence may have ceased entirely during Lion Mountain deposition, allowing enough time for the prolific development of glauconite found in this unit and for quartz sand to migrate across the essentially flat sea bottom and become intermingled with the glauconite.

Near the end of Lion Mountain sedimentation a slight emergence allowed variable amounts of erosion of the topmost beds of the Lion Mountain in the northwestern part of the Llano region and the start of the accumulation of the Welge to the southeast. Slow subsidence resumed and the Welge Sandstone spread northwestward following the shore and in turn was followed by the accumulation of the remarkably widespread and uniformly thick pelmatozoan limestone forming the lower half, or slightly less, of the Morgan Creek Limestone. Water depth, climate, and all other factors during this time must have been optimum for the growth of the animals from which the pelmatozoan debris was produced and for the growth of trilobites. The reddish-gray lower 25 feet or so of the Morgan Creek surely receives its color from incorporating hematitic material from the weathering and reworking of the glauconitic Lion Mountain.

At about the level of *Eoorthis,* conditions changed; the beds above this level are alternations of fine-grained and coarse-grained lithic types, and calcareous brachiopods become an important part of the fauna. Perhaps this change coincided with a cessation of subsidence, allowing the water to become shallower as sediment accumulated, or with the start of a cyclic period of climate, or possibly with a combination of these or other factors. Conditions favoring stromatolite growth started at about this time and continued through deposition of Moore Hollow and Ellenburger Group rocks.

Morgan Creek sedimentation ended with another but lesser flourish of pelmatozoan limestone production before the siltstone sedimentation of the Point Peak took over. Possibly local emergence with weathering at the end of Morgan Creek sedimentation accounts for the reddish color of the upper few feet of the Morgan Creek in the northeastern part of the Llano region.

Following deposition of the very uniform and widespread Morgan Creek Limestone, the type of sedimentation at any one time varies from place to place in the Llano region. The basal part of the Point Peak Member was deposited in extremely shallow water in the western area, and throughout the Llano region subsidence kept pace with sedimentation during most of Point Peak deposition, with the water deepening slightly toward the end. Wind, as is thought to be true for the Cap Mountain, appears to have been the agent of transportation for the silt, but the shore was much farther away during Point Peak deposition. This conclusion is supported by the finer grain size of the detrital feldspar in the Point Peak, indicating a greater distance of travel. The climate must have been drier also, as both the feldspar and mica are fresher and more abundant. The Point Peak thins rapidly in the southeastern part of the Llano region and perhaps is terminated in this direction by a northeast-southwest-trending stromatolitic barrier reef as postulated by Barnes (1959, p. 31).

In the western area subsidence near the end of Point Peak deposition exceeded the rate of sedimentation, and conditions in the San Saba Member became optimum for the growth of trilobites and the animals from which the abundant pelmatozoan debris in these rocks was derived. Toward the end of San Saba deposition the water grew shallow probably due to slowing of subsidence, allowing sedimentation to catch up to a point where intertidal conditions prevailed, and these conditions continued during much of the deposition of the Threadgill Member of the Tanyard Formation.

Exposed in northwestern Mason County is a great dolomitized stromatolitic reef which started its growth in the latter part of Point Peak sedimentation and continued almost through deposition of the San Saba. This exposure appeals to be part of a north-south-extending barrier reef (Barnes, 1959, p. 33) which separates the sandy San Saba to the west from the calcitic San Saba to the east.

Eastward in the Llano region the San Saba undergoes progressive changes: the limestone becomes aphanitic, shallow-water features are less abundant, dolomitization is more abundant, and the lower boundary of the San Saba Member drops until no Point Peak remains a short distance away in the subsurface. The aphanitic limestone is of a type that could develop in a bank-type environment, but there is no evidence of deeper water between the eastern and western areas. Therefore, this limestone probably was deposited in a shelf environment instead and possibly could have been winnowed from the coarser fossil debris to the west, but it seems more likely that most of it was formed near where it is now found.

Possibly the water in the coastward area to the west, where life was so abundant, was maintained at the right salinity by the influx of fresh water either from rivers or coastal rainfall or both. Away from the coast calcite was precipitated through evaporation to form ooze inimical to most forms of life.

It was noted above that intertidal conditions prevailed in the western area during much of the deposition of the Threadgill Member of the Tanyard Formation. Eastward evidence of intertidal deposition soon disappears, and the limestone is almost identical to the limestone beneath in the San Saba of the extreme eastern part of the Llano region. There is little doubt that the two formed under similar conditions. The history of the rest of the overlying Ellenburger Group has been traced by Cloud and Barnes (1948).

## BIOSTRATIGRAPHY

Bell and Barnes (1961) submitted a paper on the "Cambrian of Central Texas" for the Cambrian Symposium held in connection with the 20th International Geological Congress in Mexico City in 1956. The paper was included in the third volume of the Symposium and was eventually published in Moscow. As Bell has not since enlarged on the treatment given at that time and the paper is not readily available, this section on Biostratigraphy and the one on Geologic History have been lifted in their entirety from the Symposium paper, except for correction of typographical errors, modernization of stratigraphic nomenclature, and a few other minor changes. Fossil names in the following text are those in use in 1956:

> In the Llano region of Central Texas a carbonate and terrigenous sedimentary rock sequence, averaging about 1,200 feet in thickness, formed in a shelf environment. This rock sequence, which is composed of seven members grouped in two formations, has an even more complete fossil record than is found in equivalent rocks of the upper Mississippi Valley type area.
>
> The lower (Riley) Formation records a transgressive-regressive cycle of marine sedimentation, followed by a disconformity and renewed transgression in the lower part of the overlying (Wilberns) Formation. An influx of silt from the northwest, near the middle of the Wilberns, and of sand from the west, in the upper part of the Wilberns, may record minor fluctuations without interruption of sedimentation within the Llano region.
>
> The biostratigraphy, in part essentially parallel to the lithostratigraphy, at many levels shows crosscutting relationship—for example, the *Bolaspidella* and *Cedarina-Cedaria* Zones in the Riley Formation pass laterally from sandy Cap Mountain Limestone in the south to Hickory Sandstone in the north, and the *Plectotrophia-Billingsella* Bed in the Wilberns Formation passes laterally from the silty Point Peak Member in the northwest to the dolomitic facies of the San Saba Member to the southeast.

### RILEY FORMATION

#### Dresbachian Stage

The only attempt at a complete biostratigraphic study of the Riley Formation has been by Palmer (1954), and the following account derives largely from his work. Approximate correlations can be made with the upper Mississippi Valley Croixan type area and with Montana (Lochman and Duncan, 1944), the only two areas from which comparable biostratigraphic detail is available.

Palmer recognized six faunal units in the Riley Formation. Their boundaries apparently very nearly parallel but do not coincide with the predominant grain size changes in the terrigenous components of the Riley Formation and therefore cross-cut the carbonate-noncarbonate boundaries of the defined mappable members [fig. 12].

The lowest zonal unit is that of *Bolaspidella,* whose species dominate the zone in numbers of specimens and in breadth of geographic distribution. The zone cross-cuts the Hickory—Cap Mountain boundary but lies wholly within arenaceous strata. Whether *Bolaspidella* should be regarded as Albertan or Croixan in age is unsettled, but if it is to be assigned to the Croixan, then the Dresbachian stage must be expanded downward to include it, for the genus is unknown in the type Croixan area. The Zone correlates in part with the lower *Cedaria* subzone of Lochman and Duncan (1944).

The *Cedarina-Cedaria* Zone lies in the upper part of the Hickory and the lower arenaceous part of the Cap Mountain Member. It is faunally distinct from the underlying *Bolaspidella* Zone except for *Kormagnostus simplex,* but its top is arbitrarily defined by the highest occurrences of *Cedaria eurycheilos, Syspacheilus* cf *S. camurus* or *Meteoraspis* cf. *M. metra.* Except at the top, any given collection from this zone contains only two or three species; the composite fauna numbers about 17 species, of which at least 7 range upward into the overlying zone. The zone correlates approximately with the middle *Cedaria* Zone of Lochman and Duncan, and its upper part, identified by *Cedaria,* corresponds to the *Cedaria* Zone of the Croixan type area.

The overlying *Coosella* and *Maryvillia* Zones, which might with some justification be collectively called the *Tricrepicephalus* Zone, contain a composite fauna of some 37 species, of which at least 5 species and 8 genera are common to both zones. The *Coosella* Zone is defined primarily by the range of several species of that genus and *Meteoraspis metra* and secondarily by the presence of *Coosia connata, Arcuolimbus convexus, Tricrepicephalus texanus,* and *Llanoaspis modesta.* The *Maryvillia* Zone is defined by the range of that genus and of *Coosia* cf. *C. albertensis* and by the presence of *Llanoaspis undulata* and *L. peculiaris.* The two zones lie essentially within the silty and overlying non-arenaceous parts of

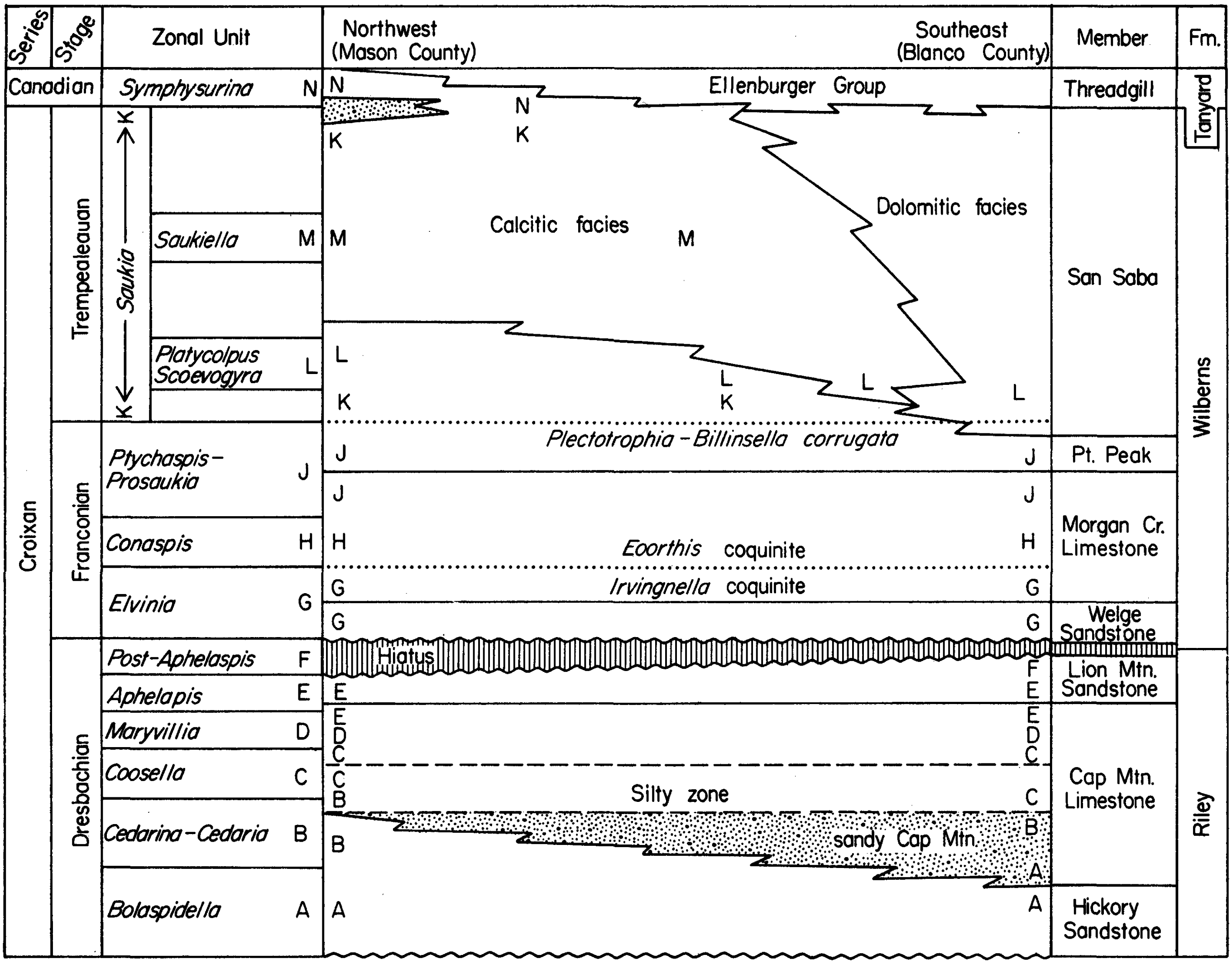



**Figure 12. Correlation of Croixan series within Llano region.**

the Cap Mountain Member and correlate approximately with the *Crepicephalus* Zone of the type Croixan area and with the upper *Cedaria* subzone and *Crepicephalus* Zone of Lochman and Duncan in Montana.

Above the *Maryvillia* Zone is an abrupt and almost complete change of faunal aspect among the trilobites, not only at the generic and specific level but at the family level as well. Only *Pseudagnostus* and *Crepicephalus* are exceptions, and in both instances a questionable generic assignment is involved. Palmer recognized two assemblages above *Maryvillia* within the Riley Formation: *Aphelaspis* and post-*Aphelaspis* Zones. The former (and lower) is characterized by some 18 species, of which at least 5 range above it, but is defined arbitrarily by the range of *Aphelaspis* associated with *Angulotreta triangularis*. The overlying zone is characterized literally by a post-*Aphelaspis* assemblage: *Apsotreta expansa* and three species of trilobites in addition to the four that range from below. The conclusion that the combined upper *Aphelaspis* and post-*Aphelaspis* Zones in Central Texas very nearly bridge the distinct hiatus between Dresbachian and Franconian stages in the Croixan type area is supported by the facts that the post-*Aphelaspis* Zone is present where the Lion Mountain Member is thickest (45 feet or more) and where also evidences of unconformity are least apparent; and that at least three of its genera are characteristic also of the overlying *Elvinia* Zone in the Wilberns Formation.

Close biologic affinities are evident between faunas of the Riley Formation and those of the Dresbach Formation of Minnesota and Wisconsin, as they are to an even greater degree with the faunas of the Pilgrim Limestone in Montana. Faunal associations in the three areas are somewhat different, and consequently correlations of zonal units are approximate—which is not at all surprising. It is reasonable to suppose that the Riley and Dresbach Formations are results of the same transgressive-regressive cycle of sedimentation, that the Riley represents a somewhat longer depositional history than does the Dresbach, and that somewhere within the middle parts of both is an unidentifiable zone of precise temporal contemporaneity.

However, it is not reasonable to equate *Cedaria* and *Aphektspis* of Texas with *Cedaria* and *Aphelaspis* of the upper Mississippi Valley in any but very approximate temporal terms. Even a cursory inspection of Palmer's range chart (1954, Table III) reveals that, almost without exception, every trilobite family is restricted to one of three phases of the Riley Formation: the transgressive arenaceous phase (Cedariidae, Menomoniidae), the arenaceous regressive phase (Ptychopariidae), or the middle silty and glauconitic carbonate phase (Asaphiscidae, Coosellidae, Llanoaspidae, Norwoodiidae, Tricrepicephalidae). In fact, the associations are so striking that the few outstanding exceptions suggest certain questions: Should the family assignments of *Syspacheilus* and *Densonella* be reevaluated? Do the specimens of *Blountia nixonensis* collected at least 30 years ago from an isolated locality properly belong with *Aphelaspis?* Were the Agnostidae pelagic?

The close correspondence between the distribution of major biologic groups and quartz sand in the Riley Formation suggests to us that ecology, not age, is primarily responsible for the faunal sequence within the Dresbachian stage. If this is so, the resolving power of a Dresbachian zone in terms of biochronology is not as precise as is one of Arkell's 55 world-wide Jurassic ammonite zones (Jeletzky, 1956, p. 693). Or is it?

## WILBERNS FORMATION
### Franeonian Stage

The lowest faunal assemblage thus far identified in the Wilberns Formation is that of the *Elvinia* Zone of the Cambrian Correlation Chart (Howell et al., 1944; Wilson, 1949). The fauna, consisting of about 20 species, is remarkably similar in almost all respects to that from the Franconia Formation of Minnesota described by Bell, Feniak, and Kurtz (1952). Several of its genera (*Cheilocephalus, Dunderbergia, Pterocephalia*) make their first appearance in the underlying *Aphelaspis* Zone in the Riley Formation. All trilobite species and the inarticulate brachiopod *Linnarssonella* apparently are restricted to the zone. Its upper limit includes an essentially continuous sheet of *Irvingella* coquinite a few inches thick. We do not subscribe to the practice (Howell et al., 1944; Wilson and Frederickson, 1950) of labelling this coquinite a zone or even a subzone; it cannot conceivably be a biochronologic unit except very locally. The *Elvinia* fauna occurs throughout the Welge Sandstone and lower Morgan Creek Limestone; the coquinite lies 60 feet above the base of the Morgan Creek Limestone on the east side of the uplift and 40 feet above it on the west side. The rate of convergence seems to be constant.

The overlying *Conaspis* Zone thickens from 30 feet on the east to 50 feet on the west, thus compensating for the thinning of the *Elvinia* Zone westward, and consequently the top of the *Conaspis* Zone maintains a level remarkably close to 90 feet above the base of the Morgan Creek Limestone Member.

The fauna of the *Conaspis* Zone has much in common with that of the Croixan type area (Nelson, 1951; Bell, Feniak, and Kurtz, 1952; Berg, 1953), but there are also striking differences. At the base throughout the Llano region is an *Eoorthis* coquinite a few inches thick; the combined *Irvingella* and *Eoorthis* coquinites rarely reach 1 foot in thickness. Bell (1950, p. 493) has interpreted the coquinites as the record of migrating contiguous biotopes and continues to hold this conviction. The *Eoorthis* coquinite consists mainly of the large valves of *Eoorthis remnicha,* but the brachiopods *E. indianola, Billingsella coloradoensis, Ceratreta hebes,* and a new species of *Angulotreta* are abundant. *Eoorthis indianola* and *Angulotreta* are common also in the *Irvingella* coquinite, and *Angulotreta* ranges upward through most of the *Conaspis* Zone. Occasional specimens of *Irvingella, Berkeia* (*Sulcocephalus* Wilson), and *Comanchia* occur with *Eoorthis remnicha* in the basal inch of the *Eoorthis* coquinite, and *Parabolinoides hebes* is not uncommon in the upper part of the coquinite and in overlying beds. This pattern of distribution is more reasonably explained by ecologic rather than temporal isolation.

*Parabolinoides, Bemaspis,* and *Orygmaspis* characterize the lower *Conaspis* Zone, and *Taenicephalus* dominates the upper part. *Billingsella coloradoensis, Huenella texana, Wilbernia expansa,* and *Pseudagnostus josepha* range into the overlying zone. *Conaspis, Croixana,* and other genera so abundant in the upper Mississippi Valley have not been identified in Central Texas. The top of the zone is arbitrarily drawn at the highest occurrence of *Taenicephalus.*

The *Ptychaspis-Prosaukia* Zone of the Cambrian Correlation Chart (Howell et al., 1944) is identified in Central Texas primarily by the combined and essentially equal ranges of *Ptychaspis* and *Idahoia.* Apparently *Ptychaspis* and *Prosaukia* subzone components are present, the latter defined, as it is in the upper Mississippi Valley, by the full range of *Chariocephalus* associated with *Prosaukia.* Four species, already mentioned, range into the zone from below, but none of the 24 species currently identified in the zone ranges above it. Any subdivisions of the zone, be they subzones or zonules, must be arbitrarily defined on selected taxons; overlapping ranges is the rule, not the exception.

The *Ptychaspis-Prosaukia* Zone incorporates thicknesses of strata that range from slightly over 100 feet in the western part of the uplift to slightly over 200 feet in the eastern part. Thus the top of the zone lies below the middle of the Point Peak Member to the west and near its upper boundary to the northeast; at White Creek in the southeast it lies well up in the dolomitic facies of the San Saba Member. Consequently the faunas characterizing this zone occur in limestone of the Morgran Creek, siltstone and limestone of the Point Peak, and dolomite of the San Saba.

Fossils are rare and sporadically distributed in the siltstone of the Point Peak, and most of the identifiable specimens have been collected from thin limestone and intraformational conglomerate beds. The top of the *Ptychaspis-Prosaukia* Zone over much of the Llano uplift is marked by a few feet of limestone characterized by abundant silicified valves of *Plectotrophia alata* and *Billingsella corrugata.* It is an important stratigraphic marker, has been mapped over long distances by Barnes, and has been discussed by Bridge, Barnes, and Cloud (1947) and by Cloud and Barnes (1948). Associated with the brachiopods is a trilobite assemblage that includes species of *Ptychaspis, Chariocephalus, Prosaukia,* and *Dikelocephalus.* This association is incompatible with currently accepted definitions of the Franconian and Trempealeauan stages (Raasch, 1952) but presumably is compatible with the earlier classification of the Cambrian Correlation Chart (Howell et al, 1944).

When rock terminology was divorced from faunal terminology in the Croixan type area, it was evident that the most reasonable (biologic) base of the Trempealeauan stage *(Saukia* Zone of Raasch, 1952) was the *Dikelocephalus postrectus* Zone (Howell et al., 1944), which Raasch (1952, p. 149) renamed the *Saukiella minor* zonal unit. The occurrence in Central Texas of *Dikelocephalus* associated with *Ptychaspis* and *Chariocephalus* presents a paradox in terms of any definition derived from the Croixan type area but in our opinion is expectable during conformable deposition of sedimentary strata in widely separated areas. Any definition involving a Franconian-Trempealeauan boundary will be of necessity arbitrary, and for the present we choose to place the *Plectotrophia-Billingsella* assemblage in the Franconian Stage.

### Trempealeauan Stage

Trempealeauan faunas occur above the *Plectotrophia-Billingsella* Bed and below a Lower Ordovician assemblage in the upper San Saba Member, and therefore to the Trempealeauan are assigned strata belonging to the Point Peak Member and to both calcitic and dolomitic facies of the San Saba Member. No satisfactory zonal subdivision has been attained in Central Texas, and comparisons with the Trempealeauan of the upper Mississippi valley are very general. Evidently most Trempealeauan genera range through all or most of the stage (Howell et al., 1944; Raasch, 1952, p. 148–149), and the 14 zonal units defined by Raasch and based on species are not likely to be recognized outside of the type area. Nelson (1956, p. 171–172) recognized some of the more broadly defined zonal units of the Cambrian Correlation Chart (Howell et al., 1944), and two of them (*Platycolpus-Scaevogyra* and *Saukiella*) can be roughly approximated in Central Texas.

The *Platycolpus-Scaevogyra* assemblage, which occurs through 50 or more feet of strata in the upper part of the Point Peak Member and the lower part of the San Saba Member, appears to be invariably associated with stromatolitic carbonate—as it is also in the upper Mississippi Valley. Well above the *Platycolpus-Scaevogyra* assemblage and known through 30 to 60 feet near the middle of the San Saba calcitic facies in the western part of the uplift, is an assemblage characterized by abundant *Saukiella.* Upper Wilberns strata are rarely abundantly fossiliferous, and although the Trempealeauan fauna numbers at least 25 species, the two assemblages mentioned above are the only ones known to have some degree of stratigraphic identity.

### Lower Ordovician Series

Upper calcitic San Saba strata are characterized by a Lower Ordovician faunal assemblage in five measured sections on the western side of the Llano region. The assemblage is dominated by the trilobites *Missisquoia, Symphysurina,* and *Hystricurus* and by the brachiopod *Apheoorthis.* The following compound numbers provide pertinent data presently available at each of the measured sections; the first number records the thickness of San Saba strata containing the assemblage, and the second records the barren interval between lowest Ordovician and highest Cambrian fossils: Calf Creek 62–23, Leon Creek 76–22(?), James River 65–69, Camp San Saba 91–10, Threadgill Creek 35–10. Barren intervals at the first three localities are accounted for mainly by quartz sandstone, but no sandstone is present at Camp San Saba or Threadgill Creek.

The trilobites listed above are commonly assumed (Lochman and Duncan, 1944, p. 4; Lochman and Duncan, 1950, p. 350–351; Ross, 1951, p. 25–32; Hintze, 1952, p. 5–6; Twenhofel et al., 1954) to characterize lowest Ordovician rocks in North America. Occurring 10 to 15 feet below them at Camp San Saba and Threadgill Creek are such typical Trempealeauan genera as Briscoia, *Calvinella, Corbinia, Euptychaspis, Eurekia, Prosaukia,* and *Saukia.* Although the faunal change appears to be complete, there is no evidence of any discontinuity in deposition of intervening strata. Those stratigraphers or paleontologists who would seize upon this faunal change as evidence for unconformity should recollect (1) that the change is rib greater than that at the *Maryvillia-Aphelaspis* and *Elvinia-Conaspis* zonal boundaries and (2) that at least three trilobite genera occur below and above the Dresbachian-Franconian unconformity.

# GEOLOGIC HISTORY

## RILEY FORMATION

Paleozoic sedimentation began in Central Texas in latest Middle Cambrian or earliest Late Cambrian time as a sea spread northward across an area of Precambrian igneous and metasedimentary rocks having local relief as great as 800 feet. Locally derived residual material, principally quartz in part wind abraded, constitutes a thin cobble conglomerate almost everywhere at the base of the Hickory Sandstone Member.

The Riley Formation, ranging in thickness from 800 feet along the south edge of the Llano region to 600 feet along the north edge, represents a transgressive-regressive cycle of marine sedimentation. It is bounded below by the Precambrian nonconformity and above by the Dresbachian-Franconian regional disconformity. Assuming that faunal zones are approximately contemporaneous in the area being considered here, control is sufficient to justify the following conclusions with respect to depositional history of the Riley Formation.

Quartz sandstone accumulated in a transgressing sea whose strandline probably was more nearly east-west than it was northeast-southwest. Deposition kept pace with depression resulting in a rather constant and shallow depth of water all over Central Texas; consequently uppermost sandstone beds in the vicinity of buried hills contain pebbles as large but not as abundant as those in the basal conglomerate. By the end of *Cedarina-Cedaria* time, or slightly later, sand-size quartz ceased to reach Central Texas, and through most of *Coosella* time the only terrigenous material deposited was silt. The top of the silt roughly parallels the top of the sand and both surfaces tend to parallel if not coincide with boundaries of faunal zones.

During *Bolaspidella* time carbonate together with quartz sand began to accumulate along an east-west line between White Creek and Threadgill Creek. The margin of carbonate deposition moved slowly northward and by the end of *Cedarina-Cedaria* time had reached a line between Little Llano River and Pontotoc. Consequently a northward-thinning wedge of calcareous sandstone and sandy limestone accumulated; to the south it is included as the lower part of the Cap Mountain and is thus laterally equivalent to much of the upper part of the Hickory to the north. Faunal planes cross northward from sandy Cap Mountain into noncalcareous Hickory.

During *Maryvillia* time the marine transgression reached its maximum, and the strandline was many tens of miles north of the Llano region; fragmental fossiliferous and glauconitic limestone of the upper part of the Cap Mountain above the "silty zone" accumulated in Central Texas. These sediments accumulated either farther from shore or in deeper water, or both, than did any others in the Riley Formation.

Near the beginning of *Aphelaspis* time either uplift or eustatic lowering of sea level drove the strandline southward and revived a shallow and/or nearshore depositional environment. Supporting evidence is the influx of quartz sand that coarsens upward, increased high-angle cross-lamination, tangential lenses of dismembered and current-transported trilobite tests and linguloid brachiopod shells, and an over-all decline in carbonate content. Simultaneously, pelletized glauconite grains accumulated in sufficient quantity to produce a greensand, supporting but not confirming a regressive, wave-agitated depositional environment. That part of the deposit just described which lacks continuously bedded carbonate erodes to a flat bench and supports sparse vegetation; it is defined as the Lion Mountain Sandstone and its base is stratigraphically erratic.

Paleontologic evidence (post-*Aphelaspis* "zone") indicates that 10 to 20 feet of Lion Mountain strata that are younger than any found elsewhere are present at James River, Threadgill Creek, White Creek, and Morgan Creek. Evidently the strandline swung more nearly northeast-southwest during regression, deposition continued longer in the southeastern quadrant, and more Lion Mountain was removed by erosion in the northwestern quadrant of the Llano region. The fact that the overlying Welge Sandstone is glauconitic at Morgan Creek, White Creek, and in the Magnolia Petroleum Company No. 1. Below well, Kendall County, suggests that deposition was very nearly continuous in the southeastern part of the region.

This regression closed Dresbachian history in Central Texas.

## WILBERNS FORMATION

The Dresbachian-Franconian disconformity present in Central Texas beneath the Wilberns Formation has been recognized at several places on the North American craton. Nowhere is there evidence of substantial erosion of underlying rock, nor does the faunal hiatus appear to be great. Central Texas lay on a shelf closely adjacent to a geosyncline to the south or southeast, and the faunal hiatus in the Llano area apparently is less than it is in the upper Mississippi Valley. The Lion Mountain and Welge as revealed by the drill merge southward and become finer grained as the area of continuous deposition is approached.

Over most of the Llano region the Welge Sandstone is clearly transgressive across a surface either of marine or subaerial erosion. Some relief on that surface is indicated by small and erratic differences in thickness of the Welge; in the Little Llano River area thicknesses of 27 and 15 feet occur less than a mile apart. As the Franconian transgression began, topographic depressions on the Lion Mountain were quickly filled, and probably a flat profile of equilibrium, similar to that on top of the sandy Cap Mountain, was attained either at the top of the Welge or in the lower 10 to 20 feet of sandy Morgan Creek.

The environment in which the noncalcareous quartz sandstone of the Welge accumulated was quickly succeeded over Central Texas by a remarkably uniform environment in which, on the average, 130 to 140 feet of fossiliferous, glauconitic Morgan Creek calcarenite accumulated. Faunal control in the Morgan Creek is good, and faunal planes not only tend to parallel each other but very nearly parallel the base and top of the member. Welge Sandstone and the lower 40 to 60 feet of Morgan Creek Limestone accumulated during *Elvinia* time, and the overlying 50 to 30 feet of limestone accumulated during *Conaspis* time. These compensatory changes in thickness, producing a remarkably constant 90 feet of limestone in the combined *Elvinia* and *Conaspis* Zones, can be explained either by differential rates of deposition in remarkably delicate balance, or by assumption that *Elvinia* and *Conaspis* "times" were in fact partly contemporaneous. The latter possibility deserves critical appraisal and is consistent with Bell's (1950, p. 493) interpretation that the *Irvingella* and *Eoorthis* coquinites constitute the record of migrating contiguous biotopes.

Deposition of Morgan Creek calcarenite in the Llano region ceased about the middle of *Ptychaspis-Prosaukia* time. In the upper part of the member, notably in the western sections, a few small stromatolitic bioherms and thin biostromes are forerunners of a new biologic factor that was to disrupt the rather simple depositional pattern thus far characteristic of Cambrian strata in Central Texas.

Several factors combine to militate against a satisfactory reconstruction of Wilberns depositional history above the Morgan Creek Limestone. An influx of silt resulted in the Point Peak Member, which not only is poorly fossiliferous, but erodes to flat benches or gentle slopes that are in large part covered. Biohermal development not only produced an erratic pattern of Point Peak terrigenous deposition but also makes it difficult to pick stratigraphically consistent Point Peak boundaries. Dolomitization of the San Saba, particularly on the eastern side of the uplift where the member occurs typically in its dolomitic facies, has obliterated not only fossils but most megascopic original depositional texture and structure. Finally, the calcitic San Saba in the northeastern sections, where it is overlain by the dolomitic facies, is essentially unfossiliferous except for small spherical stromatolites called girvanella.

The Point Peak Member represents a temporary influx of silt, probably mainly from the northwest or west, and its wave-agitated, shallow-water depositional environment was conducive to the development of ripple marks, intraformational conglomerate, and stromatolitic bioherms and biostromes. Silt deposition was initiated in middle *Ptychaspis-Prosaukia* time and continued well into the Trempealeauan; it continued through the *Platycolpus-Scaevogyra* horizon in western sections but teased prior thereto in the eastern sections If faunal lines are synchronous in this part of the sequence, silt deposition persisted considerably longer in the western than in the eastern Llano region The Point Peak thins sharply in the two most southeasterly sections (White Creek and Scott Klett), and it may be no coincidence that only in these two sections is the Point Peak directly overlain by dolomitic San Saba

Point Peak conditions were followed by a return to a carbonate depositional environment that in the westtin Llano region resulted in strata much like Morgan Creek Limestone, differing principally in the presence of abundant stromatolities and intraformational conglomerate

In the eastern Llano region girvanella-bearing calcitic San Saba is replaced laterally and vertically by dolomite containing abundant chert This chert, notably in the Morgan Creek area, preserves stromatolitic structures suggesting that part of the dolomitic San Saba originally was biohermal in origin

Deposition of calcitic San Saba strata was demonstrably continuous into the Ordovician in the western part of the Llano region Unfortunately, upper Trempealeauan fossils are essentially nonexistent in both calcitic and dolomitic San Saba strata in the eastern sections, and depositional history cannot be interpreted in terms of biostratigraphic framework

## PALEONTOLOGY

Mapping in the Central Texas area was started by Barnes in 1939 and during the initial stage of this work Josiah Bridge of the U. S. Geological Survey furnished fossil identifications. Later, Bell developed a program on the paleontology of Moore Hollow rocks and gradually took over fossil identification where needed. While Bell was in military service, during World War II, Dr. Preston E. Cloud, Jr., U. S. Geological Survey, and Barnes were associated in a study of the Ellenburger Group. During this time Cloud identified fossil collections from the upper part of the Point Peak Member and from the San Saba Member, and since has aided in an understanding of some trace fossils and problematica.

Also, for specific fossils we acknowledge with gratitude the identification and publication on bellerophont gastropods by Dr. J. Brookes Knight, U. S. National Museum; on cephalopods and some problematica by Dr. Rousseau H. Flower, New Mexico Bureau of Mines and Mineral Resources; and on *Matthevia* by Dr. Ellis L. Yochelson, U. S. Geological Survey. Cystoids collected from the Point Peak Member were in the hands of Dr. Edwin Kirk, U. S. National Museum, at the time of his death. Through the office of Dr. G. A. Cooper this material was sent to Dr. Gerhard Regnéll, Department of Paleontology, University of Lund, who proposes publication in the future. The specimens were returned to the U.S. National Museum in 1971.

Most of the paleontologic work involving Moore Hollow Group rocks has been done by graduate students under the direction of Bell since the 1940's. Published work by others will be reviewed briefly, followed by a review of published work by Bell's students.

Roemer (1849, 1852) was the first to describe fossils from rocks here termed the Moore Hollow Group. Fossils described include a phosphatic brachiopod, *Lingulepis acutangula* (Roemer), and the trilobites *Pterocephalia sanctisabae* Roemer, and *Elvinia roemeri* (Shumard).

Shumard (1861) described nine new species of Cambrian fossils from Morgan and Clear Creeks, Burnet County. These fossils are listed as follows:

| Fossil name | Present designation |
|---|---|
| *Agnostus coloradoensis* | *Geragnostus coloradoensis* (Shumard) |
| *Arionellus (Bathyurus) texanus* | *Tricrepicephalus texanus* (Shumard) |
| *Arionellus (Bathyurus) planus* | Never updated, probably unrecognizable |
| *Conocephalites depressus* | *Aphelaspis walcotti* Resser |
| *Conocephalites billingsi* | Never updated, probably unrecognizable |
| *Dikelocephalus roemeri* | *Elvinia roemeri* (Shumard) |
| *Discina microscopica* | *Angulotreta microscopica* (Shumard) |
| *Camerella* (sp.?) | Indeterminate, never updated |
| *Capulus* ( sp.?) | Indeterminate, never updated |

Walcott (1890) collected fossils from Packsaddle Mountain, Llano County and from "Tatur Hill" (probably Potatotop of Burnet 30-minute quadrangle) and Morgan Creek, Burnet County. He described the following fossils:

| Fossil name | Present designation | Locality |
|---|---|---|
| *Platyceras texanum* | Same | Packsaddle Mountain |
| *Ptychoparia burnetensis* | *Bolaspidella burnetensis* (Walcott) | "Tatur Hill" |
| *P. llanoensis* | *Orygmaspis llanoensis* (Walcott) | Packsaddle Mountain |
| *P. ?metra* | *Meteoraspis metra* (Walcott) | "Tatur Hill" |
| *P. pero* | *Wilbernia pero* (Walcott) | Morgan Creek |
| *P. suada* | *Dellea suada* (Walcott) | Morgan Creek |
| *P. ?urania* | *Burnetiella urania* (Walcott) | Packsaddle Mountain |
| *Illaenurus? dia* | *Macelloura dia* (Walcott) | Morgan Creek |

Walcott (1914) referred *Dikelocephalus roemeri* (Shumard) to *Ptychoparia,* and later he made it the type species of his new genus *Elvinia* (1924, 1925). He identified Roemer's type species, *Pterocephalia sanctisabae* Roemer, from material collected in Burnet County (1912). He also redescribed and figured *Lingula acutangula* (now *Lingulepis acutangula* (Roemer)) (1898–1912).

Dake and Bridge (1932) found two species of *Saukiella,* two species of *Scaevogyra,* fragmentary trilobites which may be referred to *Plethometopus, Stenopilus, Euptychaspis typicalis* Ulrich, and a fragmentary pygidium referable to *Plethopeltis* in rocks of Cambrian age in Central Texas.

Bridge and Girty (1937) redescribed Roemer's Paleozoic types from Texas and listed the following species:
*Lingulepis acutangula* (Roemer)
*Elvinia roemeri* (Shumard)
*Aphelaspis depressa* (Shumard)=*Aphelaspis walcotti* Resser
*Idahoia?* sp.

An important publication on the paleontology of Riley rocks is that of Lochman (1938), who described the *Cedaria, Crepicephalus,* and *Aphelaspis* faunas. She identified the following species:

| Lochman identification | Present identification |
|---|---|
| ***Cedaria* Zone** | |
| *Cedaria burnetensis* (Walcott) | *Bolaspidella burnetensis* (Walcott) |
| *Tricrepicephalus texanus* (Shumard) | same |
| *Norwoodia tenera* Walcott | *Hardyoides tenera* (Walcott) |
| *Deiracephalus aster* (Walcott) | same |
| *Millardia avitas* Walcott | *Densonella avitas* (Walcott) |
| *Millardia magnagranulata* Lochman | *Densonella magnagranulata* (Lochman) |
| *Kingstonia texana* Lochman | *Kingstonia* (Ucebia) *texana* (Lochman) |
| *Meteoraspis bipunctata* Lochman | *Meteoraspis metra* (Walcott) |
| *Coosia* sp. | same |
| *Coosella* sp. | same |
| *Agnostus* sp. | same |
| *Acrotreta* sp. | *Angulotreta* sp. |
| ***Crepicephalus* Zone** | |
| *Crepicephalus auratus* Lochman | same |
| *Crepicephalus* undet. two sp. | same |
| *Tricrepicephalus* cf. *T. dis* (Walcott) | same |
| *Llanoaspis modesta* (Lochman) | same |
| *Llanoaspis undulata* Lochman | same |
| *Kingstonia pontotocensis* Lochman | *Kingstonia* (Ucebia) *pontotocensis* (Lochman) |
| *Pemphigaspis inexpectans* Lochman | same |
| *PMeteoraspismetra* (Walcott) | same |
| *Coosia* sp. | same |
| *Coosella* sp. | same |

| | |
|---|---|
| Two genera of agnostian trilobites | same |
| *Billingsella* sp. | same |
| *Aphelaspis* Zone | |
| *Aphelaspis depressa* (Shumard) | *Aphelaspis walcotti* Resser |
| *Aphelaspis* four n. sp. | same |
| *Pseudolisania texana* Lochman | *Cheilocephalus breviloba* (Walcott) |
| *Pseudolisania raaschi* Lochman | *Cheilocephalus breviloba* (Walcott) |
| *Raaschella ornata* Lochman | *Glaphyraspis ornata* (Lochman) |
| *Blountia* sp. | same |
| *Agnostus* sp. | same |
| *Lingulella arguta* (Walcott) | same |
| *Lingulepis* sp. | same |
| *Acrotreta* sp. | *Angulotreta* sp. |

Decker (1945) described graptolites from a 6- to 10-inch, greenish-gray shale bed in the Point Peak Member about 4,000 feet from the mouth of Honey Creek, Mason County (loc. 159T-5–50A of Barnes and Bell, 1954a). The following species of graptolites were described from this locality:

*Dendrograptus edwardsi* var. *major* Ruedemann
*D. hallianus* var. *wilbernsensis* Decker
*D. helenae* Decker
*D. hilswecki* Decker
*D.* cf. *kindlei* Ruedemann
*D. minutus* Decker
*D. thomasi* Ruedemann
*Callograptus* cf. *antiquus* Ruedemann
*C. minimus* Decker
*C. plummeri* Decker
*C. subtypicus* Decker
*Callodendrograptus elongatus* Decker
*C. robustus* Decker
*C. rogersi* Decker
*C. sellardsi* Decker
*C. sellardsi* var. *expansus* Decker
*C. semicircularis* Decker
*Dictyonema eominnesotense* Decker
*D. flexibilis* Decker
*D. maximus* Decker
*D.* cf. *schucherti* Ruedemann
*D.* cf. *wyomingense* Ruedemann
D. sp.
*Aspidograptus* sp.
*Haplograptus vermiformis* Ruedemann
*Acanthograptus* sp.
*Chaunograptus irregularis* Decker
*C. palaeodictyotoides* Decker
*Archaeocryptolaria gonothecatus* Decker
*A. simplicimus* Decker.

Knight (1947) described *Anconochilus barnesi* Knight collected from the dolomitic facies of the San Saba Member from locality 86T–2–14G on the Willow City quadrangle (Barnes 1952a). Knight also described *Sinuella minuta* Knight collected by Walcott from Potatotop Hill, Burnet County and from Packsaddle Mountain, Llano County. The precise stratigraphic level from which the type specimen of *Sinuella minuta* Knight came is unknown. If the collection from Burnet County is from Potatotop Hill of the Burnet 30–minute quadrangle, the fossils would be from somewhere in the lower 79 feet of the Cap Mountain Limestone; however, if the collection is from Potato Hill of the Council Creek 7.5-minute quadrangle, the fossils could be from the Morgan Creek Limestone or lower.

Flower (1954) described seven fossil specimens from the Moore Hollow Group. Two of these are cephalopods constituting a new genus and species, *Palaeoceras mutabile* Flower. The remaining five specimens were not considered to be cephalopoda and include two genera and three species as follows:

*Shelbyoceras ellinwoodi* Flower
S. *barnesi* Flower
S. cf. *barnesi* Flower
*Kygmaeoceras perplexum* Flower.

*Palaeoceras mutabile* Flower and the holotype of *Kygmaeoceras perplexum* Flower was collected by Howard Ellinwood from 1,393 feet in the Threadgill Creek section at a point 67 feet beneath the top of the San Saba Member. The paratype of *Kygmaeoceras* was collected by J. L. Wilson from near the top of the San Saba Member in the vicinity of the Camp San Saba section. All three species of *Shelbyoceras* are from locality 86T–5–13A in the Cave Creek School quadrangle (Barnes, 1967), eastern Gillespie County. This collection by Barnes and L. E. Warren (not Warren Anderson as stated by Flower) was made from chert in the dolomitic facies of the San Saba Member and contained in addition *Scaevogyra* and aff. *Plethopeltis.*

Flower (1964) and Barnes re-collected the “cephalopod bed” at 1,393 feet in the Threadgill Creek section and obtained 14 additional cephalopod specimens representing 3 genera and 4 species as follows:

*Palaeoceras mutabile* Flower
*P. undulatum* Flower
*Plectronoceras exile* Flower
*Balkoceras gracile* Flower.

On the basis of the morphology of *Balkoceras,* Flower indicates that *Shelbyoceras* may be a cephalopod after all. Flower (1964, p. 31), in connection with locality data for *Plectronoceras exile*, states: “The holotype … is from the cephalopod bed, now closer to 30 feet than 67 feet, the previous estimate, below the top of the San Saba Limestone. . . .” Flower has equated the upper boundary of the San Saba Member with the top of the Cambrian; whereas Bell and Barnes (1961) distinctly show that the upper part of the San Saba Member in the western part of the Llano region is Ordovician in age.

Yochelson, Marek, and Flower (1969) redescribed *Kygmaeoceras* and assigned it to the Hyolitha.

Yochelson, McAllister, and Reso (1965) and Yochelson (1966) illustrate *Matthevia variabilis* Walcott collected by L. H. Dixon and Barnes from the dolomitic facies of the San Saba Member along the west side of a pasture road, 1 mile west of the Blanco County line and 3,400 feet north of North Grape Creek, Gillespie County, Texas. This material is from locality 86T-2-1F, Rocky Creek quadrangle and was originally identified by Dr. Josiah Bridge, U. S. Geological Survey (Barnes, 1965b).

Published work by Bell’s students will be considered next. In connection with his stratigraphic studies, Barnes measured sections of Moore Hollow Group rocks wherever he could find well-exposed stratigraphic sequences in the Llano region. The first section measured, described, and collected for fossils was the portion of the Threadgill Creek section in Gillespie County. James Lee Wilson (1949) in 1942 collected 11 sections of the *Elvinia* zone around the Llano region, including the Threadgill section which was the only one completed by Barnes at that time. Fossils already collected were turned over to Wilson for his use.

In his study of the *Elvinia*-Zone trilobite fauna Wilson described 16 species of which 3 belonged to new genera and 4 were new species. The fossils described are listed as follows:

| *Wilson identification* | *Present identification* |
|---|---|
| *Acrocephalites lataegenae* Wilson | *Cliffia lataegenae* (Wilson) |
| *Berkeia glabellamersa* Wilson | *Dellea saratogensis glabellamersa* (Wilson) |
| *Burnetia urania* (Walcott) | *Burnetiella urania* (Walcott) |
| *Camaraspis convexa* (Whitfield) | same |
| *Cheilocephalus* sp. | same |
| *Dellea wilbernsensis* Wilson | *Dellea suada* (Walcott) |
| *Dokimocephalus intermedius* (Resser) | same |
| *Elvinia roemeri* (Shumard) | same |
| *Iddingsia nevadaensis* Resser | *Iddingsia robusta* (Walcott) |
| *Irvingella burnetensis* Resser | *Irvingella major* Ulrich & Resser |
| *Irvingella media* Resser | *Irvingella major* Ulrich & Resser |
| *Kindbladia wichitaensis* (Resser) | same |
| *Plataspella anatina* (Resser) | same |
| *Pterocephalia sanctisabae* Roemer | same |
| *Ptychopleurites amplooculata* Frederickson | *Comanchia amplooculata* (Frederickson) |
| *Xenocheilos minutum* Wilson | same |

During the interim while Bell was away from The University of Texas, Gaines (1951) made a statistical study of *Irvingella*. He concluded that “Some of the Texas species of *Irvingella* named by Resser in 1942 are invalid and should be referred back to *I. major*.”

The faunas of the Riley Formation were described by Palmer (1954) and the abstract from that publication follows with authors’ names inserted:

> Sixty-eight species of trilobites, 10 species of inarticulate brachiopods, 2 species of articulate brachiopods, 1 ostracode and fragments of sponges, pelmatozoan echinoderms and unidentifiable organisms constitute the faunas of the Riley Formation. The fossils were collected from 8 measured sections around the periphery of the outcrop area in Mason, Gillespie, Blanco, Burnet, Llano and San Saba Counties, Texas. All of the fossils are described and illustrated by stereophotographs. Two families, 4 genera and 16 species of trilobites, and 3 genera and 5 species of brachiopods are described as new. These are: Coosellidae, Tricrepicephalidae, *Crepicephalus australis* Palmer, *C.? perplexus* (now *Coosella perplexus* (Palmer)), *Cedaria eurycheilos* Palmer, *Arcuolimbus convexus* Palmer (genotype), *Bolaspidella prooculis* Palmer, *Aphelaspis constricta* Palmer, *A. longifrons* (now *Listroa longifrons* (Palmer)), *A. spinosus* Palmer, *Blandicephalus texanus* Palmer (genotype), *Dytremacephalus granulosus* Palmer (genotype), *D. laevis* Palmer, *Labiostria conveximarginata* (genotype) (now *Aphelaspis conveximarginata* (Palmer)), *L. platifrons* (now *Taenora platifrons* (Palmer)), *L. sigmoidalis* (now *Sigmocheilus sigmoidalis* (Palmer)), *Cheilocephalus* minutas Palmer, *Dunderbergia variagranula* Palmer, *Angulotreta triangularis* Palmer (genotype), *A. postapicalis* Palmer, *Apsotreta expansa* Palmer (genotype), *A. orifera* Palmer, *Opisthotreta depressa* Palmer (genotype). Most of the fossils are early Late Cambrian in age although some from the lower part of the formation may be latest Middle Cambrian in age. Six trilobite zones are recognized. These are, from oldest to youngest: *Bolaspidella, Cedarina-Cedaria, Coosella, Maryvillia, Aphelaspis* and post-*Aphelaspis*. Inarticulate brachiopods, sponge spicules and problematica obtained from residues of limestone digested in acetic or formic acid characterize zones in which boundaries are to some extent independent of those of the trilobite zones. The boundaries of the zones and the boundaries of the members and submembers of the Riley Formation do not coincide.

In addition to introductory remarks and systematic paleontology, Palmer in an appendix makes "a comparison of linear ratios and statistical data for the species of *Aphelaspis* described from the Riley Formation," gives "the known geographic distribution of the trilobite genera of the Riley Formation," gives "the known stratigraphic ranges of the identified fossils of the Riley Formation in Central Texas," and gives faunal lists for each collection according to its position in a measured section.

Upper Franconian and lower Trempealeauan Cambrian trilobites and brachiopods of the Wilberns Formation were described by Bell and Ellinwood (1962) and the abstract from that paper follows with authors' names inserted:

> Forty-three species of trilobites belonging to 28 genera, 12 species of brachiopods belonging to 8 genera, and 1 species of gastropod are described from the Morgan Creek, Point Peak, and San Saba members of the Wilberns Formation in the Llano uplift. Systematic descriptions include one new trilobite genus: *Stigmacephaloides* (type, S. *curvabilis,* n. sp.); six other new trilobite species: *Monocheilus truncatus* Ellinwood, *Rasettia magna* Ellinwood, *Parabolinoides granulosus* Ellinwood, *Conaspis masonensis* Ellinwood, *C. testudinatus* Ellinwood, *Keithiella scrupulosa* Ellinwood; one new brachiopod genus: *Pseudodicellomus* (type, *P. mosaicus);* two new brachiopod species: *Billingsella rhomba* Ellinwood, *B. texana* Bell; and one new brachiopod subspecies: *Billingsella corrugata inornata* Ellinwood. Neotypes are designated for *Angulotreta microscopica* (Shumard) and *Billingsella coloradoensis* (Shumard). Four trilobite genera are placed in synonymy: *Meeria* Frederickson (with *Idahoia), Minkella* Lochman & Hu (with *Saratogia), Bernia* Frederickson (with *Parabolinoides), Bemaspis* Frederickson (with *Taenicephalus).* All illustrations are stereographic.

Late Cambrian and Early Ordovician faunas from the Wilberns Formation were described by Winston (1957), Nicholls (1957), and Winston and Nicholls (1967) and the abstract from the latter paper follows:

> The San Saba Member of the Wilberns Formation of Central Texas is mostly coarse-grained, trilobitic limestone that grades eastward to dolomite and contains sandstone intervals in its westernmost exposures. Faunas from the limestone place the middle part of the San Saba within the Trempealeauan Stage (*Saukia* Zone) of the Upper Cambrian, but the uppermost part belongs to the Lower Ordovician. Three subzones within the *Saukia* Zone are described. In ascending order they are: the *Saukiella junia* subzone containing *Bayfieldia, Briscoia, Corbinia, Euptychaspis, Eurekia, Saukia, Saukiella, Stenopilus, Triarthropsis,* and *Finkelnburgia;* the *Saukiella norwalkensis* subzone containing *Bayfieldia, Bowmania, Briscoia, Calvinella, ?Dikelocephalus, Eurekia, Euptychaspis, Heterocaryon, Idiomesus, Keithiella, Leiocoryphe, Macronoda, Plethometopus, Prosaukia, Saukiella, Stenopilus, Theodenisia,* and *Finkelnburgia;* the *Corbinia apopsis* subzone containing *Acheilops, Apatokephaloides, Corbinia, Eurekia, Idiomesus, Leiobienvillia, Leiocoryphe, Plethometopus, Theodenisia, Triarthropsis, Apheoorthis, Finkelnburgia, Glyptotrophia,* and *Nanorthis.* Trilobites of the *Saukiella junia* and *Saukiella norwalkensis* subzones are closely allied to those of the Trempealeauan of the upper Mississippi Valley, whereas the trilobites of the *Corbinia apopsis* subzone represent an influx of the *Hungaia magnifica* fauna.
>
> The low Ordovician faunas are subdivided into two zones. The lower zone is named the *Missisquoia* Zone and contains *Highgatella, Homagnostus, Hystricurus, Missisquoia, Parabolinella, Symphysurina, Apheoorthis, Conotreta* and *Syntrophina.* It correlates closely with a low Ordovician fauna from Vermont described by Shaw. The upper zone is the *Symphysurina* Zone and contains *Clelandia, Homagnostus, Hystricurus, Jujuyaspis, Symphysurina, Apheoorthis,* and *Syntrophina.* It correlates most closely with the *Symphysurina* Zone of Utah and Nevada.
>
> New trilobite species are *Acheilops masonensis, Bayfieldia simata, Bowmania sagitta, Briscoia llanoensis, Calvinella procera, Clelandia texana, Corbinia apopsis, Corbinia implumis, Euptychaspis jugalis, Homagnostus reductus, Keithiella patula, Leiobienvillia leonensis, Leiocoryphe halei* (now *Stenopilus latus* Ulrich), *Missisquoia inflata, Missisquoia nasuta, Saukiella planata,* and *Symphysurina bubops:*

A study of trilobites of the Upper Cambrian Pthchaspid Biomere of the Wilberns Formation by Longacre (1970) is an extension of previous paleontological work on the stratigraphic interval between the base of the *Eoorthis* Bed and the stratigraphically lowest Ordovician trilobites in Central Texas. The abstract of this publication follows:

> Trilobites collected during the past 20 years from the Morgan Creek, Point Peak, and San Saba Members of the Wilberns Formation comprise 89 species assigned to 45 genera belonging to zones of the upper Franconian and Trempealeauan Stages of the Upper Cambrian, Croixan Series. New zonal names are proposed in the interest of a regionally applicable nomenclature. Although none of the zonal nomenclature is identical to that of the 1944 Cambrian Correlation Chart of Howell and others, the four zones recognized in Central Texas are equivalent to the eight highest zones on the Chart. Stratigraphically lowest is the Franconian *Taenicephalus* Zone, with a locally recognized *Parabolinoides* Subzone at its base; this zone is equivalent to the *Conaspis* Zone of the Correlation Chart. The Franconian *Idahoia* Zone, with a locally recognized *Idahoia lirae* Subzone at its base, is equivalent to the *Ptychaspis* Subzone of the *Ptychaspis-Prosaukia* Zone of the Correlation Chart. The sparsely fossiliferous *Ellipsocephaloides* Zone corresponds to the *Prosaukia* Subzone of the *Ptychaspis-Prosaukia* Zone on the Chart. Almost two-thirds of the trilobite species described occur in the Trempealeauan *Saukia* Zone, which corresponds to the five highest zones of the Correlation Chart; local subzones in ascending order, are the *Saukiella pyrene* Subzone, the *Saukiella*

> *junia* Subzone, the *Saukiella serotina* Subzone, and the *Corbinia apopsis* Subzone.
>
> The succession of ptychoparioid trilobite faunas within these zones characterizes the Ptychaspid Biomere. The base of the biomere is at the base of the *Taenicephalus* Zone; the top coincides with the lowest occurrence of an Ordovician trilobite fauna. Trilobite families which characterize the Ptychaspid Biomere are the Ptychaspididae and the Parabolinoididae.
>
> Systematic descriptions include two new subfamilies, Drumaspidinae and Ptychaspidinae, and eight new species, *Conaspis leptoholcis, Idiomesus infimus, Euptychaspis frontalis, Keithiella scapane, Saukiella serotina, Prosaukia remora, Calvinella prethoparia,* and *Westonaspis? texana.*

Spot collections of fossils made by Barnes during his mapping in Central Texas were in part sent to Dr. Josiah Bridge and Dr. G. Arthur Cooper of the U. S. Geological Survey and U. S. National Museum respectively. Most of these collections were retained in Washington, D. C. During 1972 all other Moore Hollow and Ellenburger Group fossil collections of The University of Texas (Department of Geological Sciences and Bureau of Economic Geology) were given to the U. S. National Museum for permanent preservation as a reference collection.

The locality numbers assigned to the fossils at the time of mapping were created for convenience in knowing the county and the locality in the county from which the collection came. The locality was inked on an aerial photograph and labeled starting with A and continued alphabetically for succeeding collections. The aerial photographs for a county were divided into blocks and the blocks were labeled numerically north-south starting with the northeasternmost block then progressing westward. The photographs within a block were labeled numerically from north to south, as the flight lines were in this direction, starting with the northeasternmost photograph, then continuing with successive rows westward.

Gillespie County is a long county east-west and was divided into 21 blocks, 3 north-south and 7 east-west. The locality number 86T-16-14H indicates that the collection was made in Gillespie County (86), Texas (T), within block 16 (northwestern part of county), from photograph 14 within that block, and that it was the 8th (H) collection from the area covered by that photograph. Other county numbers used in the Llano region follow: Blanco County, 16T; Burnet County, 27T; Gillespie County, 86T; Llano County, 149T; McCulloch County, 153T; Mason County, 159T; and San Saba County, 205T. Data concerning Moore Hollow Group spot fossil collections are on open file at the Bureau of Economic Geology.

## GEOLOGIC STRUCTURE

Geologic structure of the Llano area is discussed by Cloud and Barnes (1948, p. 118–122) under the headings Faults, Detection of Faulting, Major Fault Trends, Minor Fault Patterns, Age of Faulting, Folds, Collapse Contacts and Structural Sinks, and Joints, and the reader is referred to that publication for information on these features.

In summary, the faulting is normal, the major trends are all in the northeast quadrant, a minor set trends northwest-southeast, and Strawn rocks but not Canyon rocks are involved. Folds are chiefly incidental to the faulting, and collapse contacts in the Moore Hollow Group are scarce except possibly for local collapse of Threadgill Formation rocks into the San Saba Member in the western area. Joints were not closely studied but a Widmanstatten-like pattern of jointing in the Cap Mountain Limestone is described.

In this publication the structure of each area mapped is discussed under Local Stratigraphy. Barnes (1959, p. 715) from observations of cores of pre-Simpson rocks and publications describing oil fields believes that structure similar to that in the Llano region is widespread on the cratonic area in the subsurface.

A collapse structure in the Silver Creek area of Burnet County in which Morgan Creek Limestone, now mineralized, has collapsed at least 60 feet to the level of the Lion Mountain Sandstone is described by Barnes (1956c), who suggested that the collapse was probably caused by the solution of Cap Mountain Limestone beneath. The age of this collapse is unknown.

In the Streeter area of Mason County, Barnes and Bell (1954a, b) described a filled sink at the level of the Hickory Sandstone in which Marble Falls Limestone has worked between blocks of Cap Mountain Limestone followed by deposition of stratified Marble Falls Limestone. This sink formed through solution of Precambrian marble, allowing the overlying rocks to collapse either during Marble Falls deposition or very shortly thereafter. Many similar filled sinks are present in the area (pl. 8, fig. 3).

# ECONOMIC RESOURCES

Present and potential economic resources of Moore Hollow rocks in the Llano region include water, crushed rock, sand, building stone, and low grade iron ore. Lead-zinc mineralization is present around a few monadnocks. In the subsurface in some areas petroleum is an important resource.

## WATER

The only strata of the Moore Hollow Group of rocks with sufficient porosity to yield an economically significant amount of water are in the lower part of the Hickory Sandstone. This water is used for irrigation and city water supply mainly in the northwestern part of the Llano region. The water-producing potential of Moore Hollow rocks is discussed under Porosity (p. 12–14).

## CRUSHED ROCK

The San Saba Member in the eastern area of the Llano region is the unit of the Moore Hollow Group which furnishes crushed rock for many uses. The Texas Construction Material Company in its Burnet Stone Division quarry 3 miles south of Burnet is producing coarse-grained dolomite from this member used mostly for steel mill fluxing rock and agricultural purposes (Barnes, 1958, p. 24). This stone also could be used for the various other products, except possibly riprap, produced from the Ellenburger units elsewhere in this quarry.

Similar stone located west of the highway northwest of the Burnet Stone Division quarry (Barnes, 1958, fig. 8) and in the northern part of the Sudduth area (pl. 7, fig. 20) is near railroad transportation. Other areas in which similar rock has been mapped by Barnes in Blanco, Gillespie, and Llano Counties include the Blowout (1952a), Gold (1952c; Cave Creek School, 1967), North Grape Creek (1952g; Rocky Creek, 1965b), Johnson City (1963, 1969), Kingsland (1976), Cap Mountain and Click (in preparation a, b) quadrangles. In the Blowout and North Grape Creek quadrangles the coarse-grained dolomite grades laterally to massive, aphanitic limestone which, except for its location and possibly high magnesium content, should be of value for chemical limestone.

Stone for crushed rock products which need not be of chemical grade can be obtained from the limestones of the Moore Hollow Group. In the western part of the region the upper part of the red unit of the Hickory Sandstone has been widely used for base course material for highway construction, and in the eastern part of the region the siltstone of the Point Peak Member commonly has been used for the same purpose.

## BUILDING STONE

Barnes, Dawson, and Parkmson (1947), reporting on the building stones of Central Texas, described samples of Moore Hollow Group rocks from the localities listed in table 14. The reader is referred to that publication for detailed information on the samples listed, a summary of this information for the limestones and dolomites is given in Bureau of Economic Geology Report of Investigations No. 37, table 5 (Dietrich and Lonsdale, 1958).

## SAND

Hydraulic-fracturing sand is being produced in McCulloch County, from the lower part of the Hickory Sandstone (Barnes and Schofield, 1964). This sand is of a quality that would be suitable for most purposes except glass making. Similar sand is widely distributed in northwestern Mason County and perhaps in other areas as well.

None of the sandstone in the Moore Hollow Group appears to be low enough in iron to be used for glass sand except possibly very locally in the San Saba Member, and this sandstone is mostly calcareous.

## POTENTIAL LOW-GRADE IRON ORE

At present it is not economically feasible to produce iron from either of the iron-bearing members of the Moore Hollow Group. Concretionary masses of hematite from the weathering of glauconite in the Lion Mountain Sandstone member are too widely scattered to be of value. In one sample of Lion Mountain Sandstone analyzed from along Squaw Creek, the greensand contained 12.89 percent elemental iron (Barnes, Dawson, and Parkinson, 1947, p. 122). Recalculation of the chemical analysis into minerals known to be present indicates that the greensand contains about 38.86 percent glauconite, 7.36 percent hematite, 0.30 percent ilmenite, and 0.09 percent pyrite. Such material cannot be considered as a source of iron in the foreseeable future. Also, low potassium and phosphorous content precludes the use of this greensand for a land conditioner.

The upper part of the Hickory Sandstone is hematitic, containing about the same amount of elemental iron as the greensand. Schofield (Barnes and Schofield, 1964)

Table 14. Page reference for Moore Hollow Croup rocks described in "Building stones of central Texas," Barnes, Dawson, and Parkinson, 1947.

| Locality* | Page described | Member | Rock type |
|---|---|---|---|
| Bl-13 | 123 | Hickory | Sandstone |
| M-1 | 124 | Hickory | Sandstone |
| Bu-43 | 124 | Cap Mountain | Sandstone |
| Ll-3 | 124 | Cap Mountain | Sandstone |
| S-26 | 125 | Cap Mountain | Sandstone |
| Bl-12 | 130 | Cap Mountain | Limestone |
| Bl-26 | 130 | Cap Mountain | Limestone |
| Bu-15 | 131 | Cap Mountain | Limestone |
| Bu-22 | 131 | Cap Mountain | Limestone |
| Bu-26 | 132 | Cap Mountain | Limestone |
| Bl-21 | 132 | Morgan Creek | Limestone |
| Bu-21 | 133 | Point Peak | Stromatolitic limestone |
| Bu-27 | 134 | Point Peak | Stromatolitic limestone |
| Bu-28 | 134 | Point Peak | Stromatolitic limestone |
| S-13 | 137 | Point Peak | Edgewise conglomerate |
| M-21 | 136 | Point Peak(?) | Stromatolitic limestone |
| S-12 | 136 | Point Peak(?) | Girvanella limestone |
| G-19,-20 | 134 | San Saba | Stromatolitic limestone |
| Ll-60 | 135 | San Saba | Girvanella limestone |
| Bl-2 | 148 | San Saba | Dolomite |
| Bl-16 | 149 | San Saba | Dolomite |
| Bl-17 | 149 | San Saba | Dolomite |
| Bl-18 | 150 | San Saba | Dolomite |
| G-18 | 153 | San Saba | Dolomite |
| Bu-16 | 138 | San Saba or Threadgill | Limestone |

* Symbols used: Bl, Blanco County; Bu, Burnet County; G, Gillespie County; Ll, Llano County; M, Mason County; and S, San Saba County.

found the following amounts of elemental iron in the richest portions of the various localities sampled (table 15).

As mentioned previously, this grade of hematite is not commercial at present; however, if the 60 ± percent of sand of a size used for hydraulic fracturing were removed, then the remaining portion should be of a grade which could be treated by a direct reduction process.

## LEAD-ZINC MINERALIZATION

Mineralization so far found has been chiefly in the Cap Mountain Limestone on the flanks of monadnocks in the Scott Klett area, Blanco County, in the Iron Rock Creek area, Blanco and Gillespie Counties, and near Marble Falls and in the Silver Creek-Beaver Creek area of Burnet County (Barnes, 1956). In the Silver Creek prospect, mineralization also was found in the lower part of the Morgan Creek Limestone and the Welge Sandstone and galena was detected in drill cores of the Lion Mountain Sandstone.

Table 15. Elemental iron in upper red unit of Hickory Sandstone, Riley Formation, Moore Hollow Group, Central Texas.

| Locality | Thickness (feet) | Iron (Fe) (percent) |
|---|---|---|
| Hoffman highway material pit west-northwest of Grit, Mason County | 20 | 12 1 |
| Sell highway material pit north of Camp Air, Mason County | 32 | 12 6 |
| Pontotoc section, San Saba County | 29 | 13 0 |
| Highway material pit east of Cold Creek, Llano County | 29 | 10 1 |
| Miller highway material pit, Slick Mountain, Llano County | 30 | 11 2 |

## PETROLEUM

The chief area of petroleum production from Moore Hollow rocks is northwest of the Llano region along the "Cambrian trend" of Nolan and Coke Counties. In this area through a combination of faulting and erosion, Moore Hollow and Carboniferous rocks are in juxtaposition and it is believed that the oil in the Moore Hollow rocks migrated from the Carboniferous.

No indication of oil has been seen in the Moore Hollow Group rocks in the Llano region and none of the rocks have the appearance of source rocks. However, in view of vugs filled with oil in the Precambrian Nonesuch Shale in the White Pine Copper Mine, Michigan, it seems reasonable that source beds might be present somewhere in Moore Hollow Group rocks.

# LOCAL STRATIGRAPHY

In this section the outcrop characteristics of Moore Hollow Group rocks in the vicinity of described stratigraphic sections are discussed. Originally it was planned that supporting data, including descriptions of stratigraphic sections, heavy-mineral data, insoluble-residue data, and thin-section descriptions, would be included here. However, because of increase in publication costs during the intervening years since this portion of the text was prepared, such material has been placed on open file at the Bureau of Economic Geology.

In a logical northwest to southeast sequence of sections for the Moore Hollow Group as a whole, the Calf Creek section and Carpenter Exploration Company No. 1 Bradshaw should be first, followed by the Camp San Saba section. However, it is also important to preserve the grouping of the western tier of sections, because of the sandstone and sandy limestone in the San Saba Member. Therefore, the sequence of sections starts with the James River sections and progresses northward to the Calf Creek area, even though this direction is almost opposite to the general line of section.

## JAMES RIVER AREA, MASON COUNTY

### Introductory Statement

Two areas were mapped in the James River area. The downstream James River area (pl. 7, fig. 1) includes about 2.1 square miles in the southeastern corner of the 1:24,000 scale U. S. Geological Survey Turtle Creek quadrangle. The upstream James River area (pl. 8, fig. 1) includes about 8.1 square miles straddling the boundary between the 1:24,000 scale U. S. Geological Survey Monument Mountain and Monument Mountain SE quadrangles. Both maps were originally prepared under the direction of James W. Macon from aerial photographs of the U. S. Department of Agriculture and, when topographic quadrangle maps became available, the geologic mapping was transferred to them. The upstream James River area bounds the Fall Prong quadrangle geologic map to the south (Barnes, 1956a).

The downstream James River area, at the mouth of James River, may be reached from the southeastern part of Mason by following Ranch Road 1723 south from U. S. Highway 87 about 2.3 miles, then bearing right and following a graded road about 4.7 miles to Llano River and the map area. The upstream James River section may be reached by following Ranch Road 1871 southwest from Mason 4.25 miles past Llano River, then turning left on a graded road about 7.7 miles to a road leading southeast 0.4 mile to the northwest corner of the map area. This section may also be reached from U. S. Highway 290 from a point 3.3 miles west of Harper by following Ranch Road 385 north past Little Devil's River 2.6 miles, then turning right and continuing north 6.2 miles to the road that turns southeast to the map area.

Rocks mapped in the downstream James River area include: Cap Mountain Limestone and Lion Mountain Sandstone Members of the Riley Formation; Welge Sandstone, portions of the Morgan Creek Limestone, Point Peak(?), and San Saba Members of the Wilberns Formation; Threadgill Member and portions of the Staendebach Member of the Tanyard Formation; and alluvium including gravel bars along the rivers. Moore Hollow strata beneath those measured in the upstream James River area occur, but unfortunately a complete section to the Precambrian was not found.

Rocks mapped in the upstream James River area include: the uppermost beds of the Cap Mountain Limestone Member and the Lion Mountain Sandstone Member of the Riley Formation; all the members of the Wilberns Formation; the Threadgill and Staendebach Members of the Tanyard Formation, and portions of the Gorman Formation; also Cretaceous units including the Hensell Sand, Glen Rose Limestone, Walnut Clay, and Comanche Peak Limestone, and the basal beds of the Edwards Limestone; and various Quaternary deposits including travertine, colluvium, high gravel, and alluvium.

Data in Parts II and HI on open file at the Bureau of Economic Geology are as follows: upstream James River section — description of measured section with thin-section descriptions and fossil lists, heavy-mineral data, table 25, insoluble-residue data, table 26; downstream James River section — description of measured section with thin-section descriptions and fossil lists, insoluble-residue data, table 27.

The Wilberns Formation rocks are better exposed in the upstream James River section than in any other section in the Llano region, and the quality of exposure of the Lion Mountain Sandstone equals that in the Squaw Creek section. An important feature of this section and of other sections in the western tier of sections is the presence of sandstone and sandy limestone zones in the San Saba Member.

Structure is fairly simple in the two areas. Dips are low, and faults, mostly of small displacement, are tedious to map. One fault, located in the northwestern part of the downstream James River area, is downthrown about 800 feet to the west; the remaining numerous faults in this area are of small throw. Another fault in the northeastern part of the upstream James River area, downthrown about 1,500 feet to the northwest, loses throw to the southwest and finally divides into a number of faults which die out short of the map boundary. All faults are normal, most trend northeast-southwest, a few in the upstream James River area trend north-south, and in this area a few minor faults trend northwest-southeast. A collapse contact separates the Threadgill and Staendebach Members in a few places. The character of this contact is exceptionally well displayed in James River and along the south bank of the river near the southwestern corner of the upstream James River area.

Vegetal patterns, overall color, and topographic expression as seen on aerial photographs are helpful in mapping both areas. In the downstream James River area, flat expanses of Welge Sandstone cap a number of sharp-sided ridges. Its topographic position, in addition to its white, mottled appearance and clumpy vegetation, sets it off from the slightly darker gray Lion Mountain Sandstone beneath with its faint bedding alignments and the Morgan Creek Limestone above with its distinct bedding alignments and light-gray color. The vegetation alignments along the bedding of the Cap Mountain Limestone are almost as distinct as those of the Morgan Creek Limestone. Vegetation is clumpy, showing little bedding alignment in the Threadgill and Staendebach Members; it is perhaps more abundant on the Staendebach Member. The Threadgill Member photographs very light-gray and the Staendebach Member medium light-gray, probably caused by the difference in the color of the rocks.

In the upstream James River area the Welge Sandstone is marked by a dark band of clumpy vegetation; the small area of Lion Mountain Sandstone with clumpy vegetation, and much lighter colored. The Morgan Creek Limestone and San Saba Members, both about the same color and possessing good vegetation alignment, are separated by the Point Peak Member of much lighter gray color and finely spaced vegetational banding. The banding in the San Saba is wider than in the Morgan Creek Member, especially in the upper sandy portion where the sandy beds photograph medium dark gray. Vegetational alignments in the Ellenburger Group rocks are very faintly contrasted, and the only consistent distinction is that the Threadgill Member photographs lighter gray. The Hensell Sand produces a clumpy vegetation without alignment, the Edwards Limestone has very distinct bedding alignments of vegetation, and the other three Cretaceous units mapped are situated in the steep upper portion of a scarp and are so thin that they have little opportunity to develop their usual distinctive vegetational patterns.

## Moore Hollow Group

### Riley Formation

*Cap Mountain Limestone Member.*—The isopach map of the Cap Mountain Limestone (fig. 5) shows that a thickness of about 325 feet should be present in the downstream James River area; only 225 feet was measured, indicating that about 100 feet of Cap Mountain Limestone is not exposed. The lower 15 feet in the measured section is mostly sandy limestone and a few very calcareous sandstone beds. The sand is mostly fine to coarse, the larger grains are well rounded, smooth, iron-oxide coated, and some show a bronzy luster. The limestone is fine to medium grained and pale to dark yellowish brown and several shades of moderate brown.

Fine to medium sand is common in a few sandy limestone beds, and silt and very fine sand are common throughout the Cap Mountain Limestone, being somewhat more abundant in the lower part. The limestone is mostly fine to medium grained; some is coarse grained. It is mostly pale to moderate yellowish brown, light olive gray to olive gray, greenish gray, yellowish gray, light brownish gray, light gray, and in the lower third is in part dark yellowish orange and light to moderate brown. The upper 110 feet is in part oolitic with the ooids in part replaced by dolomite. Other dolomitized objects and dolomite rhombs are common, and glauconite is present in many beds throughout the section. Mica is common especially in the lower part.

*Maryvillia*-Zone fossils are in 4 collections between 201 and 223 feet, *Coosella*-Zone fossils in 3 collections from 132 to 163 feet, and *Cederina-Cedaria*-Zone fossils in 1 collection at 42 feet. Of the fossils listed, spicule type B is the only one identified in thin section; however, much trilobite, pelmatozoan, and phosphatic brachiopod debris can be recognized.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone Member is 55 feet thick in the downstream James River section and 57 feet thick in the upstream James River section, where it is exceptionally well exposed. The upper 8 feet of the upstream exposure and most of the underlying 24 feet is greensand composed about equally of glauconite and quartz sand, the latter mostly fine to very coarse and angular from reconstitution. The glauconite in part is in smooth, elliptical to lobate, irregular grains and in part is finely comminuted. Hematite, formed along joints, is well displayed in Pole Pen Hollow. Limestone composed of trilobite coquinite crossbeds, relatively scarce in the upper part, becomes progressively more abundant downward where it forms a few fairly continuous beds. Shale in this portion of the member is scarce.

The remainder of the Lion Mountain Sandstone is composed of greensand, limestone, shale, and in the lower 6 feet is mostly sandstone, brownish yellow to yellowish brown, glauconitic, calcitic, argillaceous, and fine to coarse grained in the upper part to fine grained in the lower part. The shale is grayish olive green, calcareous, sandy, and most of it is burrowed and reworked by organisms. The limestone is in part lenticular crossbeds of white, trilobite coquinite up to 2 feet long and in part more or less continuous beds which are of various shades of green, the more glauconitic ones ranging from dusky green to dusky yellowish green. The greensand is similar to that in the upper part of the Lion Mountain Sandstone and in places has weathered to form hematite concretions up to 6 inches thick and 5 feet long along the bedding. The greensand throughout the Lion Mountain is somewhat hematitic, as shown by a resulting red streak when a portion is struck a glancing blow.

Fossils were not collected systematically from the Lion Mountain Sandstone in this section, but *Crepicephalus* fauna trilobites were seen in the lower 5 feet, *Aphelaspis* is abundant above this level, and phosphatic brachiopods are common throughout.

In the downstream James River section the upper 30 feet of the Lion Mountain Sandstone in the line of section is very poorly exposed on a gently sloping bench. The lower 25 feet nearer the river is fairly well exposed, but more weathered than in the upstream section, and consists mostly of limestone, sandstone, and shale similar to that in the upstream section. However, differing from the upstream section, ooids are in part dolomitized, and dolomite rhombs and replacement of fossil debris are present in some of the limestone beds. In this section, *Aphelaspis*-Zone fossils are in 5 collections between 247 and 265 feet and post-*Aphelaspis*-Zone fossils in 1 collection at 275 feet.

### Wilberns Formation

All units of the Wilberns Formation were measured and described in the upstream James River section.

*Welge Sandstone Member.*—The basal 2 feet of the Welge Sandstone is fine-grained, argillaceous, yellowish brown, nonglauconitic sandstone and appears to have been extensively reworked by organisms. The rest of the Welge is medium to very coarse grained, and a few granules and small pebbles are up to 0.15 inch in size. The grains are mostly well rounded and slightly reconstituted, showing many reflections in sunlight. A few thin shale films preserve polygonally-arranged excavations similar to those so well displayed in the Squaw Creek section (p. 125).

The 2-foot, fine-grained sandstone bed at the base of the Welge is difficult to explain unless the first reworking of the Lion Mountain Sandstone, at least in this area, was very gentle and finer materials were washed into a low area. No fossils were seen in the Welge Limestone in either of the map areas.

*Morgan Creek Limestone Member.*—The 127-foot-thick Morgan Creek Limestone Member is mainly fine to coarse grained; the granularity is caused by the presence of fossil debris. In the lower 38 feet, aphanitic to very fine-grained stromatolite beds and beds with widely dispersed stromatolites are common. Except for the stromatolites, which in general are fairly pure limestone, the Morgan Creek is glauconitic throughout; it is silty, argillaceous, and micaceous in the upper part and somewhat less so downward. Sand is common at many levels and is mostly fine and very fine grained; toward the base it coarsens and becomes progressively more abundant. Dolomite replaces fossil debris in some beds, and dark yellowish orange dolomite patches occur in a few beds. The bulk of the Morgan Creek is greenish gray, and some is medium light gray and light olive gray. The lower 20 feet is grayish red, and some beds in the overlying 30 feet are reddish to pinkish gray. Ooids were recorded in very few beds and in only one thin section, suggesting that the Morgan Creek Limestone is less oolitic in this section than normal.

*Point Peak Member.*—The Point Peak Member, 188 feet thick, is composed mostly of siltstone, limestone, and some shale. Stromatolites are common in the lower 36 feet of the Point Peak Member and also occur about 120 feet above its base. The upper stromatolites, near the middle of a 17-foot, coarsely granular limestone zone, form patch reefs up to 0.3 mile across in the upstream James River map area (pl. 8, fig. 1). A smaller patch reef along the line of section is 5 feet thick. Above this reef-bearing zone, limestone predominates, siltstone is abundant, and this portion of the Point Peak is set off from the San Saba Member chiefly by the thinness of its bedding. Beneath the reef-bearing zone is 78 feet of siltstone, limestone, and some shale (mainly in the lower 10 feet). A 6-inch bed of shale, between brownish gray and pale brown in color, contains graptolites. Siltstone predominates and is generally very light olive gray and some light greenish gray; limestone intraformational conglomerate is abundant; some beds are lenticular and others traverse the entire length of the outcrop. Intraformational conglomerate is also common in most of the rest of the Point Peak Member.

Tiny grains of glauconite are found in the siltstone, and most of the intraformational conglomerate contains glauconite, some of which forms thin films along borders of pebbles. A few beds of coarsely granular limestone contain rounded to lobate glauconite grains. The calcite-cemented siltstone is mostly detrital feldspar in part with authigenic overgrowth; rhombs of authigenic feldspar are common. Quartz is abundant; mica is common and is represented by muscovite, biotite, hydrobiotite, and a micaceous product which is opaque from weathering.

Trails and burrows are common in many beds and are probably more abundant in the upper part of the member. In the predominantly siltstone zone in the lower 30 feet, trails and other signs of life are scarce and several beds exhibit tiny ripple-mark patterns which show that the water in which they formed was only 1 mm or so deep. Circular pits seen on one bedding surface may be raindrop impressions, but some other origin is not ruled out. Ripple marks at 286 feet, 4.5 to 5 feet between crests, trend N. 80° E., and others at 319.5 feet, 1.5 feet between crests, trend N. 45° W. Beds with ooids are scarce and exist mostly in the upper part.

San *Saba Member.*—The San Saba Member, 284 feet thick in the James River area, is exceeded in thickness in the Llano region only in the Camp San Saba and Tanyard areas. The member is composed chiefly of finely to coarsely granular limestone, sandstone is abundant, and dolomite amounts to about 23 feet of section. A few beds in the uppermost part of the San Saba are aphanitic, and the upper boundary is arbitrarily placed by balancing the downward extension of aphanitic beds and Ordovician gastropods characteristic of the Threadgill Member against the upward extension of glauconite characteristic of the Moore Hollow Group. Sandstone, amounting to about 40 feet of section, is confined to a 130-foot zone in the upper part of the San Saba Member. Scattered sand grains are present at other levels, and the sand throughout the San Saba ranges from fine to coarse grained and most of it is well rounded and frosted.

The dolomite is very fine grained, ranges from pale to dark yellowish orange, light brown, grayish orange, and pale yellowish brown, and is mostly sandy and silty. The main zone, 21 feet thick, is sandwiched between sandstone beds and may not be as persistent laterally as the widespread, upper 18-inch bed.

The limestone is mostly glauconitic, some beds are oolitic, intraformational conglomerate is present at several levels, and sand and silt are common. In some beds dolomite occurs as isolated rhombs and replaces fossil debris; in at least one bed it occurs as dark grayish-yellow lenses up to 2 feet in length. In color the limestone ranges among a wide variety of greenish grays, light to medium olive grays, pale to dark yellowish orange, pale to moderate yellowish brown, light to medium gray, and various other colors, such as grayish orange, yellowish gray, and pale brown. Crossbedding is common; in fact many beds show evidence of burrowing. The unit as a whole is medium bedded, thin and thick beds are common, and sandstone zones tend to be massive. Ripple marks near the base of the member extend 4 feet between crests and trend N. 80° W.

## Ellenburger Group

### Tanyard Formation

*Threadgill Member.*—A complete sequence of the Threadgill Member is mapped in the downstream James River; a complete sequence may be present in the upstream James River area but because of faulting this is not conclusively known. The Threadgill Member in this area, as in much of the western part of the Llano region, is designated as the lower calcitic part of the Tanyard Formation, and the placement of its lower boundary is discussed above. The upper boundary ranges from normal superposition of dolomite on aphanitic limestone to lateral intergradation of dolomite and limestone. Collapse of dolomite has taken place for rather long distances where solution of the underlying limestone has taken place.

*Staendebach Member.*—A complete sequence of the Staendebach Member is mapped in the upstream James River area, and its lower portion is mapped in the downstream James River area. The lower boundary is discussed above; the upper boundary of the mostly fine-grained, cherty dolomite of the Staendebach Member is in normal contact with the overlying microgranular dolomite of the Gorman Formation.

### Gorman Formation

The largest Gorman outcrop area is located in the northern part of the upstream James River area along the northwestern side of the main northeast-southwest fault, and two small outcrops are in the southwestern portion of the map area. Except for two very small eyes of massive aphanitic limestone in the northern area, all of the Gorman is dolomite, identified by its grain size and occasional beds containing a scattering of sand. The Gorman *Archaeoscyphia* Bed, if present in this area, was not found.

### Cretaceous Rocks

Cretaceous units were mapped only in the upstream James River area, and since these same units are mapped and described in the adjacent Fall Prong quadrangle to the south (Barnes, 1956a), the reader is referred to that publication for their description.

### Quaternary Deposits

Alluvium is present in both map areas. In addition, in the upstream James River area deposits of high gravel, colluvium, and travertine are mapped.

## BLUFF CREEK-STREETER-LEON CREEK AREA, MASON COUNTY

### Introductory Statement

The second group in logical sequence are those sections in westernmost Mason County including the Streeter section about 2 miles west of the town of Streeter, the Bluff Creek section of Cloud (Cloud and Barnes, 1948, p. 179–185) 5 miles south of Streeter, and the Leon Creek group of sections (Alexander, 1956; Winston, 1957) in an arc of about 30 degrees about 6 miles west-southwest of Streeter. These sections, in addition to furnishing information on thickness and lithologic changes for the Moore Hollow Group of rocks as a whole, give another example of sandy zones and sandstone beds in the San Saba Member.

Three areas were mapped in western Mason County, two for geologic sections and the third, in the vicinity of Grit, to show the location of wind-abraded pebbles at the base of the Hickory Sandstone. The Grit area (pl. 7, fig. 3) includes about 1.9 square miles mapped geologically and is named after Grit post office on State Highway 29 in the southeastern part of the area. The area is situated within the 1:24,000 scale Grit U. S. Geological Survey topographic quadrangle map.

The Streeter area (pl. 8, fig. 3) includes about 10.3 square miles mapped geologically and includes parts of the 1:24,000 scale Long Mountain, Grit, Turtle Creek, and Sheep Run Creek U. S. Geological Survey topographic quadrangle maps. It takes its name from the town of Streeter, located on U. S. Highway 377 in the eastern part of the area. The Grit map and a portion of the Streeter map were included in the San Angelo Geological Society guidebook for 1954 (Barnes and Bell, 1954a).

The Leon Creek map area (pl. 8, fig. 5), mostly in Mason County, extends about 200 yards into Menard and Kimble Counties and embraces about 9.8 square miles. The area was mapped geologically by Alexander and Winston, under the direction of Bell and Barnes, as part of the fulfillment of requirements for master's theses. U.S. Highway 377, approximately 16 miles west of the town of Mason, traverses the extreme northwestern part of the area. The area takes its name from Leon Creek, the principal hydrographic feature, and is located within the area of the 1:24,000 scale Sheep Run Creek U. S. Geological Survey topographic quadrangle map.

The Bluff Creek area (pl. 7, fig. 2) is a portion of Cloud's Bear Spring area (Cloud and Barnes, 1948, pl. 5) in the vicinity of the Bluff Creek section. This area includes 1.9 square miles mapped geologically by Cloud and is situated within the area of the 1:24,000 scale Sheep Run Creek and Turtle Creek U. S. Geological Survey topographic quadrangle maps. It is reached from a point 0.7 mile west of Streeter by following a graded road and private road south along Bluff Creek about 6 miles.

Rocks mapped in the Grit area include Hickory Sandstone and three Precambrian units, Packsaddle Schist, Oatman Creek Granite, and Town Mountain Granite. In the westernmost ventifact locality, boulders up to 1 foot in size are wind abraded, and in the locality along the highway the ventifacts are mostly less than 5 inches in size. Pegmatites in the Oatman Creek Granite (Streeter granite mass) appear to be the source of gem-grade, clear to blue topaz found in the weathering debris and alluvium along streams on the granite mass. According to White (1960) topaz has been incorporated in the basal part of the Hickory Sandstone where it rests on the Streeter granite mass. White has also mapped several topaz localities in the basal part of the Hickory Sandstone where it rests on the Katemcy granite mass in northern Mason County.

Rocks mapped in normal stratigraphic position in the Streeter area include: six units of the Moore Hollow Group from the base of the Hickory Sandstone Member into the Point Peak Member; four Cretaceous units — Hensell Sand, Walnut Clay, Comanche Peak Limestone, and Edwards Limestone; and Quaternary deposits including alluvium and a patch of high gravel of questionable origin. Rocks filling sinkholes and others that collapsed and subsided to the level of the Hickory Sandstone and Cap Mountain Limestone include all units of the Moore Hollow Group except the Hickory Sandstone, the Threadgill and Staendebach Members of the Tanyard Formation, and the Marble Falls Limestone. The Marble Falls Limestone appears to have been deposited directly at the level it is now found; if this is true, it must have been deposited in a sinkhole at least 2,000 feet deep. The sink apparently originated by the solution of Precambrian marble similar to that mapped in the southeastern part of the Streeter area. The other units in these sinks occur as jumbled blocks which have fallen to where they are now preserved, or possibly in part collapsed and subsided to this level.

Marble of the Packsaddle Schist and Oatman Creek Granite of the Streeter granite mass pass beneath the Hickory Sandstone in the eastern part of the area. Two localities in which White (1960) reports topaz in the basal part of the Hickory Sandstone are a short distance beyond the eastern border of the Streeter map area. The marble of the Packsaddle Schist now forms a high area, and some small patches of red Hickory Sandstone on the highest surfaces of marble appear to be resting on the marble rather than being collapsed into it. If this is true, the marble stood several hundred feet above its surroundings when the Cambrian seas invaded the Llano region. The climatic implications of the topographic expression of this marble are discussed on pages 8–10.

Small patches of Hickory Sandstone which are now topographically low probably are collapsed into the marble. Many details remain to be mapped in the area of marble outcrop. Only the broader features were outlined in this study, and it is possible that units higher than the Hickory Sandstone may be found collapsed into the marble.

Rocks in the Leon Creek area mapped by Alexander (1956) and Winston (1957) include: in the Moore Hollow group, part of the Morgan Creek Limestone and the Point Peak and San Saba Members; in the Ellenburger Group, the Threadgill and Staendebach Members of the Tanyard Formation, and calcitic and dolomitic facies of the Gorman Formation; in the Carboniferous, the Chappel Limestone, Barnett Formation, and Marble Falls Limestone; in the Cretaceous, the lowermost part of the Hensell Sand; and in the Quaternary, alluvium. The area was very tedious to map because of innumerable faults, and for this reason was not entirely satisfactory for piecing together of a section. The various segments of the section probably tie together as shown in figure 13. The Leon Creek area is important in giving additional information about the distribution of sand in the San Saba Member and the amount of increase of sand from the Bluff Creek section. This is the westernmost place in the Llano region where a fairly complete section of San Saba rocks crops out.

Rocks mapped by Cloud (Cloud and Barnes, 1948) in the Bluff Creek area (pl. 7, fig. 2) include the upper part of the Wilberns Formation, the Threadgill and Staendebach Members of the Tanyard Formation, and alluvium. Barnes and Winston mapped the stromatolitic bioherm and boundary between the San Saba and Point Peak Members.

Data in Parts II and III on open file at the Bureau of

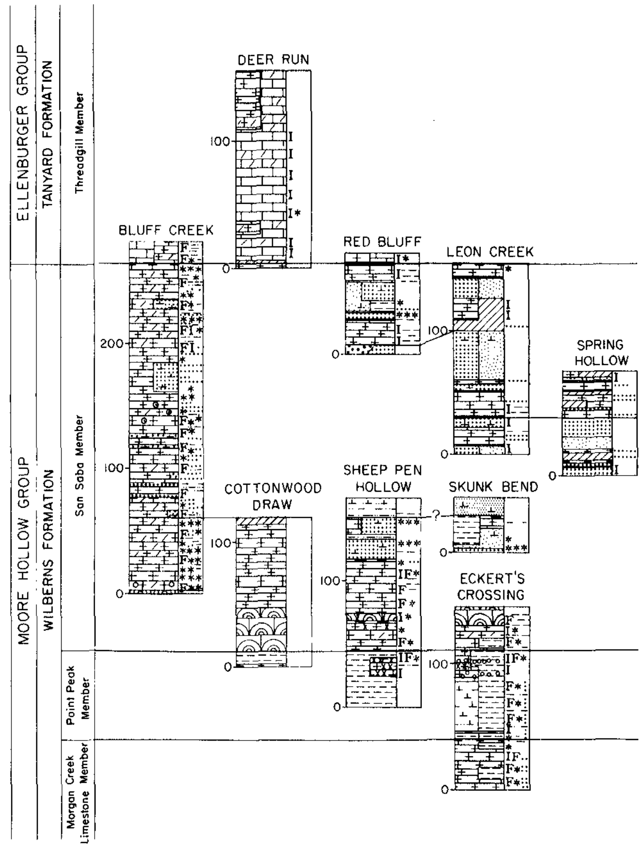



**Figure 13. Correlation of sections in the Leon Creek area, Mason County, Texas.**

Economic Geology are as follows. Bluff Creek section — fossil lists, description of measured section, description of insoluble residues, heavy-mineral data, table 28, insoluble-residue data, table 29, Streeter section — description of measured section with fossil lists, Leon Creek sections — description of measured sections with fossil lists.

The beds in all areas dip very gently except in collapse structures and in places along faults. One fault of relatively small displacement was mapped in the Grit area and a few minor ones in the Streeter area Cloud in the Bluff Creek area mapped the Bluff Creek fault, maximum displacement about 700 feet, and a few minor faults, and Alexander and Winston in the Leon Creek area mapped dozens of minor faults, several with important displacement, and one fault zone with perhaps 1,500 feet total displacement. Most of the faults trend northeast-southwest, a few trend north-south, several are in the octant between these directions, and a large number in the Leon Creek area with small displacement trend northwest-southeast

Collapsed boundaries, indicated by jumbled blocks and steeply tilted beds, are common between the limestone of the Threadgill Member and the dolomite of the

Staendebach Member in the Bluff Creek and Leon Creek areas. Five sinks in the Streeter area at the level of the Hickory Sandstone are filled by a jumble of Cap Mountain Limestone blocks, and four others, two at the level of the Hickory Sandstone and two at the level of the Cap Mountain Sandstone, are filled by blocks from various units. One of these south of the highway contains recognizable blocks of every unit from the Cap Mountain Limestone to the Staendebach Member, and if a prolonged search were made Gorman rocks, too, might be found. Various members are represented in the remaining three sinks; the one with the least variety appears to be the excellently exposed sink on the east bank of Bluff Creek containing large blocks of Cap Mountain Limestone with Marble Falls Limestone deposited in nearly horizontal strata above the blocks. Some Marble Falls Limestone has worked downward several tens of feet between the blocks.

Vegetal patterns as expressed on aerial photographs are helpful in mapping some units. The Town Mountain Granite supports widely spaced deciduous oaks with mesquite occupying low flat areas where clay has accumulated. The Oatman Creek Granite is very sparsely vegetated, as is the marble in the Packsaddle Schist. The schist or phyllite of the Packsaddle in the Grit area is brushy, and the Hickory Sandstone is cultivated for the most part except for the middle unit in the Streeter area which bears deciduous oak and mesquite.

The Cap Mountain Limestone shows vegetal bedding alignments of live oak, some cedar, abundant tasajillo (the jointed-pencil cactus) and other lime-loving plants. The Lion Mountain forms a bench with widely spaced clumps of live oak; the Welge Sandstone with somewhat more uniformly distributed vegetation is not as distinct as in some areas. The Morgan Creek vegetation and its bedding alignment pattern are similar to those of the Cap Mountain Limestone and San Saba Members. In scarp exposures the Point Peak Member is easily identified by its lighter color and closely spaced bedding alignments of thorny shrubs, but in flat areas appears little different from the units above and below.

The sandstone zones of the San Saba Member in the Leon Creek area grow mostly live oak, a few black persimmon and cedar exist, deciduous oak is scarce, and spiny vegetation, such as cat claw, bear grass, agarita, and tasajillo, is common. Cloud found that the top sandstone in the Bluff Creek area shows on aerial photographs as a narrow dark band because black persimmon thrives on it. Because of the calcite cement in these sandstones, the vegetation on most of them is not much different from that on the interbedded limestones.

The San Saba Member photographs light gray and slightly darker than the Threadgill above, but this latter difference is too subtle to be depended upon in mapping. Aerial photographs of Ellenburger rocks display very little difference between the various units, but the Ellenburger Group as a whole is sharply set off from the more thickly wooded Carboniferous rocks. The Mississippian strata commonly bear a thick growth of blue brush and other spiny bushes and the Marble Falls Limestone supports cedar.

## Precambrian Rocks

The Precambrian in the Grit and Streeter areas is represented by the Packsaddle Schist, Town Mountain Granite, and Oatman Creek Granite. The Packsaddle Schist in the Grit area is very poorly exposed and, where seen in places along streams and in the highway ditch beneath the Hickory Sandstone (locality 4-69A, pl. 7, fig. 3) has the appearance more of phyllite than of schist. The Packsaddle in the Streeter area is excellently exposed and entirely marble; it is in a mass 2 miles long in an east-west direction, passes beneath Hickory Sandstone to the west, and beyond the map area to the east is terminated by Town Mountain Granite. In a north-south direction the outcrop belt is 1.5 miles wide between Oatman Creek Granite to the north and downfaulted Paleozoic rocks to the south. The extent of the marble beneath the Hickory Sandstone is unknown, but it must be present beneath the area of filled sinks along Bluff Creek; a number of years ago the writers came across a well drilling operation somewhere between the Streeter area and Llano River which was coring vertical marble.

Town Mountain Granite exposed in the Grit map area appears to be part of a large mass of coarse-grained granite extending southeast beneath Paleozoic rocks and outcropping again south-southeast of Mason. It is proposed that this granite mass be named the Grit granite mass. Oatman Creek granite exposed in both the Grit and Streeter map areas is fine grained and younger than the Town Mountain Granite. It is proposed that this mass of granite be named the Streeter granite mass. A report on "Building Stones of Central Texas" includes additional information about these granites and marble (Barnes, Dawson, and Parkinson, 1947, p. 79–80, 82–83, 85–86, 100).

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone Member.*—The lower part of the Hickory Sandstone crops out in the Grit area and most of it is cultivated. The only exposures are located at the base, and in places they contain ventifacts; however, ventifacts are mostly scattered over the surface of the ground where they have weathered out of the sandstone. All portions of the Hickory Sandstone crop out in the Streeter area, but only the lowermost and uppermost parts are well exposed. The expression of all three units is fairly well displayed on aerial photographs, and on the map of the Streeter area the boundaries between these are sketched in their approximate positions. The lower 30 or 50 feet of Hickory Sandstone, well exposed along the eastern branch of Bluff Creek, has not been measured or described. Cursory inspection shows it to be mostly very coarse grained and toward the base somewhat conglomeratic. The lower and upper units are largely cultivated; and widely spaced deciduous oaks grow in the uncultivated parts. The middle unit is mainly uncultivated and is characterized by mesquite, suggesting that it is argillaceous.

Only 116 feet of the upper unit of the Hickory Sandstone was well enough exposed to be measured, starting at a fault 400 feet west of the west branch of Bluff Creek. The lower 105 feet is mostly very dusky red to grayish red, in part streaked moderate yellowish brown; a few fine-grained beds are dark yellowish brown, and beds from 67 to 69 feet are grayish orange mottled, moderate yellowish brown; brown predominates in the upper 11 feet. The medium- to fine-grained and some coarse-grained sand is mostly quartz coated by iron oxide; some grains are concentrically layered ooids of iron oxide. The quartz grains are well rounded, smooth, and poorly sorted. Crossbeds and trails are common and a few ripple marks are preserved by blackish red shale in films to 1/4-inch beds. *Cedarina-Cedaria*-Zone fossils were collected at the base and at 105 feet.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone is 273 feet thick in the Streeter section and thus intermediate in thickness between that found in the Threadgill Creek section to the southeast and Carpenter Exploration Company No. 1 Bradshaw to the north. The lower 159 feet is mostly siltstone, limestone, and, in the lower 46 feet, some sandstone. Limestone increases in amount upward. The siltstone is moderate yellowish brown in the lower part to grayish orange in the upper part, much burrowed, mostly very calcareous, and trails are common. The sandstone is mostly moderate yellowish brown to moderate brown with some streaks of grayish red and is calcareous. The limestone is silty, in the lower part pale yellowish brown to light olive gray. In the upper part light olive-gray mottled by medium to light yellowish-orange dolomite possibly occupies burrows. The upper 114 feet of the Cap Mountain Limestone is mostly fine-grained limestone with some medium and coarse-grained beds toward the top. The limestone is light olive gray, and is speckled by moderate yellowish-brown dolomite which appears to have replaced ooids and fossil fragments. The dolomite is mottled perhaps from burrows, is in part glauconitic, silty, and shaly, and in the top few feet fine sand is common.

*Cedarina-Cedaria*-Zone fossils are present in 3 collections between 130 and 183 feet, *Coosella*-Zone fossils in 3 collections between 287 and 325 feet, *Maryvillia*-Zone fossils in 1 collection at 369 feet, and *Aphelaspis*-Zone fossils in 1 collection at 387 feet.

*Lion Mountain Sandstone Member.*—The 29 feet of Lion Mountain Sandstone measured in this section is one of the thinnest sections of Lion Mountain measured in the Llano region. It is composed of greensand, limestone, shale, and sandstone. When the highway cut was first made, much of the greensand was grayish olive green but now little greensand can be seen. Where slightly weathered, the greensand as originally exposed was still green and had a moderate reddish-brown streak; with additional weathering it became very dusky red with dusky red streak; and the final product of weathering is blackish-red, hard, hematite concretions which break into fist-sized fragments littering the surface of the Lion Mountain outcrop. These iron nodules contain phosphatic brachiopods as well as sand grains held so tightly that the grains break across when the nodules are broken. The greensand ranges from about half glauconite and half quartz sand to sandstone with very little glauconite. Sandstone in the lower part is mostly fine grained and that in the upper part mostly coarse grained. Shale alternates with other rock types and most is yellowish gray to dusky yellow and thin bedded. Limestone is in the greensand as almost white crossbeds of trilobite coquinite, and toward the base of the member there are continuous beds of light gray- and greenish-gray, sandy, glauconitic limestone.

*Aplielaspis*-Zone fossils exist in 4 collections between 387 and 412 feet; no post-*Aphelaspis*-Zone fossils were found, suggesting that erosion at the top of the Lion Mountain Sandstone explains its thinness in this section.

**Wilberns Formation**

*Welge Sandstone Member.*—The Welge Sandstone in the Streeter section is 22 feet thick, mostly massive, in part burrowed, and grayish orange, pale to dark yellowish orange and light brown. Sand grains are mostly medium; the rest are fine or coarse. No fossils were found in the Welge Sandstone in this area.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone is 141 feet thick in the poorly exposed Streeter section, mostly coarse grained in the lower part, finer grained upward, glauconitic, sandy in the lower part, micaceous in the upper part, and dolomitic at various levels, the dolomite replacing fossil fragments and other objects. Dark yellowish-orange, lenticular patches of dolomite are common in some beds. The lower 10 feet of the Morgan Creek Limestone is pale red to grayish red, the next 10 feet is pale red in the lower part to grayish pink at the top, and the remainder is mostly yellowish brown, greenish brown, and pale yellowish brown.

The upper 40 feet of the Morgan Creek Limestone is well exposed in the Eckert's Crossing section in the Leon Creek area where, according to Alexander (1956), Franconian stage *Conaspis*-Zone fossils are in 9 collections between 1 and 14 feet, and *Ptychaspis-Prosaukia*-Zone fossils are in 13 collections between 20.5 and 38 feet.

*Point Peak Member.*—The Point Peak Member is 71 feet thick in the Leon Creek area, abnormally thin for this part of the Llano region; the thinness cannot be explained as it is in the Camp San Saba area, where a stromatolitic reef started its growth while more nearly normal Point Peak sediments were being deposited in adjacent areas. It seems likely that beds included in the Point Peak in the upstream James River area are more limy in the Leon Creek area and have been included in the San Saba Member in the Leon Creek area. Because a complete section of the San Saba Member could not be measured in the Leon Creek area, thickness data are not available for checking this conjecture. A complete section of the Point Peak Member is in the Eckert's Crossing section, and 45 feet of Point Peak was measured in the Sheep Pen Hollow section. Intraformational conglomerate, abundant in the upper 20 feet or so, is scarce in the lower 50 feet. Stromatolitic zones were not recorded, and most of the rock in the Point Peak Member is siltstone interbedded with shale.

About 1/2 mile upstream from Cloud's section in the Bluff Creek area (pl. 7, fig. 2) Winston and Barnes measured 10 feet of shaly siltstone at the top of the Point Peak Member beneath a stromatolitic reef. The shaly siltstone rests on granular limestone 1 foot or so thick which contains a few silicified brachiopods and ripple marks on the upper surface 2 to 3 feet between crests trending N. 60° W. Beneath this a few feet of shaly siltstone is poorly exposed to the level of the alluvium on the flood plain.

Alexander found *Ptychaspis-Prosaukia*-Zone fossils in the Sheep Pen Hollow section in 1 collection at 40.5 feet and in the Eckert's Crossing section in 4 collections between 60 and 103 feet.

San *Saba Member.*—Cloud (Cloud and Barnes, 1948, p. 180–185) in the Bluff Creek area measured in unfaulted sequence 262 feet of strata to the base of the Threadgill Member; he assigned 260 feet to the San Saba Member and 2 feet of stromatolites to the Point Peak Member. This value for the thickness of the San Saba is too thin when compared with a partial thickness of 295 feet of San Saba strata in the nearby composite Leon Creek section where stromatolites are absent. It seems likely that the base chosen for the San Saba in the Bluff Creek section may correspond to a point 50 feet more or less above the base of the San Saba in the composite Leon Creek section.

During February 1960 Winston and Barnes measured a section upstream about 1/2 mile from Cloud's section (pl. 7, fig. 2), beneath the lowest sandy zone described by Cloud, the base of which is at 60 feet. They found 72 feet of bedded limestone and dolomite to the top of the reef, which is 14 feet more than was present in the equivalent position in Cloud's section. The reef is 35 feet thick and interreef beds are granular limestone (shaly siltstone was seen in only one place), suggesting that if the reef were absent the interval occupied by the reef would be dominantly limestone allied to the San Saba instead of to the Point Peak Member. If this is true, the thickness of the San Saba in this area is about 309 feet, which compares closely to the 295 feet measured in the Leon Creek area, indicating that the missing section in the Leon Creek area amounts to only 10 or 15 feet.

In the Bluff Creek section Cloud described 5 zones ranging from sandstone to sandy limestone with patches of sandstone, totaling 86 feet of strata distributed through 174 feet of the San Saba Member; the top sandstone is 28 feet beneath the base of the Threadgill Member. The sandstone is mostly fine to medium grained and, where not weathered and stained, appears to be mostly light yellowish gray. Most of the limestone is very fine to medium grained, some is coarse grained, and toward the top microgranular, limestone becomes progressively more abundant. It appears in various colors such as yellowish to brownish gray, medium to light brown, greenish gray, grayish brown to brownish yellow, and mottled yellow and gray. Intraformational conglomerate is common to abundant in the upper half, some ooids are near the middle, and glauconite is sparsely distributed through most of the strata, absent in some, and abundant in only a few. Dolomite is common as mottles, rhombs, specks, and variously shaped replacements.

In the Leon Creek area, Alexander (1956) and Winston (1957) found it impossible to piece together a complete section of the San Saba Member, even after seven partial sections were measured. The top 154 feet was measured in the Leon Creek section, the bottom 121 feet in the Sheep Pen Hollow section, and the lower 20 feet of the Spring Hollow section partly fills the remaining gap.

In the Sheep Pen Hollow section the lower 36 feet of the San Saba Member immediately overlying the Point Peak Member is fine- to coarse-grained limestone, mostly glauconitic, greenish gray and light to medium gray, and occurs in beds most of which are 2 to 8 inches thick. The next 34-foot interval is for the most part medium grained sandstone (glauconitic, calcareous, and various shades of green) and some siltstone and limestone. This is the lowest level in reference to the top of the Point Peak Member at which appreciable sand has been recorded in the San Saba Member in the Llano region. The top 15 feet in this section is olive-tan, calcareous siltstone, thinly bedded at base to beds 6 to 12 inches thick at the top.

The lower part of the Spring Hollow section appears to occupy about 20 feet of the gap between the Sheep Pen Hollow and Leon Creek sections and consists of a lower 13-foot interval of mostly sandstone and some coarse-grained limestone overlain by 6.5 feet of very fine-grained, reddish, calcareous dolomite.

The San Saba in the Leon Creek section is composed of 5 sandstone zones ranging from 5 to 42 feet thick alternating with 5 limestone and dolomite zones ranging from 7 to 25 feet thick. The sandstone, totaling nearly 80 feet in thickness, is fine to medium grained; mostly very light yellowish gray, grayish yellow to yellowish gray, grayish orange, and very pale orange; mostly crossbedded, in some zones massively crossbedded; and mostly calcareous, with some beds approaching very sandy limestone in composition. The remaining 74 feet is mostly limestone and some dolomite. The limestone is fine to coarse grained, in part sandy, in part silty, slightly glauconitic, in beds 2 to 8 inches thick, and it contains some intraformational conglomerate. Dolomite, composing about half the 25-foot interval between the top 2 sandstone zones, is fine grained, pale yellowish orange and grayish orange to light brown, massive, and in part very sandy.

The top of the highest sandstone in the Leon Creek section is within 11.5 feet of the level chosen as the base of the Threadgill Member, and the lowest sandstone in the Sheep Pen Hollow section is within 36 feet of the top of the Point Peak Member, making a total known interval of about 247 feet of San Saba strata containing sandstone beds. This is much the thickest sandstone-bearing interval in the San Saba Member in the Llano region. If the thickness of the portion of the San Saba not bridged by section were known, it would increase this value at least by a small amount.

Winston (1957) recognized a *Saukiella pyrene* fauna represented by 24 collections in the middle portion of the San Saba Member, followed upward by a *Theodenisia* fauna represented by 11 collections, both faunas belonging to the Trempealeauan. He found that the upper 45.2 feet of the San Saba Member in the Leon Creek section and the upper 64 feet in the Red Bluff section contain a Lower Ordovician *Symphysurina* fauna represented by 12 collections, and that 52.8 feet of barren beds is located between the lowest Ordovician collection of fossils and the highest Cambrian collection of fossils in the Leon Creek section. The finding of Ordovician fossils beneath sandstone in this area confirms a similar determination in the Hext area made by Barnes, Bell, and Pavlovic (1954).

Alexander (1956) made 15 fossil collections from the lower part of the San Saba member in the Sheep Pen Hollow section which do not fit the zonation of the Trempealeauan of Howell and others (1944) or Raasch (1952). These collections probably represent the lower part of the *Saukiella pyrene* fauna recognized by Winston.

## Ellenburger Croup

### Tanyard Formation

*Threadgill Member.*—Threadgill strata measured and described (Alexander, 1956; Winston, 1957) in the Deer Run section of the Leon Creek area total 152.5 feet. The base of the Threadgill Member in this area is placed at the base of 1.5 feet of fine-grained, yellow to buff dolomite occurring in beds 1 to 6 inches thick. The overlying 104 feet of rock is mostly aphanitic limestone containing numerous intraformational conglomerate beds, except that an 11-foot interval starting 21 feet above its base is free of intraformational conglomerate and contains some fine-grained limestone. Scattered glauconite was seen at one level about 35 feet above the base of the member. Beds range mostly between 1 and 6 inches in thickness, some are between 6 and 12 inches, and in the lower 21 feet, 1- to 2-inch beds predominate. The upper 47 feet of this section is aphanitic to very fine-grained limestone in beds mostly 1 to 4 inches thick. Dolomite is common as splotches throughout most of the Threadgill Member and in some beds occurs as raised ropy patterns.

Alexander (1956) and Winston (1957) measured 162 feet of Threadgill strata, which is about half the thickness that should be present. The Threadgill Member crops out over a relatively large part of the Leon Creek area (pl. 8, fig. 5). Alexander and Winston also measured the basal 110 feet of Staendebach strata, which also is about half the thickness that should be present. This member is widely distributed in the southeastern part of the map area. The Staendebach is dolomite which is mainly medium grained in the upper part to fine grained in the lower part; a few beds are microgranular.

Tanyard rocks in the Bluff Creek and adjoining areas have been described by Cloud (Cloud and Barnes, 1948); Tanyard rocks in the Streeter area were seen only in sinks or collapsed structures.

### Gorman Formation

Alexander and Winston measured in the Leon Creek area a total thickness of 232 feet of calcitic Gorman, which is within 5 feet of the 237 feet measured by Cloud in the Rattlesnake Hill section (Cloud and Barnes, 1948, p. 164–170). The dolomitic facies of the Gorman Formation in this area was so poorly exposed that no attempt was made to measure it. Gorman rocks are mostly in the southern part of the Leon Creek area (pl. 8, fig. 5). No Honeycut rocks were found.

### Carboniferous Rocks

Carboniferous rocks mapped by Alexander and Winston in the southwestern part of the Leon Creek area include 12.5 feet of Chappel Limestone and 83 feet of the Barnett Formation, of Mississippian age, and the basal part of the Marble Falls Limestone, of Pennsylvanian age. The Barnett in the line of measured section consists of a lower 27.5 feet of medium-grained, white, crinoidal limestone overlain by and laterally grading to coarse-grained, white limesand. The top 35.5 feet of the measured section is dark-gray to medium-gray, fissile shale containing a few thin, dark-colored limestone beds.

The only other Carboniferous rock mapped is in a sink in the Streeter area and consists of coarse-grained Marble Falls Limestone deposited in part as strata in the sink and in part between the underlying blocks of collapsed Cap Mountain Limestone.

### Cretaceous Rocks

Cretaceous rocks confined to the Streeter and Leon Creek areas consist mostly of Hensell Sand as a thin veneer of very coarse, reddish quartz sand; locally, dark red conglomeratic boulders were seen. In the Streeter area in Cut Off Mountain, the Hensell Sand is overlain by poorly exposed Walnut Clay, followed by Comanche Peak Limestone, and a basal massive bed of Edwards Limestone. The Cretaceous rocks exist mainly in the western part of the Streeter area and the northern and western parts of the Leon Creek area.

### Quaternary Deposits

Quaternary deposits consist mostly of alluvium along major stream and one local patch of high gravel of unknown origin in the Streeter area.

## HEXT-CALF CREEK AREA, MENARD AND MASON COUNTIES

### Introductory Statement

The area discussed in the following pages lies mostly in northeastern Menard and northwestern Mason Counties with a slight overlap into McCulloch County and includes the Hext, Ziegler Ranch, and Calf Creek areas. The Hext area (pl. 7, fig. 4) in Menard County, the westernmost of the 3 areas, embraces about 1.9 square miles, and is situated in the 1:24,000 scale Robbers Roost and Hext U. S. Geological Survey topographic quadrangle maps. The village of Hext, 19 miles west of Mason and 17 miles east of Menard, is on State Highway 29, and is situated in the southern part of the area.

The Ziegler Ranch area (pl. 7, fig. 5) in Menard and Mason Counties is astride Ranch Road 1311 between State Highway 29, about 1.6 miles east of Hext, and Ranch Road 42, 12 miles southwest of Brady. About 1.9 square miles were mapped geologically.

The Calf Creek area (pl. 7, fig. 6) in Mason and McCulloch Counties is about 2 miles east of Ranch Road 1311 and may be reached either from Ranch Road 1311 at a point 0.5 mile north of San Saba River or from State Highway 29 about 3.7 miles east of Hext. About 1.6 square miles were mapped geologically. The Ziegler Ranch and Calf Creek areas are situated in the 1:24,000 scale Calf Creek U. S. Geological Survey topographic quadrangle map.

Rocks mapped in the Hext area include sandstone and limestone of the San Saba Member of the Wilberns Formation, small areas of the Staendebach and Threadgill Members of the Tanyard Formation, limestone and shale, not separately mapped, of the Canyon Group, Hensell Sand of Cretaceous age, and high gravel and alluvium. This area is important in showing that the Tanyard and Wilberns rocks were faulted and truncated before the deposition of Canyon rocks on their eroded and somewhat hilly surface. Harlton (1929) identified these Canyon rocks on the basis of ostracodes. The Hext area is of special interest because it is the only area in the Llano region in which Moore Hollow Group rocks are known to have been truncated by erosion during the Paleozoic era.

Rocks mapped in the Ziegler ranch area, in addition to those also mapped in the Hext area, include dolomitic and calcitic facies of the Gorman Formation and an area of collapsed rocks which may belong to the Honeycut Formation. Even though Moore Hollow Group rocks were not found, this area is important in showing the nature of overlap of Canyon strata on Ellenburger strata, the presence of collapsed contacts, and the location of Carpenter Exploration Company No. 1 Bradshaw, which furnishes an important tie between the surface and the subsurface for the Moore Hollow Group in the northwest portion of the Llano region. This map was prepared originally to demonstrate the relationship to the surrounding rocks of the oil seep uncovered by road-building operations.

Rocks mapped in the Calf Creek area include the dolomitic and calcitic facies of the San Saba Member of the Wilberns Formation, the Threadgill Member of the Tanyard Formation, a probable patch of Hensell Sand, some high gravel, and alluvium. The Calf Creek area is of special interest because the lower part of the San Saba Member is dolomitized stromatolitic reef, which has demonstrable relief sufficient to confine the sand in the San Saba Member to the area west of the reef.

The structure is fairly simple for the most part with gentle dips and major faults trending north-south or north-northeast — south-southwest, as is common elsewhere in the Llano region. A northwest-southeast direction of faulting, uncommon except in the western part of the Llano region, is well displayed in the Ziegler ranch and Hext areas. That the faults, all of which are normal, are pre-Canyon in age is indicated in the Ziegler ranch area and positively demonstrated in the Hext area.

The contact between the Threadgill and Staendebach Members in the Ziegler ranch area is commonly a collapse contact and as traced in the field has the appearance of a gigantic stylolite. It is inferred that Honeycut rocks were originally deposited across this area and that they were eroded prior to the deposition of Mississippian and Pennsylvanian rocks. A collapse structure in the calcitic facies of the Gorman Formation just northeast of the oil seep may contain Honeycut rocks; if this is true this is the farthest point northwest that Honeycut rocks have been recognized in the Llano region. If the rocks in this collapse structure are Honeycut in age, they must have reached their present position before the Honeycut Formation was eroded.

Vegetal patterns as expressed on aerial photographs are helpful in mapping some units. The area of Point Peak outcrop supports a sparse growth of mesquite and other thorny shrubs which contrasts with the scattered live oak clumps of the dolomitic and calcitic facies of the San Saba Member and all units of the Ellenburger. Vegetational alignments along bedding are fairly distinct in the sandy portion of the San Saba Member, the sand zones supporting a slightly denser growth including some deciduous oaks and black persimmon. The Canyon strata show strong vegetational and topographic alignments with sparse vegetation on shale benches, and scarps held up by limestone beds marked by narrow bands of dense vegetation. High gravel deposits and the Hensell Sand have mostly sparse vegetation and on aerial photographs appear lighter gray. On the alluvium along San Saba River grow large pecan trees.

## Moore Hollow Group

### Riley Formation

The Riley Formation is not exposed in this area; however, Carpenter Exploration Company No. 1 Bradshaw in the northern part of the Ziegler ranch area (pl. 7, fig. 5) drilled 245 feet of Riley rocks (Barnes, 1959, pl. 2). The bottom 40 feet is typical of the upper part of the Hickory Sandstone, consisting of medium- to coarse-grained sandstone, grains well rounded, mostly smooth to slightly rough, and grayish red to reddish brown and light brown.

The next 155 feet — assigned to the Cap Mountain Limestone even though it is predominantly very fine and fine-grained sandstone — is very calcareous, somewhat glauconitic, silty, and argillaceous, and medium olive gray to pale yellowish brown. At the top of the Cap Mountain 35 feet of limestone is coarse grained, pale yellowish brown to dark yellowish brown, glauconitic, and mostly sandy. Another 20 feet of limestone near the middle is fine grained, light olive gray, sandy, silty, and glauconitic. The Cap Mountain in this well is thinner than in any section measured in the northern part of the Llano region and also contains more terrigenous material.

The Lion Mountain Sandstone Member is 50 feet thick, which is slightly thinner than normal in this part of the Llano region but considerably thicker than the aberrant section in the Streeter area. It is composed of sandstone, shale, limestone, and siltstone, with the sandstone ranging from very coarse in the upper part, some grains 1/8 inch, to fine and medium grained in the lower part. Much of the sandstone, even though it is from a depth of 850 to 900 feet, appears weathered, being generally pale red to grayish red to moderate brown, and moderate yellowish brown. Some in the top sample is light gray with a greenish cast from adhering clay, and interstitial glauconite is abundant from about 865 to 875 feet. The shale is dark greenish gray, slightly calcareous, and silty, and the siltstone is grayish red and in part glauconitic. The limestone is granular, yellowish gray to greenish gray and glauconitic.

### Wilberns Formation

*Welge Sandstone and Morgan Creek Limestone Members.*—The lower two members of the Wilberns Formation are not exposed in this area; however, the Welge, 25 feet thick, and the Morgan Creek, 120 feet thick (Barnes, 1959, pl. 2), were penetrated in Carpenter Exploration Company No. 1 Bradshaw in the Ziegler ranch area (pl. 7, fig. 5).

The Welge Sandstone is of normal thickness and is coarse grained in the upper part to medium grained in the lower part. It ranges from white in the lower 10 feet to between light and moderate brown to pale red in the upper sample. The Welge is calcareous and the grains are well rounded and fairly rough from reconstitution.

The Morgan Creek Limestone is of about normal thickness and mostly coarse to very coarse grained and in some places fine grained. It is mostly greenish gray to very light olive gray and yellowish gray; the lower few samples are brownish gray to pinkish gray and pale red; some pale red is in one sample below the middle; and some reddish-gray, micaceous, silty, splintery shale is in the upper 10 feet. The Morgan Creek is glauconitic throughout, slightly to abundantly oolitic at many levels; the upper two-thirds is silty, micaceous, and argillaceous; and the lower 5 feet is sandy. A few large sand grains are below the middle. Fossil fragments are abundant, consisting of trilobites at many levels, calcareous brachiopods in the upper two-thirds, and phosphatic brachiopods at several levels.

*Point Peak Member.*—The uppermost part of the Point Peak Member is exposed in a broad, flat, faulted dome in the southeastern part of the Blockhouse ranch area (Barnes, Bell, and Pavlovic, 1954), in which the Calf Creek area is situated. Exposures are poor except for a small one of shaly siltstone along Spring Creek at the northern side of the outcrop area and one of siltstone and limestone with gigantic ripple marks along Spring Creek in a small inlier near Hal Pasture Mill. The boundary between the Point Peak and overlying dolomitic facies of the San Saba was mapped mainly on the basis of vegetation. Subsequent mapping between the Calf Creek area and the Cretaceous overlap to the south reveals a broad outcrop area of the Point Peak Member almost devoid of exposures, except along Big Ten Mile Creek where the various rock types are similar to those in other sections in this part of the Llano region. The southernmost exposures along Big Ten Mile Creek are reddish limestone and may be the uppermost beds of the Morgan Creek Limestone.

In Carpenter Exploration Company No. 1 Bradshaw, the Point Peak is 75 feet thick (Barnes, 1959, pl. 2). The rocks are mostly siltstone, limestone, and some shale. The siltstone is very light greenish gray in the upper part to greenish gray in the lower part with some yellowish brown near the middle; very calcareous, micaceous, and argillaceous; somewhat glauconitic throughout, and sparingly fossiliferous. The limestone is mostly coarse grained, partly fine grained, greenish gray, and fossiliferous with trilobite fragments most abundant. Some shale in the lower part is greenish gray and very micaceous and silty, and some just above the middle is grayish red, calcareous, glauconitic and micaceous.

The Point Peak in this well, normal in lithologic appearance, is abnormally thin for this portion of the Llano region and helps substantiate the correctness of the measurement of 71 feet of the Point Peak Member in the Leon Creek area. The total thickness of the Point Peak and San Saba Members in the No. 1 Bradshaw well is not far from average, and perhaps the abnormal thinness of the Point Peak is caused by the downward extension of reef similar to that found in the Camp San Saba area. Very little reef, however, was recognized in this position in the Leon Creek area.

San *Saba Member.*—The Calf Creek area furnishes the most instructive, albeit anomalous, section of the San Saba Member in the whole Llano region. In this area, fine-grained dolomite forms the lower part of the San Saba, whereas the normal position of dolomite, if present, is at the top of the member. The dolomite replaces an enormous stromatolitic reef which extends higher in this area in the San Saba than anywhere known in the Llano region. Evidence that the dolomite replaces stromatolitic reef limestone is furnished by local eyes of stromatolitic limestone and wavy interreef limestone beds and by the preservation of similar bedding characteristics in the dolomitized portion. The dolomite was not examined in detail except locally north of San Saba River where some interreef fine-grained, yellowish-gray to medium-gray, 6- to 12-inch beds of dolomite preserved burrows which weather in relief. The dolomitized stromatolites are light brownish gray to pinkish gray and slightly more vuggy than the bedded dolomite. About 40 feet of dolomite is present north of San Saba River below the zero mark of the Calf Creek section. The rest is exposed mostly on a broad dip slope and its thickness cannot be approximated by measurement in the field, but judging from the thickness of the San Saba Member in other sections and the height to which the dolomite extends in the San Saba, it must be almost 300 feet thick.

Another feature of the San Saba Member common only to the extreme western part of the Llano region is the presence of sandy zones and sandstone beds in the upper part of the member. In the Calf Creek section the dominantly sandy interval extends from 3 to 91 feet;

however, there is a small amount of sand above this level to the top of the member at 152 feet. Only 2 miles to the west in Carpenter Exploration Company No. 1 Bradshaw the sandy interval has increased 100 feet in thickness to about its normal thickness from this point westward through Menard County. Northeast from the Calf Creek section the sandy beds cut out against the stromatolitic reef in a distance of about 2 miles, and very little sand has been found east of the crest of the reef in this area. The crest of the reef must have extended several tens of feet higher than its present eroded surface to stop the sand from reaching equivalent beds east of the reef which, if projected, would pass above the present surface of the reef.

The sandstone and sand in this portion of the San Saba Member are fine to medium grained in the upper part, very fine to medium grained in the lower part, and near the middle medium to coarse grained with some very coarse grains. The sandstone is mostly very calcitic, locally may be quartzitic, and ranges in color from various shades of brownish yellow, in part with an orange cast, to white. The grains are fairly well rounded to well rounded and slightly rough. The interbedded limestone, much of it sandy, is coarsely granular, greenish gray to light yellowish gray and light brownish gray, brownish yellow, and yellowish orange. It is in part glauconitic and silty, intraformational conglomerate is at one level, and trilobites are common.

The top 61 feet of the San Saba Member is limestone with a 6-inch bed of very fine-grained, brownish-yellow dolomite at the base and some similarly-colored patches of dolomite and dolomitized burrows in the upper part. The limestone is mostly fine to coarse grained in the upper part and very fine to medium grained in the lower part, various shades of greenish gray, yellowish gray, and brownish gray, in part glauconitic, some beds are silty and argillaceous, sand is common, and intraformational conglomerate is common to abundant.

Another significant bit of geologic history long known from the subsurface and thought likely to occur at the surface in the northwesternmmost area is the truncation of Moore Hollow Group rocks with deposition of Carboniferous rocks directly on them. Robert Pavlovic, Magnolia Petroleum Company, reported on July 15, 1953, the discovery of various outcrops of San Saba Member rocks overlapped by Canyon Group rocks. He also recognized the dolomite along the eastern side of the San Saba outcrop and mapped part of the Ziegler ranch area (pl. 7, fig. 5) but did not complete the mapping because of the complications introduced by collapse and boundaries within the Ellenburger. The mapping of the Hext area was completed by Barnes and Bell and of the Ziegler ranch area by Barnes, Bell, and Lane Dixon; these maps and one of the Calf Creek area maps first appeared in a San Angelo Geological Society guidebook (Barnes, Bell and Pavlovic, 1954).

The northwesternmost inlier of San Saba Member rocks in the Hext area (pl. 7, fig. 4) furnishes important information about the position of the systemic boundary. In this outcrop, limestone sandwiched between sandstone zones contains Ordovician trilobites, showing that the systemic boundary does not coincide with the top of the sandy unit but is somewhere within the sandy unit. Cambrian trilobites were found 24 feet beneath the top of the sandy unit in the Calf Creek section.

In Carpenter Exploration Company No. 1 Bradshaw, the San Saba Member forms three fairly distinct divisions. The lower one, 105 feet thick, is mainly dolomite and limestone with a minor amount of dolomitic sandstone in the upper sample. The dolomite is fine and very fine grained, various shades of yellowish brown, yellowish orange, grayish orange, very light olive gray, moderate grayish red, pale red, and yellowish gray. The limestone is granular, glauconitic, greenish gray to yellowish gray, and in part silty, argillaceous, and micaceous. Some near the base is oolitic and fossiliferous with abundant pelmatozoan and trilobite fragments. The middle portion, 150 feet thick, is mostly sandstone and some dolomite and limestone. The sandstone is mostly fine and very fine grained, with some medium grained near the middle, pale to dark yellowish orange, moderate yellowish brown, with some white in the upper part. The dolomite is fine grained and of similar color, and the limestone is very fine grained and light greenish gray. The upper portion, 85 feet thick, is mainly limestone and some sandstone, dolomite and shale. The limestone, mostly finely granular in the lower part, is microgranular and aphanitic in the upper part where it is distinguished from the Threadgill Member by the presence of glauconite. It is mostly yellowish gray, grayish orange to yellowish brown, and some greenish gray in the basal few feet. A very fossiliferous interval about 40 to 45 feet beneath the top may correlate with a level at 142.5 feet in the Calf Creek section.

## Ellenburger Group

### Tanyard Formation

*Threadgill Member.*—The calcitic facies of this unit, mapped in all three areas, is best represented in the Calf Creek area where it covers a broad belt between the top of the San Saba Member and the base of the Staendebach Member. In the Ziegler ranch area the upper portion is present mainly in collapse contact, complicated by faulting, with the overlying dolomite mapped as Staendebach. This dolomite, in part at least, is probably laterally equivalent to limestone of the Threadgill Member. That this is true can be seen in the log of the nearby Carpenter Exploration Company No. 1 Bradshaw (pl. 2), where almost all of the Threadgill Member has graded to fine- and very fine-grained dolomite. The dolomite is mostly yellowish gray to very light olive gray and various shades of yellowish brown, pinkish gray, and medium reddish brown. Of the 185-foot interval of Threadgill rocks in this well, only the lower 35 and upper 10 feet contain aphanitic limestone and this is gradational to dolomite.

*Staendebach Member.*—The Staendebach Member, poorly represented in the Calf Creek and Hext areas, is well represented in the Ziegler ranch area. It is mostly fine grained with some microgranular and medium-grained beds and is mostly yellowish gray to various shades of very light to medium gray. Chert is common and is mostly white, dolomoldic, finely granular, and in part quartzose. Some of the dolomite, as mentioned above, mapped as Staendebach in the vicinity of the contact with the Threadgill Member may actually be Threadgill instead of Staendebach. In Carpenter Exploration Company No. 1 Bradshaw, 70 feet of dolomitic and calcitic Staendebach Member was drilled, with the calcitic portion consisting of about 15 feet of dolomitic limestone. Similar limestone was not recognized in outcrop, unless the four small areas along the highway south of the San Saba River mapped as the calcitic facies of the Threadgill Member should be so classified.

#### Gorman Formation

Gorman rocks are limited to a wedge-shaped graben near the center of the Ziegler ranch area. Both the dolomitic and calcitic facies of the Gorman are present including the *Archaeoscyphia* Bed, which was mapped for a short distance. The dolomitic facies is mostly microgranular dolomite and the calcitic facies is mostly massive, aphanitic limestone and some interbedded dolomite.

#### Honeycut(?) Formation

Rocks of possible Honeycut age are confined to an elliptical area of collapse having a mean diameter of about 700 feet. That these rocks are Honeycut in age is based in part on the appearance of the interbedded limestone and dolomite and in part on the position of the collapse structure, which appears to be high in the Gorman formation. It seems likely that the rock in a structure so jumbled in its marginal portion would have settled too far to have Gorman rocks in it at the level now exposed.

### Carboniferous Rocks

#### Canyon Group

The Canyon Group, consisting of fossiliferous, granular limestone zones and interbedded shale areas, is exposed in the Ziegler ranch and Hext areas. In the Ziegler ranch area, the Canyon unconformably overlies Threadgill(?) and Staendebach Members, and calcitic Gorman Formation, and in the Hext area it rests on limestone and sandstone of the San Saba Member and on dolomitic Staendebach. That faulting took place prior to deposition of Canyon rocks is unquestionably shown in the Hext area (pl. 7, fig. 4).

### Cretaceous Rocks

The Cretaceous represented by Hensell Sand appears to be present in all three areas. Only in the Calf Creek area are exposures so poor that areas mapped as Hensell Sand (mostly on the basis of photointerpretation) are questioned. High gravel deposits give similar expression on aerial photographs and might easily be confused with conglomeratic portions of the Hensell. The Hensell Sand is mostly reddish, argillaceous, silty, and locally calcareous and conglomeratic.

### Quaternary Deposits

High terrace gravel covers large areas in the Hext and Ziegler ranch areas and smaller areas in the Calf Creek area. Alluvium is mostly along San Saba River and along the southern part of the most prominent drainage in the Hext area. An interesting feature of the Ziegler ranch area is the rock-bottomed abandoned channel of San Saba River now carrying only local drainage except during floods.

### Carpenter Exploration Company No. 1 Bradshaw

Because of the unusual development of the San Saba Member and the presence of the Cambrian-Ordovician boundary within the San Saba Member in this part of the Llano region, it was important to try to find a measurable section of these rocks. Mapping showed that only the upper portion of the San Saba Member could be measured with any confidence in accuracy, and some of it is not very well exposed. Fortunately, Carpenter Exploration Company No. 1 Bradshaw was drilled near the outcrop area, yielding important information for interpreting these rocks.

Cuttings from this well were described by Barnes (1959, p. 510–513); these descriptions will not be repeated except for summaries given above under discussions of the various units. A diagrammatic representation of the rocks drilled in this well (Barnes, 1959, pl. 2) is repeated herein (pl. 2).

The thicknesses of the various units drilled in this well are given in table 16.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Calf Creek section — description of measured section with thin-section descriptions and fossil lists, heavy-mineral data, table 30, insoluble-residue data, table 31.

Table 16. Thicknesses of geologic units in Carpenter Exploration Company No. 1 Bradshaw well, Mason County, Texas.

| Unit | Thickness (feet) | Depth (feet) |
|---|---|---|
| Terrace gravel | 15 | 0–15 |
| Canyon Group | 20 | 15–35 |
| Tanyard Formation | 255 | 35–290 |
| Staendebach Member | 70 | 35–105 |
| Threadgill Member | 185 | 105–290 |
| Wilberns Formation | 560 | 290–850 |
| San Saba Member | 340 | 290–630 |
| Point Peak Member | 75 | 630–705 |
| Morgan Creek Limestone Member | 120 | 705–825 |
| Welge Sandstone Member | 25 | 825–850 |
| Riley Formation | 245 | 850–1,095 |
| Lion Mountain Sandstone Member | 50 | 850–900 |
| Cap Mountain Limestone Member | 155 | 900–1,055 |
| Hickory Sandstone Member | 40 | 1,055–1,095 |

# CAMP SAN SABA-CAMP AIR AREA, MCCULLOCH AND MASON COUNTIES

## Introductory Statement

The Camp San Saba area is important in that it furnishes the name and type section for the San Saba Member and is one of the better-known localities long visited by geologists to obtain a better understanding of Upper Cambrian rocks and their relationship to the overlying Lower Ordovician rocks. The San Saba Member in this area is almost entirely free of sand, in marked contrast to the abundance of sand in it in the Calf Creek area 12 miles to the southwest; also stromatolitic reefs are chiefly limestone in the San Saba area whereas they are dolomite in the Calf Creek area.

The following areas were mapped: (1) Camp San Saba area, McCulloch County, in which the Camp San Saba section is situated, including all the Wilberns Formation except the lower few feet of the Welge Sandstone; (2) Brook's Katemcy ranch area, McCulloch County, in which exposures are poor but in which the thicknesses of the Cap Mountain Limestone, Lion Mountain Sandstone, and Welge Sandstone Members were measurable; (3) Camp Air area, Mason County, in which the upper part of the red Hickory Sandstone is exposed in a highway material pit on the H. Sell farm, and the three divisions of the Hickory Sandstone recognized in the northwestern part of the Llano region can be demonstrated by their expression on aerial photographs.

The Camp San Saba area (pl. 8, fig. 2) includes 4.9 square miles and is situated in the 1:24,000 scale Brady South and Katemcy U. S. Geological Survey topographic quadrangle maps. The Brook's Katemcy ranch area (pl. 7, fig. 7) includes about 0.9 square mile; and the Camp Air area (pl. 7, fig. 8) includes 2.0 square miles and both are situated in the 1:24,000 scale Katemcy U. S. Geological Survey topographic quadrangle map. The map of the Camp San Saba area previously appeared in a San Angelo Geological Society guidebook (Barnes and Bell, 1954a).

Included in the discussion of the Camp San Saba—Camp Air area, but not situated in any of the map areas, is the Tommy Brook irrigation well, 2.4 miles east-northeast of the post office at Camp San Saba. This well is important because it shows that more than half of the Threadgill Member has graded to dolomite in a distance of 2.5 miles from the measured section; the same type of lateral gradation is seen in the opposite direction from the Camp San Saba section in Carpenter Exploration Company No. 1 Bradshaw. This indicates that the Threadgill Member in the northwestern part of the Llano region may not be as predominantly limestone as originally thought. In the Tommy Brook well, the lower part of the San Saba Member contains about 100 feet of dolomite which approximately corresponds to the limestone stromatolites in the Camp San Saba section, and in this respect the San Saba Member is similar to its occurrence in the Calf Creek area where dolomite replaces stromatolites.

Rocks mapped in the Camp San Saba area include the upper part of the Cap Mountain Limestone Member and the Lion Mountain Sandstone Member of the Riley Formation, all members of the Wilberns Formation, the Threadgill Member of the Tanyard Formation, colluvium, and alluvium.

Rocks mapped in the Brook's Katemcy ranch area include all parts of the Riley Formation except the lower half of the Hickory Sandstone Member, and the Welge Sandstone and Morgan Creek Limestone Members of the Wilberns Formation.

Rocks mapped in the Camp Air area include Town Mountain Granite of the Katemcy granite mass, all members of the Riley Formation and the Welge and Morgan Creek Members of the Wilberns Formation.

The rocks in all 3 areas generally dip very gently, a minor fault is in each of the three, and a north-south fault, with perhaps 1,200 to 1,500 feet displacement at the point of greatest movement, is situated in the eastern part of the Camp San Saba and Brook's ranch areas. The minor fault in the Camp San Saba area trends north-northeast and was identified on both sides of the San Saba Member part of the measured section but could not be traced across the section.

Vegetal patterns as seen on aerial photographs are an aid in mapping. The bedding alignment patterns of the Cap Mountain Limestone, Morgan Creek Limestone, and San Saba Members are similar except that the massive stromatolitic part of the San Saba Member exhibits bedding alignments in very few places. The Cap Mountain Limestone grows abundant scrub live oak, tasajillo, and prickly pear among other plants, and the Morgan Creek Limestone, which supports similar vegetation, appears to grow a larger proportion of cedar, agarita, bee brush, and bear grass. The vegetation on these members is very similar to that on the San Saba except that the latter appears to have a greater abundance of prickly pear and black persimmon. The Threadgill Member photographs lighter gray than the San Saba Member, is less densely vegetated, and grows live oak but very little else except prickly pear and bear grass and, toward the top, a few black persimmon. The Staendebach supports very few trees except for a few widely spaced, large live oaks and sparsely distributed mesquite; prickly pear is abundant.

The Point Peak Member is very light gray, forms a scarp, and grows very little vegetation. That which is present is thorny and on aerial photographs contrasts strongly with the medium gray limestones above and below. The Lion Mountain and Welge Sandstones are cultivated for the most part; where not cultivated, the Lion Mountain supports a few mesquite and other thorny shrubs and the Welge, mostly along streams, grows large live oaks.

The Hickory Sandstone Member is divisible into three parts; the upper and lower ones are mostly cultivated; the middle one, mostly not cultivated, forms a low scarp and is characterized by mesquite, other thorny shrubs, and some deciduous oak. Where not cultivated, the upper and lower members support large deciduous oak, which because of their size can be distinguished on aerial photographs from those growing on the middle member. Most of the Town Mountain granite mapped forms bare rock surfaces.

## Precambrian Rocks

### Town Mountain Granite

Town Mountain Granite of the Katemcy granite mass, exposed in the Camp Air map area, crops out mostly as elevated bare granite surfaces. That similar elevated areas of granite were present when the Cambrian sea invaded the Llano region is shown by the top of a buried hill reaching high into the middle part of the Hickory Sandstone member in the western part of the area.

## Moore Hollow Croup

### Riley Formation

*Hickory Sandstone Member.*—All parts of the Hickory Sandstone crop out in the Camp Air area (pl. 7, fig. 8), but no measurable section of the entire member was found in this area or adjacent areas to the south and east. In the highway material pit on the H. Sell farm, the upper 32 feet of red Hickory Sandstone was measured, described, and sampled in connection with an economic study of the sandstones of the Cambrian (Barnes and Schofield, 1964).

Irrigation wells drilled to the base of the Hickory Sandstone are numerous in the Camp Air and adjacent areas; some of these are more than 400 feet deep, but none of those investigated by the writer penetrated the Hickory's entire thickness. A 200-foot well near the southwestern corner of the area penetrated almost all of the lower part of the Hickory Sandstone; another well 1 mile due west of the first and west of the area penetrated 419 feet of Hickory Sandstone without reaching granite. This second well is estimated to have been started about 50 feet below the base of the red portion of the Hickory Sandstone. No information was found on the thickness of the red Hickory Sandstone in this area, but in the Pontotoc area it is about 130 feet thick and in the Streeter area 116 feet was measured without reaching its base. It seems likely that a reasonable figure for the maximum thickness of the Hickory Sandstone in this part of the Llano region is about 600 feet, distributed about as follows: upper red portion, 130 feet; middle argillaceous portion, 250 feet, lower tilled portion, 220 feet. Locally, the Hickory Sandstone will be much thinner than 600 feet — for example, where it rests on buried hills of Precambrian rock.

Quartz conglomerate is present but is not a conspicuous feature of the basal part of the Hickory Sandstone in this area. White (1960) mapped three topaz-bearing localities in the conglomerate in the Camp Air area (pl. 7, fig. 8) and four others to the northeast. The conglomeratic base of the Hickory Sandstone is well exposed where its lower contact crosses Katemcy Creek.

In the highway material pit on the H. Sell farm, 32 feet of red Hickory Sandstone was measured and described. It is mostly massive, coarse grained, dusky red, hematitic sandstone, in part crossbedded, in part burrowed, and in part calcitic, becoming more so upward. Phosphatic brachiopods are common to abundant throughout.

Exposures are scarce of the lower and upper parts of the Hickory Sandstone; however, exposures of the middle portion are common. In the road ditch in the southwestern part of the Camp Air area, exposures of the middle part of the Hickory reveal that it is in part thin bedded, argillaceous, silty, and fine grained, alternating with medium to coarse-grained, medium to thick sandstone beds.

*Cap Mountain Limestone Member.*—In the Brook's Katemcy ranch area 205 feet of poorly exposed Cap Mountain Limestone was measured. The lower 10 feet is sandy, the next 35 feet silty, and the rest, in the line of section, is mostly soil covered. The Cap Mountain Limestone forms a gentle, downward steepening scarp between the Lion Mountain bench and the flat at its lower edge formed by the Hickory Sandstone. Most of the surface elsewhere is thinly covered by soil with leached, dark-brown siltstone beds and irregular masses exposed in places. In the lower steeper part of the scarp, bedded rock is common.

*Lion Mountain Sandstone Member.*—The measured thickness of the Lion Mountain Sandstone Member in the poorly exposed Brook's Katemcy ranch section is 65 feet. The lower 15 feet consists of greensand and lenses of trilobite coquinite, followed by a 25-foot covered interval and 25 feet of greensand. Fresher exposures of the Lion Mountain in the Camp San Saba area are near the mouth of Katemcy Creek, and the contact between the Lion Mountain and Welge Sandstones is well exposed south of the cemetery south of Camp San Saba. About 50 feet of Lion Mountain Sandstone was penetrated in the Tommy Brook well. The quartz sand ranges from fine to medium in the lower part to coarse to very coarse in the upper part. It is mostly well rounded, in part reconstituted in the upper part, and mostly greenish gray from adhering glauconite. Some white sandy limestone and greenish-gray to pale-red shale exists in the lower part.

### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone Member in the Brook's Katemcy ranch section is 30 feet thick and is the thickest section of Welge Sandstone measured at the surface in the Llano region. About 18 feet of the lower part of the Welge (the only part sampled) in the Tommy Brook well is medium to coarse grained, the grains are well rounded, 10 to 20 percent are reconstituted and smoky from inclusion of a black substance in the secondary silica, some in the middle portion are pinkish brown, and the rest are mostly white.

The bottom 9 feet of the Camp San Saba section is Welge Sandstone. It is medium to coarse grained coarsening upward to 1/4-inch pebbles at the top, is more calcareous toward the top, and is mostly yellowish brown and pale to dark yellowish orange with some pale yellowish brown and light olive gray, the latter in a few beds which are slightly glauconitic. Grains are poorly sorted and well rounded to angular; some are smooth, a few are chatter marked, most are rough from slight reconstitution, and most are quartz. Fossils were not found in the Welge in this area.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone in the Camp San Saba section is 114 feet thick, one of the thinner sections in the Llano region. The 90 feet assigned to it in the Tommy Brook well on the basis of rather sketchy samples is obviously too thin. The lower 6 feet of the Morgan Creek Limestone in the Camp San Saba section contains a few quartz granules, is very sandy, grayish red, slightly glauconitic, and medium to thick bedded. The sand is mainly quartz, fine to very coarse, the coarser grains are well rounded, and the rest subrounded to angular. The next 28 feet is mostly coarse grained, medium to thick bedded, grayish red to light brownish gray in lower part with the red grading out upward, dolomite specks common, sandy, sand more abundant downward, and grains mostly fine to medium, some coarse. Some zones in this interval are fine grained, yellowish gray to light olive gray, glauconitic, silty, argillaceous, and burrowed.

The overlying 46 feet is about equally coarse and fine grained. The coarse-grained part is medium to thick bedded, mostly yellowish gray to light olive gray, glauconitic, crossbedded, in part oolitic, and dolomitic with the dolomite replacing fossil fragments and other objects and occurring as pale yellowish-orange lenses or patches in some beds. The fine-grained portion is nodular to thin bedded, pale olive to light olive gray to pale yellowish brown, glauconitic, silty, argillaceous, somewhat micaceous, and burrowed. Sand is mostly very fine grained; coarse grains are very scarce. The upper 34 feet of the Morgan Creek Limestone is very similar to that just described except that stromatolites occupy the bottom foot, another zone is located near the middle of the interval, ripple marks are present, dolomite specks and patches are more numerous, and mica is more abundant. Stylolites are common to abundant in most of the coarser grained beds throughout the Morgan Creek Limestone.

*Point Peak Member.*—The Point Peak Member in the Camp San Saba section, is abnormally thin, 94 feet, which is not far in thickness from the 100 feet allotted to it in the Tommy Brook well. The lower 15 feet in the surface section is mostly limestone, very silty, fine grained, medium light gray weathering pale olive, glauconitic, micaceous, in part burrowed, alternating with thin films of greenish-gray shale. Above this is 17 feet of thin-bedded siltstone bordering on limestone which contains trails and minute ripple marks. The next 48 feet is mostly siltstone, yellowish gray, calcareous, micaceous, and slightly glauconitic alternating with very thin films of light brownish-gray shale and a few limestone intraformational conglomerate beds. Minute ripples are common in the lower part and trails in the upper part. The top 31 feet of the Point Peak, mostly siltstone, is bottomed by a 2—foot bed of stromatolites, a 3-foot bed of stromatolites exists near the middle, and 2 doughnut-shaped stromatolites occur in an intraformational conglomerate in the upper part. The siltstone is yellowish gray, slightly micaceous, calcareous, slightly glauconitic, and it exists in beds from about 0.25 to 1 inch thick. Limestone intraformational conglomerate beds are abundant.

San *Saba Member.*—In the Llano region the 299-foot thickness of the San Saba Member in the Camp San Saba area is exceeded only in the Tanyard area and in the Tommy Brook well, where 324 and 340 feet of strata respectively are assigned to it. In comparing the Camp San Saba section with the Tommy Brook well (pl. 2), about 20 feet of the increased thickness in the well is at the top. The abnormally thick San Saba and the abnormally thin Point Peak Members in this area are at least partly explained by the lower stratigraphic level of their mutual boundary, influenced by the growth of stromatolites.

The lower 14 feet of the San Saba Member in the Camp San Saba section is massive, low-residue limestone, coarse grained, pale yellowish orange to grayish orange, broadly ripple marked at the top, bottomed by a 10-inch intraformational conglomerate bed, and laterally displaced by stromatolitic reef. The next 5 feet is very fine- to coarse-grained limestone, with much very fine sand, some silt, dolomite, biotite, and glauconite; this is followed by an 11-foot covered interval which is probably siltstone. On aerial photographs, a series of elongate, lighter colored areas at this level separated by a normal reef pattern suggest that this interval also is occupied laterally by stromatolitic reef.

The covered interval is followed by 48 feet of reef and interreef limestone and dolomite. The approximately 22 feet of interreef beds is all dolomite, pale red to light brown to dark yellowish orange and light brown to grayish orange. The stromatolitic reefs are mainly yellowish-gray, aphanitic limestone with various amounts of pale yellowish-orange dolomite outlining the stromatolitic structure, and the top 10-foot interval is mostly dolomite. The top of the reef within 1/2 mile of the section reaches at least 80 feet higher stratigraphically, indicating that the reef may attain a maximum thickness of 160 feet in this area.

Of the equivalent, 160-foot zone in the Tommy Brook well about 100 feet is dolomite, mostly very fine grained and some fine grained, possibly replacing reef. The paucity of glauconite and the presence of some aphanitic limestone above and below the dolomite suggest that about 160 feet of stromatolitic reef may be present in this well.

The next 58 feet above the reef in the Camp San Saba section may reflect the lateral nearness of reef in its aphanitic to microgranular and very fine-grained character and the presence of 6 feet of fine-grained, grayish-orange dolomite mottled very pale orange and medium yellowish orange. Beneath the dolomite the limestone is yellowish gray, in part glauconitic and oolitic, and mottled by pale yellowish-orange dolomite. Above the dolomite the limestone is massive, yellowish gray and nonglauconitic.

The next 60 feet of limestone is predominantly medium to coarse grained, light olive gray, in upper part medium yellowish gray, glauconitic, oolitic mottled by pale yellowish-orange and grayish-orange dolomite, and with some intraformational conglomerate in the lower part. The next 57 feet of limestone is for the most part alternations of very fine- and medium-grained zones, and is yellowish gray to light olive gray with some pale yellowish brown in the lower part. Intraformational conglomerate is common, ripple marks are present in the upper part, and grayish-yellow mottles and grayish-orange and dark yellowish-orange patches of dolomite are common.

The top 46 feet of the San Saba Member is mainly very fine-grained to aphanitic limestone with a few fine- and medium-grained beds, the lower part is yellowish gray, and the upper part pale yellowish brown. It is glauconitic and silty, and dolomite as dark yellowish-orange mottles and patches is abundant. The fine-grained beds are mostly intraformational conglomerate; fine sand grains are very scarce.

A small amount of silt and very fine sand is distributed throughout the San Saba Member.

## Ellenburger Croup

### Tanyard Formation

*Threadgill Member.*—During the present study, 76 feet of the Threadgill Member was measured and described; Cloud (Cloud and Barnes, 1948, p. 140–147) measured and described all the Threadgill Member, as well as the rest of the overlying Ellenburger rocks and the underlying San Saba rocks, in the nearby Highway 87 section. The 76 feet of Threadgill described in the Camp San Saba section is yellowish gray, mostly aphanitic, in part fine to very fine grained, and in part mottled by pale to dark yellowish-orange dolomite; trails and other markings are common except in the upper 15 feet.

Cloud (Cloud and Barnes, 1948, p. 144–145) found the Threadgill Member to be 255 feet thick in the Highway 87 section. This is very near the 245-foot thickness found in the Tommy Brook well. Instead of being entirely limestone as it is in the surface section, the top 135 feet in the well is fine-grained dolomite; also very fine-grained dolomite is prominent in most of the lower part of the member in the well.

#### Ellenburger undivided

In the eastern part of the Brook's Katemcy ranch and Camp San Saba areas, the various units of the Ellenburger have not been separately mapped. Staendebach Member rocks are surely present, and it seems likely that dolomitic Gorman Formation also may be present.

### Quaternary Deposits

Material mapped as colluvium in the Camp San Saba area is of uncertain derivation. It is in about the position where high terrace gravel might be located; however, it appears to be locally derived and its advanced degree of calichification suggests that it is colluvium instead. Alluvium exists mostly along San Saba River and Katemcy Creek.

## Description of Rocks in Camp San Saba—Camp Air Area

Cloud (Cloud and Barnes, 1948, p. 145–147) measured and described the upper 230 feet of Wilberns Formation rocks in the Highway 87 section and designated the upper 200 feet of these strata as the type section of the San Saba Limestone Member. The remaining 30 feet of stromatolitic bioherm was placed with the Point Peak Member even though included with the San Saba Member in the map of the Bald Ridge area (Cloud and Barnes, 1948, p. 147, pl. 4). Additional mapping showed that most of the stromatolitic reef is at the stratigraphic level of the San Saba Member, and even though its base is at a stratigraphic level normally within the Point Peak Member, it should be included with the San Saba Member as is done in the Calf Creek area, where dolomitized reef constitutes most of the San Saba Member. The reef can be traced continuously between the two sections except for minor offsets by faulting.

Because the Highway 87 section, while convenient for inspection, is poorly exposed, collapse in the vicinity of the San Saba—Threadgill boundary obscures the relationships, and because almost 100 feet of strata have been added to the San Saba Member in this report, it is proposed that the measured and described section of the San Saba Member following this discussion be designated as the type section, rather than the one described in the 1948 report. The new section is placed to take advantage of the best exposures, crosses the Highway 87 section, and can be tied directly to the Highway 87 section. The description of the complete Camp San Saba section is on open file at the Bureau of Economic Geology.

As previously stated, exposures are very poor in the line of section in the Brook's Katemcy ranch area, only the uppermost part of the Hickory Sandstone can be placed in its proper measured position in the stratigraphic sequence in the Camp Air area, and the Tommy Brook well is included to show the amount of lateral gradation from limestone to dolomite that can take place in a short distance.

#### Tommy Brook water well

Cuttings from this well were described by Barnes (1959, p. 514–515); these descriptions are not repeated except for brief summaries included above in the discussion of the various units. A diagrammatic representation of the rocks drilled in this well (Barnes, 1959, pl. 2) is repeated herein (pl. 2).

The thicknesses of the various units drilled in this well are given in table 17.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Camp San Saba section — description of measured section with thin-section descriptions and fossil lists, insoluble-residue data,

**Table 17. Thicknesses of geologic units in Tommy Brook water well, McCulloch County, Texas.**

| Unit | Thickness (feet) | Depth (feet) |
|---|---|---|
| Terrace gravel(?) | 25 | 0–25 |
| Tanyard Formation | 540 | 25–565 |
| Staendebach Member | 295 | 25–320 |
| Threadgill Member | 245 | 320–565 |
| Wilberns Formation | 555 | 565–1,120 |
| San Saba Member | 340 | 565–905 |
| Point Peak Member | 100 | 905–1,005 |
| Morgan Creek Limestone Member | 90 | 1,005–1,095 |
| Welge Sandstone Member | 25 | 1,095–1,120 |
| Riley Formation | 50 | 1,120–1,170 |
| Lion Mountain Sandstone Member | 50 | 1,120–1,170 |

table 32; Brook's Katemcy ranch section — description of measured section with fossil lists; Sell highway material pit section — description of measured section with thin section descriptions.

**San Saba Member type section**

The top of the Camp San Saba section, which includes the type section of the San Saba Member of the Wilberns Formation, is located at the top of a hill about 1,500 feet N. 52° S. from the R. Appleton ranch house and 4,500 feet N. 62° W. from the U. S. Highway 87 bridge over San Saba River. The bottom of the section is at the lowest exposed bed at the edge of a boulder-strewn alluvial plain on the left bank of San Saba River, downstream about 1,000 feet from the rock-crossing ford 1/2 mile northeast of Camp San Saba.

The section was measured during the fall of 1949 by Barnes and Ellinwood. Ellinwood collected fossils and chip-sampled the section in 5-foot intervals; the description is by Barnes. The line of section is shown on pl. 8, fig. 2. The fossil lists were updated by Bell during July and August 1968. The description that follows is extracted from Part II, Description of stratigraphic sections, Camp San Saba section, McCulloch County, Texas, on open file at the Bureau of Economic Geology.

**Description of the type section of the San Saba Member of the Wilberns Formation, McCulloch County, Texas**

| Description | Thickness in feet Interval | Thickness in feet Cumulative | Feet above base |
|---|---|---|---|
| *Wilberns Formation: 516 feet described*<br>*San Saba Member: 299 feet thick*<br>*Cakitic facies: 299 feet thick* | | | |
| The top of the Wilberns formation was arbitrarily chosen by using lithologic characteristics; the limestone beneath the boundary is mostly granular, that above mostly aphanitic. The choice of the boundary was also influenced by the distribution of glauconite. Description of 76 feet of Threadgill Member rocks, described in the section on open file at the Bureau of Economic Geology, are not included here. | | | |
| 3. Limestone—mostly very fine, some fine- and medium-grained; mostly somber hues of pale yellowish brown, greenish cast where glauconitic; limonite common; dolomite pale to dark yellowish orange common as mottles and patches; beds mostly 6 to 12 inches. Residue—clay, silt, sand, and glauconite; silt contains various amounts of quartz and feldspar both authigenic and detrital; sand scarce, mostly very fine, a few grains fine from 495 to 500 feet; glauconite scarce to very abundant. | 26 | 102 | 490–516 |
| From 490 to 496 feet, glauconitic, fossiliferous; 496 to 497 feet, fine grained, mottled by dolomite; 497 to 503 feet, fine to very fine grained, the latter thin bedded; 503 to 505 feet, covered; 505 to 507 feet, very fine grained, nodular, thin bedded; 507 to 508 feet, very fine grained; 508 to 509 feet, fine grained, mottled by dolomite; 509 to 510 feet, covered; 510 to 511 feet, fine grained, mottled by dolomite; 511 to 514 feet, mostly covered; 514 to 516 feet, lower part very fine grained, middle part fine grained, mottled by dolomite, upper part fine to very fine grained, glauconitic. | | | |
| Thin sectioned at 508 and 511 feet. At 508 feet, limestone—numerous intraclasts and pellets, some silt, a few trilobite and pelmatozoan fragments and finely radiate organisms in an aphanitic to microgranular matrix; intraclasts aphanitic, in part may be cavity fillings of fossils; swirled areas of denser aphanitic limestone with centers of calcite may be filled burrows; silt mostly authigenic feldspar, a few detrital centers; tiny glauconite grains scarce; stylolites have limonitic clay along them. At 511 feet, limestone — irregularly distributed trilobite and pelmatozoan debris and patches of dolomite in aphanitic to microgranular matrix, in part pelleted, in part structureless; silt common, mostly authigenic feldspar; dolomite, 0.05 to 0.15 mm, strongly zoned, replaces matrix, cavity fillings in fossils; intraclasts(?), yellowish orange from weathering, in part replaced by calcite; stylolites have limonitic clay along them and probably formed after dolomitization, as indicated by truncated rhombs. | | | |
| Fossils collected by Ellinwood from 490.5 feet, *Apheoorthis ornata* Ulrich & Cooper, *Symphysurina brevispicata* Hintze, and *Jujuyaspis keideli* Kobayashi; from 491 feet, *Symphysurina brevispicata* Hintze, and *Jujuyaspis keideli* Kobayashi; from 491.5 feet, *Symphysurina brevispicata* Hintze, and *Jujuyaspis keideli* Kobayashi; from 509, 512, and 515 feet, *Symphysurina brevispicata* Hintze. | | | |

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| Fossils collected by Nicholls and Ellinwood from 496 feet, *Jujuyaspis keideli* Kobayashi, *Symphysurina brevispicata* Hintze, and *Hystricurus millardensis* Hintze. | | | |
| Fossils collected by Nicholls from 515 feet, *Symphysurina brevispicata* Hintze, and *Homagnostus reductus* Winston & Nicholls; from 516 feet, conodonts. | | | |
| 4. Limestone—alternating intervals of very fine-grained to aphanitic, thin-bedded, yellowish-gray and fine-grained beds, mostly intraformational conglomerate; dolomite mottles and patches common; silty, silt mostly feldspar both detrital and authigenic; some very fine sand, and a few fine grains, in upper 5 feet. | 20 | 122 | 470–490 |
| Thin sectioned at 475, 485, and 486 (two sections) feet. At 475 feet, limestone—intraclasts and a few trilobite fragments mostly in a microgranular to very fine-grained, pelleted matrix, some fine- to coarse-grained matrix of secondarily enlarged pelmatozoan debris; intraclasts in part very densely aphanitic; much finely comminuted fossil debris; some silt, in part pelleted; silt mostly feldspar, in part authigenic; dolomite, 0.15 mm, a few small masses in matrix, replaced by limonitic calcite; limonite specks fairly abundant; stylolites have limonitic clay along them. At 485 feet, limestone—gastropod steinkerns, some trilobite and secondarily enlarged pelmatozoan debris in a microgranular, partly pelleted matrix; medium-grained, clear calcite fills a void; gastropod steinkerns very densely aphanitic, some fossil debris, in part pelleted; gastropod shell material where present replaced by mosaic calcite, which in turn was partly replaced by dolomite now altered to calcite and limonite; dolomite, 0.05 to 0.1 mm, a few rhombs in matrix; glauconite scarce, tiny fragments. At 486 feet, limestone—aphanitic gastropod steinkerns and intraclasts(?), trilobite and secondarily enlarged pelmatozoan debris, and glauconite and dolomite in aphanitic to very fine-grained matrix; steinkerns and intraclasts contain fossil debris and silt; a few large intraclasts sharply bounded on one side merge with the matrix on the other; glauconite altered, mostly admixed with carbonate and limonitic clay(?); dolomite, 0.05 to 0.15 mm, replaces many steinkerns and small intraclasts(?), and some fossil debris, in turn mostly replaced by limonitic calcite; gastropod shell material replaced by calcite mosaic; silt mostly authigenic feldspar; stylolites weakly developed. | | | |
| Fossils collected by Nicholls from 482,5 feet, *Symphysurina brevispicata* Hintze; from 485 feet, *Highgatella cordilleri* (Lochman), *Jujuyaspis keideli* Kobayashi, *Symphysurina brevispicata* Hintze, *Syntrophina carinifera* Ulrich & Cooper, and gastropod coquinite. | | | |
| Fossils collected by Ellinwood from 485 feet, gastropod coquinite. | | | |
| SHIFT about 50 feet east; continue down in section. | | | |
| 5. Limestone—very fine grained, between yellowish gray and light olive gray, mottled by grayish-yellow dolomite, shaly bedded alternating with thicker bedded, mostly fine to medium grained; slightly silty, mostly feldspar both detrital and authigenic; ripple marks and intraformational conglomerate common. | 33 | 155 | 437–470 |
| From 437 to 437.5 feet, small-fragment intraformational conglomerate; 437.5 to 438 feet, fine grained; 438 to 439 feet, very fine grained; 439 to 439.5 feet, coarse-grained, glauconitic; 439.5 to 440 feet, very fine grained; 440 to 440.5 feet, fine-grained, dark yellowish-orange patches of dolomite on bedding surfaces; 440.5 to 441.5 feet, medium grained, slightly glauconite, large ripple marks on top surface; 441.5 to 442 feet, very fine grained, recessive, argillaceous; 442 to 445 feet, fine- to medium-grained, dark yellowish-orange dolomite patches in bottom bed, next bed intraformational breccia, top bed mostly a small-pebble intraformational conglomerate; at 443 feet, a small, medium-spired, gastropod coquinite is replaced by dolomite; 445 to 451.5 feet, very fine grained to aphanitic; 451.5 to 452 feet, very fine grained, one bed; 452 to 461 feet, very fine grained to aphanitic; 461 to 461.5 feet, intraformational conglomerate, one bed; 461.5 to 464 feet, very fine grained; 2-inch intraformational conglomerate at 462.5 feet; 464 to 466.5 feet, mostly intraformational conglomerate; 466.5 to 467 feet, fine-grained, one bed; 467 to 470 feet, mostly fine grained, much mottled by dark yellowish-orange dolomite. | | | |
| Chert from 437 to 440 and 455 to 465 feet white, mostly granulated, possibly recent as some of it appears to be hyaline opal. | | | |
| Thin sectioned at 437.5, 443 (two sections), and 459 feet. At 437.5 feet, limestone—intraclasts | | | |

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| and a few trilobite fragments mostly in microgranular to very fine-grained matrix, in part in fine- to coarse-grained matrix of secondarily enlarged pelmatozoan debris; intraclasts mostly aphanitic to microgranular, pelleted, some fossil debris; a few rhombic to square holes surrounded by yellowish-orange stain which indicates removal of dolomite; stylolites fairly common, indistinct. At 443 feet, limestone—numerous gastropod steinkerns and much trilobite and pelmatozoan debris in aphanitic to microgranular matrix; gastropod steinkerns very densely aphanitic, probably argillaceous, limonitic material along peripheries in part with greenish cast probably formed from glauconite; gastropod shell material where present replaced by mosaic of tiny calcite crystals; one clear calcite vein; limonitic clay along a stylolite. At 459 feet, limestone—aphanitic intraclasts, finely radiate organisms and a few trilobite fragments mostly in fine-grained, clear calcite matrix, some aphanitic matrix; a few large intraclasts enveloped by a very thin, dense peripheral film followed inward by a very thin, slightly coarser, translucent film; small limonite masses probably formed from pyrite; dolomite scarce, replaces intraclasts, mostly replaced by limonitic calcite; limonitic clay along stylolites. | | | |
| Fossils collected by Nicholls from 442 feet, *Missisquoia typicalis* Shaw. | | | |
| 6. Limestone—mostly fine and medium grained, some very fine and coarse grained; mostly pale yellowish brown and yellowish gray mottled by minute specks of grayish-orange and dark yellowish-orange dolomite; dark yellowish-orange dolomite patches on several bedding surfaces; silty, mostly feldspar both detrital and authigenic, quartz scarce; beds mostly 6 to 12 inches. | 7 | 162 | **430–437** |
| Thin sectioned at 435 feet. Limestone—intraclasts, gastropod steinkerns, and trilobites and calcareous brachiopod debris in part in an aphanitic, pelleted matrix, in part in a fine- to coarse-grained matrix of secondarily enlarged pelmatozoan debris; many intraclasts and steinkerns contain some finely comminuted fossil debris, some in part and others wholly replaced by dolomite, a few coated by glauconite; dolomite, 0.05 to 0.2 mm, mostly indiscriminately distributed, in part replaced by limonitic calcite; silt scarce; glauconite in part appears to be replaced by dolomite. | | | |
| Fossils collected by Nicholls from 430 feet, *Symphysurina brevispicata* Hintze; from 432 feet, *Highgatella cordilleri* (Lochman), *Missisquoia nasuta* Winston & Nicholls, and *Apheoorthis* ornate Ulrich & Cooper; from 433 feet, *Highgatella cordilleri* (Lochman), *Missisquoia nasuta* Winston & Nicholls, and *Apheoorthis* ornate Ulrich & Cooper. | | | |
| SHIFT down Flat Branch about 400 feet; continue down in section. | | | |
| 7. Limestone—fine, very fine, and medium grained and aphanitic; mostly pale yellowish brown; minor splotches of dark yellowish-orange and moderate yellowish brown in a few beds; in part nodular from irregular shale films; a few beds pelleted; glauconite absent; from 427 to 427.5 feet, intraformational conglomerate, pebblelike objects in a few other beds; slightly silty, silt mostly feldspar both detrital and authigenic, some quartz; from 416 to 420 feet in line of section, a resistant ledge, laterally thin bedded. | 14 | 176 | 416–430 |
| Thin sectioned at 428 feet. Limestone—intraclasts and abundant trilobite and calcareous brachiopod debris in a very fine to fine-grained matrix of secondarily enlarged pelmatozoan debris; intraclasts mostly very finely comminuted fossil debris in a minimum of aphanitic matrix, in part pelleted, one contains limonite cubes, a few silty; silt mostly authigenic feldspar; dolomite common in matrix, fairly fresh, where replacing intraclasts altered to limonitic calcite. | | | |
| Fossils collected by Nicholls from 416 feet, *Corbinia apopsis* Winston & Nicholls; from 417 feet, *Missisquoia typicalis* Shaw, *Schizapea?* sp. ; from 420 feet, *Missisquoia typicalis* Shaw; from 424 feet, *Schizopea?* sp.; from 425 feet, *Missisquoia nasuta* Winston & Nicholls, *Missisquoia typicalis* Shaw, and gastropod; from 427 feet, *Symphysurina brevispicata* Hintze and *Missisquoia typicalis* Shaw; from 428 feet, *Symphysurina brevispicata* Hintze; from 429 feet, *Highgatella cordilleri* (Lochman), *Missisquoia typicalis* Shaw, *Symphysurina brevispicata* Hintze, and high-spired gastropod. | | | |
| 8. Limestone—mostly very fine grained to aphanitic, some medium grained; pale yellowish brown; slightly silty, silt mostly feldspar both detrital and authigenic, quartz scarce; a few grains of very fine sand; beds irregular, mostly 1 to 2 inches. | 3 | 179 | 413–416 |
| Thin sectioned at 413 and 414 feet. At 413 feet, limestone—gastropod and hyolithid steinkerns, | | | |

| Description | Thickness in feet Interval | Thickness in feet Cumulative | Feet above base |
|---|---|---|---|
| intraclasts, and a few trilobite and secondarily enlarged pelmatozoan fragments in an aphanitic to very fine-grained, clear calcite matrix; fossil fillings and intraclasts mostly replaced by dolomite, some in matrix, rhombs 0.05 to 0.1 mm, mostly altered to densely limonitic calcite; one faint stylolite. At 414 feet, limestone—aphanitic, almost structureless; clear, mosaic calcite patches may fill voids; very slightly dolomitic and silty; silt mostly authigenic feldspar, a few tiny detrital centers; dolomite mostly microgranular, a mass at one end of slide 0.05 to 0.15 mm, about half replaced by calcite starting at center of rhombs; tiny grains of glauconite very scarce. | | | |
| Fossils collected by Ellinwood from 413 feet, *Corbinia apopsis* Winston & Nicholls, and orthid brachiopods. | | | |
| SHIFT about 1 mile east to Hudson Creek, using hyolithid bed to make shift and overlying thin-bedded, aphanitic to very fine-grained, light gray-weathering limestone as a check. | | | |
| 9. Limestone—mostly coarse grained, some medium grained, a little fine grained; mostly yellowish gray to darker, mottled by pale yellowish-orange and grayish-orange dolomite which appears to be replacing fossil fragments and other objects; glauconite and ooids common; slightly argillaceous; very slightly silty, silt both quartz and feldspar; some very fine sand in bottom sample; mud balls(?) in some beds. | 22 | 201 | 391–413 |
| Thin sectioned at 400 feet. Limestone—much trilobite debris with some radial calcite and a few intraclasts mostly in a medium- to coarse-grained matrix of secondarily enlarged pelmatozoan debris, a little microgranular matrix; intraclasts aphanitic, silty, much finely comminuted fossil debris, mostly replaced by dolomite; silt mostly authigenic feldspar; dolomite, mostly 0.05 to 0.1 mm, replaces intraclasts, fillings in fossils, and rarely fossils; some 0.3-mm rhombs scattered in matrix, some limonitic staining. | | | |
| Fossils collected by Ellinwood from 395 feet, *Owenella* sp.; from 398 feet, *Bayfieldia simata* Winston & Nicholls, *Euptychaspis kirki* Kobayashi, *Eurekia eos* (Hall), and *Owenella* sp.; from 409 feet, *Briscoia llanoensis* Winston & Nicholls, *Euptychaspis kirki* Kobayashi, *Eurekia eos* (Hall), and *Keithiella patula* Winston & Nicholls. | | | |
| Fossils collected by Nicholls from 411 feet, *Acheilops masonensis* Winston & Nicholls, *Apatokephaloides clivosus* Raymond, *Corbinia apopsis* Winston & Nicholls, *Idiomesus levisensis* (Rasetti), *Leiobienvillia leonensis* Winston & Nicholls, *Plethometopus obtusus* Rasetti, *Westonaspis? texana* Longacre, and orthid? brachiopod. | | | |
| 10. Limestone and shale—limestone coarse grained, light olive gray mottled grayish orange, oolitic, mud balls(?) common, glauconitic, very slightly silty, dolomite in minute mottles appears to replace fossil debris and other objects, beds 1 to 6 inches; shale silty, grayish-yellow, thin glauconitic streaks and fine-grained limestone beds common. | 14 | 215 | 377–391 |
| From 377 to 383 feet, mostly limestone; 383 to 384.5 feet, mostly shale; 384.5 to 385.5 feet, mostly limestone; 385.5 to 386 feet, mostly shale; 386 to 391 feet, limestone with thin shale partings. | | | |
| Thin sectioned at 383 feet. Limestone—much trilobite and calcareous brachiopod debris and some dolomite in a medium- to coarse-grained matrix of secondarily enlarged pelmatozoan debris, a little aphanitic, pelleted matrix at one end of slide; fossil fillings densely aphanitic; silt scarce, mostly authigenic feldspar, dolomite, 0.05 to 0.15 mm, mostly replaces matrix, some fossil replacement, some along stylolites, mostly fresh, some limonitic staining, limonitic clay along stylolites. | | | |
| Fossils collected by Ellinwood from 381 feet, *Bayfieldia simata* Winston & Nicholls, *Idiomesus levisensis* (Rasetti), orthid brachiopod, and *Owenella* sp.; from 383 feet, *Bayfieldia simata* Winston & Nicholls, *Calvinella procera* Winston & Nicholls, dikelocephalid fragments, *Finkelnburgia* sp., *Owenella* sp., and high-spired gastropods; from 385 feet, pelmatozoan columnals. | | | |
| 11. Limestone—coarse to medium grained; dolomite replacement occurs as minute mottles; mostly glauconitic, some beds very glauconitic, pebbles very glauconitic in intraformational conglomerate at 371 feet; mud balls(?) and ooids common; slightly silty; beds mostly 6 to 12 inches; covered | 24 | 239 | 353–377 |

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| from 365 to 368 feet in line of section except for one 6-inch bed near middle; interval exposed along face of bluff 125 feet to north. | | | |
| Thin sectioned at 360 and 376 feet. At 360 feet, limestone—much trilobite debris with a little radial calcite, some dolomite, a few grains of glauconite, and a few pellets in a medium- to coarse-grained matrix of secondarily enlarged pelmatozoan debris; silt very scarce, mostly authigenic feldspar; glauconite scarce, fragmental to rounded; dolomite, 0.1 to 0.2 mm, replaces fossils, cavity fillings, matrix, sutured along stylolites, some limonitic stain; one stylolite with silt, glauconite, yellowish-orange clay, and dolomite along it. At 376 feet, limestone—much glauconite and trilobite debris with a narrow rim of radial calcite around some fragments and some pellets and dolomite mostly in a fine- to coarse-grained matrix of secondarily enlarged pelmatozoan debris, a little pelleted aphanitic matrix at one end of slide; glauconite grains small, mostly fragmental; silt scarce, mostly authigenic feldspar; a few 0.05-mm, clear-brown, isotropic objects; a few tiny specks of limonite; dolomite, 0.1 to 0.2 mm, mostly replaces matrix, in part replaces fossil debris, slightly limonite stained; stylolites scarce. | | | |
| Fossils collected by Ellinwood from 356 feet, *Bayfieldia binodosa* (Hall), *Bayfieldia simata* var. A Winston & Nicholls, *Euptychaspis typicalis* Ulrich, *Saukia tumida* Ulrich & Resser, *Saukiella junia* (Walcott), var. B Winston & Nicholls, *Stenopilus latus* Ulrich, and *Owenella* sp.; from 360.5 feet, *Bayfieldia simata* Winston & Nicholls, *Saukia tumida* Ulrich & Resser, *Stenopilus latus* Ulrich, *Finkelnburgi* sp., and *Owenella* sp.; from 370 feet, *Saukiella junia* (Walcott), var. B Winston & Nicholls, and *Stenopilus latus* Ulrich; from 372.5 feet, *Briscoia hartti* (Walcott) and *Euptychaspis typicalis* Ulrich; from 375 feet, *Bayfieldia simata* Winston & Nicholls, *Calvinella tenuisculpta* Walcott, *Eurekia eos* (Hall), *Idiomesus levisensis* (Rasetti), and orthid brachiopod. | | | |
| 12. Limestone—aphanitic to very fine grained, yellowish gray, massive, slightly rough weathering; residue scarce, mostly silt. | 15 | 254 | 338–353 |
| From 338 to 341 and 342 to 348 feet, pelleted; 341 to 342 feet, nonpelleted; 348 to 350.5 feet, nodular, mottled, greenish shaly material in lower part; dolomite moderate yellowish brown appears to follow burrows in upper part; from 350.5 to 353 feet, aphanitic, mottled by light-brown dolomite, one bed. | | | |
| Thin sectioned at 343 and 347 feet. At 343 feet, limestone—abundant aphanitic intraclasts, a few pellets, and a few finely radiate fossils in a microgranular to very fine-grained, clear calcite matrix; a few irregular patches of coarse-grained calcite probably fill voids. At 347 feet, limestone—intraclasts and a few finely radiate fossils in a microgranular- to fine-grained, clear calcite matrix; some medium-grained, clear calcite may fill voids; intraclasts, 0.05 to 5 mm, all have sharp borders, larger ones intraclastic to pelleted; a few very narrow calcite veins; stylolites indistinct, scarce. | | | |
| Cross Hudson Creek at 341 feet in section. A sharp change in lithologic character at the top of this interval roughly coincides with the top of a stromatolitic reef 100 yards to east. | | | |
| 13. Covered. | 2 | 256 | 336–338 |
| 14. Dolomite—fine grained; in part mottled grayish orange, in part very pale orange, in part a color between pale and dark yellowish orange; calcitic; weathers smooth to rough; residue very scarce, mostly silt; beds indistinct, probably about 6 to 12 inches. | 6 | 262 | 330–336 |
| Thin sectioned at 334 feet. Limestone—much dolomite and a few trilobite fragments mostly in an aphanitic, pelleted matrix, some microgranular matrix; silt very scarce, mostly authigenic feldspar; dolomite, 0.05 to 0.1 mm, patchy to scattered rhombs, destroys pelleted structure, a few rhombs partly replaced by calcite; a few stylolites. | | | |
| SHIFT downstream about 500 feet; continue down in section along each bank of Hudson Creek. | | | |
| 15. Limestone—microgranular to fine grained and coarser, some beds very glauconitic, others nonglauconitic; from 305 to 310 feet, some very fine sand, mostly detrital feldspar with authigenic overgrowths, some quartz; slightly silty, similar in composition to sand; beds mostly 1 to 12 inches. | 30 | 292 | 300–330 |

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| From 300 to 302 feet, very fine grained, thin bedded, nodular, shale films about nodules; 302 to 306 feet, very fine grained, yellowish gray mottled by pale yellowish-orange dolomite, massive, rough weathering; 306 to 308 feet, medium grained, oolitic in upper part, coarse glauconite common, mottled by minute specks of pale yellowish-orange dolomite, bedding indistinct, weathers smooth; 308 to 310 feet, very fine grained, yellowish gray, nodular, shale films about nodules, thin bedded, recessive; 310 to 313 feet, same as above except more massive, rough weathering; 313 to 314 feet, medium-grained, mottled by minute specks of very pale yellowish-orange dolomite which appears to be replacing fossil fragments, smooth weathering; 314 to 323 feet, very fine grained, nodular, mottled by pale yellowish-orange dolomite, massive in bluff, thin bedded away from bluff; 323 to 324 feet, medium grained, slightly glauconitic, dolomitic, smooth weathering; 324 to 330 feet, very fine grained, mottled by pale yellowish-orange dolomite, rough weathering. | | | |
| Thin sectioned at 302, 308, 308.5, and 311 feet. At 302 feet, limestone—ooids, some trilobite and secondarily enlarged pelmatozoan debris, and a few intraclasts similar to those at 308 feet in radial, clear calcite matrix; authigenic feldspar silt and fragmental glauconite very scarce; ooids finely radiate, very little concentric structure, a few contain fossil fragments, others glauconite, some sharp, many hazy, many replaced or partly replaced by dolomite, some rhombs truncated at peripheries of ooids, others project beyond borders (pl. 16, fig. 3); dolomite, 0.1 to 0.2 mm, in part replaces fossils, in part replaced by calcite. At 308 feet, limestone—ooids with much radial calcite, intraclasts(?), minor trilobite and pelmatozoan debris, and a few pellets(?) in a microgranular, clear calcite matrix; intraclasts(?) may be fossils that originally had finely radiate structure; this is suggested by their shape and an overgrowth of finely radiate calcite; ooids, 0.1 to 0.75 mm, most finely radiate, some concentric structure, a few distinct, most with hazy borders, a few with fossil fragments at center, in part replaced by 0.1–mm dolomite, which rarely projects beyond boundaries; dolomite scarce between ooids, mostly fresh; limonite specks scarce; a vein of clear calcite fills a crack cutting a few ooids and following peripheries of others; portions of ooids and dolomite rhombs missing along stylolites. At 308.5 feet, limestone—intraclasts, finely radiate fossils, and a few trilobite and secondarily enlarged pelmatozoan fragments in a very fine-grained to microgranular, clear calcite matrix; glauconite very scarce, fragmental; intraclasts in part aphanitic, a few contain fossil debris, a few slightly silty, most very small, a few very large, many in part or entirely replaced by dolomite; dolomite, 0.05 to 0.1 mm, very fresh; one large pelmatozoan fragment replaced centrally by chert. At 311 feet, limestone—about half dolomite, some trilobite and secondarily enlarged pelmatozoan debris, a few finely radiate fossils, phosphatic brachiopod fragments, and glauconite grains in an aphanitic, indistinctly pelleted matrix; silt very scarce, mostly authigenic feldspar; glauconite fragmental; dolomite, 0.05 to 0.1 mm, replaces matrix, in part replaced by calcite starting at centers of rhombs, some limonitic stain. | | | |
| Fossils collected by Ellinwood from 302.5 feet, *Briscoia* sp. or *Dikelocephalus* sp., *Elkia?,* sp., *Euptychaspis frontalis* Longacre, *Idiomesus levisensis* (Rasetti), *Keithiella scrupulosa* Ellinwood, *Leiocoryphe occipitalis* Rasetti, *Monocheilus truncatus* Ellinwood, *Plethometopus convergens* (Raymond), *Saukiella fallax* (Walcott), saukid pygidia; and *Triarthropsis* sp., and from 307.5 feet, *Bowmania* sp., *Briscoia* sp. or *Dikelocephalus* sp., *Euptychaspis frontalis* Longacre, *Idiomesus levisensis* (Rasetti), *Keithiella scrupulosa* Ellinwood, *Leiocoryphe occipitalis* Rasetti, *Monocheilus truncatus* Ellinwood, *Plethometopus convergens* (Raymond), *Saukiella fallax* (Walcott), *Triarthropsis* sp., and *Owenella* sp. | | | |
| 16. Covered in line of section. Laterally appears to be interreef limestone. | 5 | 297 | 295–300 |
| The stromatolitic biohermal part of the San Saba Member was crossed, using an average of the dips from below and above the reef. The thickness of the reef, therefore, may be in error. The top of the reef is very irregular, fluctuating through at least 80 feet of section within 1/2 mile of the line of section. | | | |
| 17. Limestone and dolomite-reef and interreef beds; very slightly silty, silt mostly feldspar, both detrital and authigenic, some quartz. From 247 to 251 feet, interreef dolomite, dark yellowish orange; 251 to 259 feet, reef, individual stromatolites about 1 foot across, yellowish gray, concentric structure brought out by incipient dolomitization, dolomite pale yellowish orange; 259 to 270 feet, interreef dolomite, light brown to grayish orange; 270 to 276 feet, reef, foot-sized stromatolites about one-third dolomite with excellently displayed concentric structure; 276 to 277 feet, interreef dolomite, light brown to dark yellowish orange; 277 to 280 feet, dolomite-mottled reef and interreef beds on a dip slope; 280 to 285 feet, interreef dolomite, pale red to light brown; 285 to 295 feet, dolomitic reef, some interreef dolomite at about 290 feet. | 48 | 345 | 247–295 |

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| Thin sectioned at 250, 261, 278, 290, and 292 feet. At 250 feet, limestone-dolomite replacement of limestone entirely replaced by limonite-stained calcite, large areas have synchronous extinction; dolomite ghosts average about 0.1 mm; some interstitial limonite; weathered glauconite scarce. At 261 feet, limestone-dolomite and a little trilobite debris in an aphanitic matrix; a few irregular, fine-grained, clear calcite masses probably fill voids; dolomite, mostly 0.05 to 0.1 mm, replaces matrix, almost entirely replaced by limonite-stained calcite; some caliche along bedding openings. At 278 feet, limestone—numerous intraclasts (pl. 16, fig. 2) and a few trilobite, pelmatozoan, and calcareous brachiopod framents in a fine-grained, clear calcite mosaic, calcite radial to fossil fragments scarce; intraclasts mostly aphanitic, many very thin, long, somewhat irregular, a few very small, others of pebble size, a few partly to entirely replaced by dolomite; dolomite fine grained, mostly replaced by limonite-stained calcite. At 290 feet, limestone-much dolomite in an aphanitic to microgranular matrix, in part indistinctly pelleted and intraclastic; silt very scarce, mostly authigenic feldspar; large areas of microgranular dolomite may be intraclasts, rest of dolomite mostly 0.1 to 0.15 mm, mostly fresh, some slightly hematite stained, replaces matrix; one vein of fine- to coarse-grained calcite cut by stylolites with limonitic clay and silt along them. At 292 feet, limestone—mostly densely aphanitic, with lighter, aphanitic wavy bands indicating stromatolitic structure; one calcareous brachiopod shell; much microgranular dolomite, very fresh; silt scarce, mostly authigenic feldspar; veins of medium-grained calcite offset along stylolites with limonitic clay along them. | | | |
| 18. Limestone and covered—lower 5 feet very fine to coarse grained; dolomitic; much very fine sand and some silt, mostly authigenic feldspar, some detrital centers; biotite and glauconite common; 1 sample of residue from 240 to 245 feet is similar except detrital feldspar is mostly clear followed by clear overgrowths, biotite and glauconite abundant; rest of interval covered, probably shale as indicated by local folding of adjacent beds. | 16 | 361 | 231–247 |
| Thin sectioned at 232 feet. Limestone—trilobite and pelmatozoan debris, a few phosphatic brachiopod fragments, glauconite and intraclasts mostly in an aphanitic, pelleted matrix, a little microgranular- to fine-grained, clear calcite; intraclasts and cavity fillings in fossils, densely aphanitic, in part slightly fossiliferous, silty, glauconitic, limonitic, pelleted, dolomitic; dolomite fine grained, replaces intraclasts and fossil fillings, altered to calcite and limonite; silt mostly authigenic feldspar; glauconite fragmental; some weathered biotite; stylolites indistinct. | | | |
| 19. Limestone—coarse grained; mostly pale yellowish orange to grayish orange; residue very small; large ripple marks on top surface indistinct; 10 inches of intraformational conglomerate at base of interval; thick bedded, bottom bed 7 feet, followed by 1-foot bed, 4-foot bed, and a top 2-foot bed. | 14 | 375 | 217–231 |
| A sample from 228 feet containing girvanella and hexactinellid spicules as well as another sample from 229 feet containing hyolithids(?) and trilobites were thin sectioned. At 228 feet, limestone—a little trilobite and pelmatozoan debris and a few finely radiate fossils in an aphanitic matrix; matrix about half replaced by 0.1-mm dolomite with finely radiate fossils and pelmatozoan debris which is not dolomitized; some pelmatozoan debris replaced by chert; silt scarce, mostly authigenic feldspar; stylolites indistinct. At 229 feet, limestone—much well-rounded pelmatozoan debris and numerous trilobite fragments, both with radial calcite about them, some faintly pelleted, aphanitic matrix; glauconite fragmental, very scarce; dolomite, 0.1 to 0.2 mm, replaces cavity fillings and intraclasts(?), slightly replaced by calcite and limonite; stylolites of large amplitude truncate dolomite rhombs, showing that the stylolites are younger. | | | |
| Description of 217 feet of Wilberns rocks below this interval, described in the section on file at the Bureau of Economic Geology, are not included here. | | | |

## THREADGILL CREEK AREA, MASON AND GILLESPIE COUNTIES

### Introductory Statement

The composite Threadgill Creek section in the Threadgill Creek area is one of two described complete sections of Moore Hollow Group rocks in the Llano region; it includes also the type section of the Threadgill Member of the Tanyard Formation (Cloud and Barnes, 1948, p. 190–191, pl. 6). The base of the Threadgill Creek section of Bridge, Barnes, and Cloud (1947) is in the top part of the Cap Mountain Limestone, whereas the composite Threadgill Creek section of this report starts at the base of the Moore Hollow Group and includes 1,450 feet of Moore Hollow[1] and 280 feet of Ellenburger Group rocks, a total of 1,730 feet of strata. Only the part of the composite Threadgill Creek section containing Moore Hollow rocks is shown on the Threadgill Creek area map (pl. 8, fig. 4); however, the geologic map of the Squaw Creek quadrangle (Barnes, 1952i) shows the areal relationship of both the Threadgill and Moore Hollow portions of the section.

The Threadgill Creek area comprises 12.0 square miles situated within the area of the 1:24,000 scale Cherry Spring and Loyal Valley U.S. Geological Survey topographic quadrangle maps. The southwestern corner of this area is 2 miles due north of Doss, a hamlet in northwestern Gillespie County. In addition to the composite Threadgill Creek section, the Squaw Creek section, containing the type section of the Welge Sandstone, is situated in the Threadgill Creek map area. The excellent exposures of Wilberns Formation rocks in the composite Threadgill Creek section are exceeded in quality only by those in the upstream James River section, and exposures of the Lion Mountain and Welge Sandstones are equal in quality to those in the upstream James River section.

Rocks mapped in the Threadgill Creek area include the Precambrian Town Mountain Granite, all members of the Moore Hollow Group, both members of the Tanyard Formation of the Ellenburger Group, Cretaceous rocks including the Hensell Sand and Glen Rose Limestone of the Trinity Group, the Walnut Clay, Comanche Peak Limestone, and Edwards Limestone of the Fredericksburg Group—and Quaternary deposits, including colluvium and alluvium.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Threadgill section—description of measured section with thin-section descriptions and fossil lists, heavy-mineral data, table 33; insoluble-residue data, table 34; Squaw Creek section-description of measured section with thin-section descriptions, heavy-mineral data, table 35, insoluble-residue data, table 36.

The Cretaceous strata are almost exactly horizontal and most of the Paleozoic beds are gently dipping from about 3 or 4 degrees in the eastern part of the area to about 10 degrees along the line of section in the southwestern part of the area. Faulting confined to the Paleozoic rocks mostly in the northwestern part of the area forms two broad northeast-southwest-trending zones with many faults of small displacement in each zone. Since the faults are all normal, such zones are not as complicated as they appear to be but are very tedious to map. In the extreme southeastern part of the area, there is a small block of the Staendebach Member in a rather peculiarly oriented graben. Since the exposures in this area are poor and were mapped before the widespread occurrence of collapse between the members of the Tanyard was recognized, it is possible that the graben interpretation is wrong and that this area of the Staendebach Member should be shown collapsed into the Threadgill Member.

The base of the composite Threadgill Creek section starts at the edge of a granite exposure which appears to be an exhumed exfoliation dome. The height at which this dome stands above the surrounding Precambrian surface is unknown, but it seems likely that Hickory Sandstone is present in the subsurface which is not included in the section.

Vegetal patterns as displayed on aerial photographs and geologic units probably correlate better in the Threadgill area than in any other area mapped during the present study, in spite of the abundance of cedar on all the limy units. The Town Mountain Granite, however, is not in an exposure where its typical vegetal pattern can be developed, but the other units are for the most part very well displayed. The lower unit of the Hickory Sandstone, unlike the tilled flats which it formed in the Camp San Saba area, is sufficiently cemented to resist weathering and forms elevated areas with deciduous oaks, and much bee brush and other shrubs. The argilla-

[1] James F. Miller, in a letter of June 17, 1976, states: "Our studies [made with James Stitt] confirmed my prediction after last summer's work, which was that about 50 (now I think about 54') of the uppermost Wilberns were lost when the section was offset at 1460′ from the Upper Threadgill Creek Segment to the Mormon Creek Segment . . . .My conclusions are based entirely on physical stratigraphy, not on biostratigraphy." This possibility of lost section should be kept in mind when thicknesses of the Moore Hollow Group and of the San Saba Member of the Wilberns Formation are compared with those in other sections. Professor Miller has described a section, including this missing interval, which will be placed on open file at the Bureau of Economic Geology.

ceous, silty unit of the Hickory, because of its relative ease of disintegration, forms a narrow, mesquite-covered lowland between the lower unit of the Hickory Sandstone and the Cap Mountain Limestone in this area in contrast to a low scarp as found in the Camp San Saba area. Formerly, much of this lowland was cultivated. The upper red unit of the Hickory Sandstone, because of increase in calcite content, has passed into the Cap Mountain Limestone of this area.

The Cap Mountain Limestone has a tripartite vegetational pattern with the middle siltstone zone having little bedding alignment and supporting closely spaced, dark, clumpy live oaks on a background lighter in color than either adjacent unit of the Cap Mountain Limestone. The lower and upper units support a more nearly uniform growth of vegetation, mostly cedar, with indistinct vegetational alignments and an increase in amount of vegetation toward the base of the lower unit which steepens into a scarp. The Lion Mountain Sandstone bench is characterized by widely spaced live oak clumps on a very light-gray background, and the overlying Welge Sandstone scarp is characterized by dense vegetation forming a dark band. The Morgan Creek Limestone displays vegetation alignments along the bedding which are fairly distinct but not nearly so pronounced as those in the Point Peak Member.

The Point Peak Member is on northward-facing slopes and the rainfall is greater, accounting for the much greater abundance of vegetation on it in this area as compared with areas so far described. A centrally located reef in the Point Peak divides it into three parts, a lighter-colored band with uniformly distributed vegetation in the position of the reef and upper and lower darker units with distinct vegetational alignments. These units also photograph darker than the subjacent Morgan Creek Limestone and the superjacent San Saba Member.

The San Saba Member exhibits exceptionally distinct vegetational alignments except in reef areas, and the bedding alignments in the overlying Threadgill Member are only slightly less distinct. The large stromatolitic reef in the eastern part of the area has uniformly distributed vegetation in contrast to the alignments shown in the rest of the San Saba, but the amount of vegetation on the two is about the same, with the consequence that there is little color contrast on photographs.

The Hensell Sand normally has a clumpy vegetation; where the sand is fairly pure, deciduous oaks predominate; where clay is present, mesquite is prominent; and elsewhere in its steep upper part vegetation is scarce with prominent clumps of live oak; in the rest of the area various proportions of deciduous oak, mesquite, cedar, and thorny shrubs are found. The Glen Rose Limestone and Walnut Clay are so thin and on such a steep slope that they show no vegetational contrast and cannot be distinguished on aerial photographs from the steep scarp lip of Comanche Peak Limestone with its characteristic growth of Spanish oak. The Edwards Limestone has the most distinct pattern of vegetational alignment along the bedding of any unit in the Llano region.

## Precambrian Rocks

### Town Mountain Granite

An exposure of coarse-grained Town Mountain Granite along Squaw Creek in the northeastern part of the area appears to be the top of a buried exfoliation dome similar to others found in the Llano region today. A gravity survey (Barnes, Romberg, and Anderson, 1956) indicated the outline of the southern end of a large granite mass. Not enough gravity data are available to determine if this granite is part of the Grit granite mass or if it is part of some other mass.

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone Member, 364 feet thick, is composed of 2 units. The lower, 275 feet thick, is sharply distinct from the overlying 89 feet of argillaceous, silty, darker colored, fossiliferous strata. In the lower unit the only evidence of fossils is trails and imprints classified as *Climactonites* and *Cruziana*, respectively. Cuneiform markings abundant in the upper part of the lower unit could possibly be of organic origin; however, their shape suggests that they may be ice crystal casts.

From an examination of the composite Threadgill Creek section alone, one might be convinced from the sharpness of the change from one to the other unit of the Hickory Sandstone that the plane between the two represents a stratigraphic hiatus. If this plane actually represents an interruption in sedimentation, then the lower unit of the Hickory could be as old as Lower Cambrian; however, this interpretation is unlikely.

The basal 7 feet of the lower unit is massive, mostly conglomerate composed of granules and pebbles up to 3/4 inch in size, a few of which are wind faceted, some coarse to very coarse sandstone, and much light-brown to pale yellowish-brown clay matrix. This massive bed rests on weathered granite with sandstone, scarcely distinguishable from decomposed granite, reaching a depth of 3 feet between exfoliation boulders of granite.

The next 16 feet of fine- to coarse-grained sandstone with some pebbles and granules is distinct from the overlying 47 feet of medium- to very coarse-grained sandstone and quartzite, which also contains granules and a few pebbles in the lower part. From the top downward these strata are pale red to grayish orange, light brown, moderate orange pink to moderate reddish orange with some grayish orange, and light brown to orange pink. The sand grains are very poorly sorted, rough from reconstitution, and those in the lower 16 feet appear to have been originally very well rounded to spherical. Crossbedding is common throughout.

Quartzite, cuneiform markings, silty and argillaceous beds (except in the lower 37 feet), and crossbeds are common from this level to the top of the lower unit of the Hickory Sandstone. The upper half is mostly yellowish gray; where microcline-bearing, light grayish orange; and the lower half from the top down is mostly moderate reddish orange, pinkish gray, moderate red to pale red, and light to moderate brown. The sand grains vary in size from bed to bed but any 5- or 10-foot interval contains all sizes of grains and granules. The coarser sand sizes show evidence of having been mostly well rounded to spherical but are now rough from reconstitution. The top 48 feet of this interval contains *Cruziaria, Climactonites,* and other trails; beneath this level, markings on some bedding surfaces may be caused by organisms.

The upper unit is free of quartzite, contains many hematitic beds, and, as mentioned above, is silty, argillaceous, and fossiliferous. The hematitic beds in the upper 69 feet of the upper unit are mostly grayish red to blackish red and alternate with beds which are grayish orange to moderate brown, moderate yellowish brown, pale to medium yellowish brown, and pale brown. The coarser sand in the top 49 feet of this unit is spherical and polished, and grains of similar size in the lower 40 feet appear to have been originally of similar sphericity but are now rough from reconstitution.

*Bolaspidella*-Zone fossils exist in 4 collections between 288 and 330 feet, and *Cedarina-Cedaria*-Zone fossils are in 4 collections between 340 and 362 feet. Phosphatic brachiopods are common throughout the upper unit of the Hickory Sandstone, and, as mentioned above, this unit contains *Climactonites, Cruziana,* and other markings.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone Member, 418 feet thick, is divisible in the Threadgill Creek area into 3 fairly distinct units, as follows:

1. The lower unit, 236 feet thick, is composed mostly of very calcareous sandstone and fine- to coarse-grained limestone as follows: (a) A lower 107—foot sandstone zone, mostly very fine to fine grained, and some fine to medium grained in the upper part; a few coarse-grained beds are hematitic and grayish red. The sandstone, mostly pale to dark yellowish brown and some grayish orange to dark yellowish brown to grayish brown, is mostly very calcareous, carbonate decreases downward, and the lower half is very silty. The exposures consist of resistant beds 6 to 24 inches thick separated by recessive intervals. (b) A middle 16-foot zone, bottomed by 1 foot and topped by 5 feet of coarse-grained, variously mottled, sandy, oolitic, thick-bedded limestone, separated by 10 feet of very fine- to fine-grained, pale yellowish-brown to medium orange-pink, very calcareous sandstone. (c) An upper 88-foot zone composed mainly of sandstone and limestone. The top 25 feet of this zone is fine to coarse-grained limestone, very light gray to very pale orange, dark yellowish brown, and very light olive gray mottled and speckled grayish orange, glauconitic, oolitic, wavy bedded, with beds about 6 inches thick. Some very sandy limestone beneath this in the next 30 feet is fine to very coarse grained, light to medium brown, yellowish gray, and pale brown mottled grayish orange and dark yellowish orange. The sandstone, mostly very fine to fine grained in the lower part and fine to coarse grained in the upper part, is predominantly pale brown and grayish orange to medium yellowish brown, yellowish brown, and light brown; hematitic, coarser grained portions are grayish red to grayish brown. Glauconite is very scarce and crossbeds are common. The coarser sand is well rounded to spherical and polished.

2. The middle unit, 75 feet thick, is mainly fine-grained limestone verging on siltstone with about half of the upper 23 feet coarse-grained, very light-gray to yellowish-gray and light olive-gray, glauconitic, silty, and oolitic limestone. The fine-grained part is very pale orange to pale yellowish brown and grayish orange, and some in upper part is light gray to yellowish gray mottled and speckled by yellowish orange. Glauconite is very scarce, bedding wavy, and massive smooth surfaces form where weathering products are removed.

3. The upper unit, 107 feet thick, is mainly coarse-grained limestone, some medium-grained in lower half, pale yellowish brown to medium yellowish brown, very light olive gray to yellowish gray mottled and speckled grayish orange and dark yellowish orange and pale to dusky yellowish brown speckled in part yellowish brown, glauconitic, silty, sandy; grains are fine to very fine, some medium in upper part, and beds average perhaps 6 inches in thickness. The lower 60 feet is oolitic and solution has widened joints to 1 foot or so.

*Maryvillia*-Zone fossils are in 5 collections between 732 and 787 feet, *Coosella*-Zone fossils in 9 collections between 583 and 702 feet, and *Cedarina-Cedaria*-Zone fossils in 11 collections between 340 and 580 feet. Spicule type B, easily seen in thin section and residues, extends through about 150 feet of section starting about 60 feet below the top of the Cap Mountain Limestone.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone Member, about 68 feet thick in the composite Threadgill Creek section and 69 feet thick in the Squaw Creek section, is composed of greensand, limestone, sandstone, and shale. Most of the upper 40 feet is dusky green to dusky yellowish-green greensand composed about equally of glauconite and fine to very coarse quartz sand in part reconstituted and somewhat coarser upward. Limestone, abundant in the lower part to scarce in the upper part, exists in lenticular crossbeds of trilobite coquinite. Hematite concretions, common in the lower part of this 40—foot interval and in the next 9 feet beneath, have formed from the greensand through weathering.

In the rest of the lower part of the Lion Mountain Member, limestone and sandstone increase in amount downward and greensand decreases in amount. Some of the limestone is lenses of crossbedded trilobite coquinite, but most of it is bedded, coarse-grained limestone, white to greenish gray and yellowish brown speckled by dark yellowish orange, glauconitic, sandy, silty, argillaceous, crossbedded, and somewhat fossiliferous. The sandstone is fine to very fine grained, dark yellowish brown and brownish gray, glauconitic, silty, argillaceous, and calcareous. The shale, amounting to about 1 foot, is moderate yellowish brown and silty; a few thin beds are grayish orange pink.

*Aphelaspis*-Zone fossils are in 9 collections between 800 and 829 feet, and post-*Aphelaspis*-Zone fossils are in 5 collections between 835 and 850 feet. In addition to acrotretids, other types of phosphatic brachiopods are common.

#### Wilberns Formation

*Welge Sandstone Member.*—The massive Welge Sandstone Member, 22 feet thick in its type section along Squaw Creek and 23 feet thick in the composite Threadgill Creek section, is fine to coarse grained; some granules in the top foot are up to 1/4 inch in size. The Welge is mostly pale to dark yellowish orange mottled by pale olive and in part is pale reddish brown. Locally, quartzite at its base is grayish brown, limonite cemented, and glauconitic. The sand grains are well rounded to angular, in part spherical, and in part reconstituted. Crossbedding is common and pale-olive, fissile shale beds up to 6 inches thick have excavations in their upper part which have been filled by sand, preserved, and attached to the base of the overlying sandstone beds. The origin of these excavations is conjectural. Molds of trilobites are in the basal foot in the line of section.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone Member, 142 feet thick, is mostly coarse grained; some fine grained limestone is in the upper part, and the lower part is very coarse grained. It is glauconitic throughout, micaceous in the middle part, and very sandy in the basal few feet; the sand grains are fine to very coarse and well rounded. Very fine to fine sand above this level is scarce; silt is common above the basal reddish interval. Stromatolites are at a few levels in the upper 29 feet and ooids exist in some beds throughout the member. Colors in the upper 100 or so feet include very light gray, yellowish gray, light olive gray, and greenish gray speckled and mottled dark yellowish orange. Below this, a variety of colors include, from the top down, grayish orange pink, pale brown, light to very light brown, pale grayish orange brown, moderate brown, grayish red, pale reddish brown, yellowish orange, moderate yellowish brown, and various shades of pale red and brown speckled by dark yellowish orange. Most beds are from 4 to 12 inches thick, some in the upper part are up to 24 inches, and the middle part is somewhat thinner bedded.

*Point Peak Member.*—The Point Peak Member, 154 feet thick, is composed of 3 parts: The lower one, 37 feet thick, mostly siltstone, is yellowish gray, dusky grayish yellow, pale yellowish orange, and light gray speckled by dark yellowish orange, very calcareous, glauconitic, micaceous, and argillaceous; there is some fine to medium-grained, light-gray, and very silty limestone. The next part, 44 feet thick, is stromatolitic reef, aphanitic to microgranular and very fine grained, very light gray to yellowish gray; in the line of section some grayish orange is in the lower 10 feet.

The upper part, 73 feet thick, is divided by a 7-foot, coarse-grained limestone, which is light olive gray mottled light brown, slightly glauconitic, silty, micaceous, and characterized by silicified alate *Billingsella* and *Plectotrophia.* The rest of the interval is mostly siltstone, with limestone slightly more abundant in the upper part. The siltstone is pale olive, calcareous, argillaceous, micaceous, slightly glauconitic, and very thin bedded. The limestone is fine to coarse grained, very light gray to light gray to yellowish gray in part speckled dark yellowish orange, and light olive gray speckled light brown, glauconitic, slightly silty, in part intraformational conglomerate; in the lower part it contains a few girvanella.

*San Saba Member.*—The 281-foot-thick San Saba Member is composed mostly of medium- to coarse-grained limestone; in the line of section in the lower 103 feet some aphanitic and much fine to very fine-grained, silty, argillaceous, glauconitic, nodular limestone with wavy bedding is laterally equivalent to a stromatolitic reef mapped 1.5 miles to the northeast (pl. 8, fig. 4). Some of the limestone in this interval resembles stromatolitic limestone and may possibly be stromatolitic material washed from the reef and deposited where it is now found.

The upper 75 feet of limestone in the San Saba Member is mostly very fine to coarse grained, aphanitic beds are fairly common toward the top, glauconite is present in some beds, many beds are oolitic, granule-sized intraformational conglomerate is abundant, and most beds are 6 inches or less in thickness. Most of the remaining 103 feet of limestone is abundantly glauconitic and oolitic, intraclasts are common, and beds are 4 inches to 3 feet thick. Sand in this and most of the overlying interval is very scarce, seldom seen except in residues, and the grains are fine to medium and only a few are coarse. The paucity of sand is in marked contrast to its abundance in the upstream James River section 16 miles to the west.

The upper and lower units are mostly yellowish gray, light olive gray, and very light gray; a 20-foot, very argillaceous and silty zone near the top of the lower unit is very light pinkish gray, very pale yellowish brown, and pale olive. In addition, the middle portion of the San Saba Member is in part pale yellowish brown, greenish gray, brownish gray, and moderate brown. Throughout the San Saba there is much speckling and mottling of yellowish to dark yellowish orange, grayish orange, and yellowish brown and a 5-foot bed 103 feet above the base of the member has a dark yellowish-orange, anastomosing, raised dolomite pattern which may follow burrows.

## Ellenburger Croup

### Tanyard Formation

Tanyard Formation rocks mapped in the Threadgill Creek area, except for one small outcrop of the Staendebach Member in the southeastern part, are all limestone of the Threadgill Member. The limestone in the Threadgill Member is mostly aphanitic with some fine grained in the lower 30 feet or so, mostly yellowish gray to very light olive gray; trails and burrows abundant in most beds are dolomitized and yellowish to dark yellowish orange, grayish orange, and locally medium orange pink. Small pebble and granule intraformational conglomerate is common in the lower 70 feet, a few tiny grains of glauconite are in the lower 16 feet, and the lower 215 feet beneath a 19-foot covered interval is mostly silty, and thin, irregularly bedded to medium-bedded limestone with a few thicker bedded intervals. Above the covered interval, 46 feet of thick-bedded rock is mostly limestone and 2 dolomite zones, one 3 feet and the other 18 inches thick. The top of the Threadgill Member is not exposed in this area, but judging from comparison with the Pete Hollow section of Cloud (Cloud and Barnes, 1948, p. 172–179), the bottom of the Staendebach Member cannot be far above stratigraphically.

## Cretaceous Rocks and Quaternary Deposits

All the Cretaceous units and Quaternary deposits in the southern part of the Threadgill Creek area have been mapped in the Squaw Creek quadrangle (Barnes, 1952i); the reader is referred to that publication for their description.

### Welge Sandstone Member type section

The Welge Sandstone Member was named for the H. Welge land surveys in the Threadgill Creek area. When the entire area was mapped, an excellent section of Welge Sandstone was found along Squaw Creek in the J. V. Massey survey just north of one of the Welge surveys. This section is designated as the type section of the Welge Sandstone Member of the Wilberns Formation and its location is shown on plate 8, figure 4. Also, one of the best exposures in the Llano region of the Lion Mountain Sandstone Member of the Riley Formation is described in the Squaw Creek section. The following description is extracted from Description of Squaw Creek section, Mason County, in Part II on open file at the Bureau of Economic Geology.

**Description of the type section of the Welge Sandstone Member of the Wilberns Formation, Mason County, Texas**

| Description | Thickness in feet Interval | Cumulative | Feet above base |
|---|---|---|---|
| *Wilberns Formation; 25 feet described* | | | |
| *Welge Sandstone Member: 22 feet thick* | | | |
| Three feet of section above this interval is described in the section on file at the Bureau of Economic Geology. | | | |
| 2. Sandstone and shale—mostly sandstone, fine- to medium-grained, some 1/4-inch granules in top foot, in part silty and argillaceous; from 83 to 92 and 96 to 105 feet, pale to dark yellowish orange mottled by pale olive; from 92 to 96 feet, pale reddish brown and moderate reddish brown; grains in part reconstituted, glitter in sunlight; top foot glauconitic, trilobitic; top 2.5 feet somewhat calcareous, crossbedded, crossbeds brown, weather in relief; beds 0.5 to 6 feet, from top down about 3, 6, 3, 1, 0.5, and 2 feet, followed by 3.5 feet of thinner beds, and a bottom 2.5-foot bed. Shale from 85.6 to 86 and 88.5 to 89 feet, and a 2-inch bed at about 91 feet, pale olive, fissile, upper surfaces burrowed, shape of burrows preserved by filling from overlying sandstone. | 22 | 25 | 83–105 |
| Burrows(?) at 86 feet attached to bottom side of a sandstone bed are very numerous, up to about 4 inches long and 1 inch in diameter, local swellings and irregularities cause them to resemble coprolites; a few similar burrows(?) are preserved on under sides of beds at 91, 91.5, and 93 feet; mostly, however, burrows(?) on these surfaces are of a different shape, very numerous, and arranged in geometric patterns, commonly in squares, triangles, pentagons, or as individuals and pairs. An average burrow measures about 1/4 by 1 1/2 inches and 3/8 inch in depth. Longitudinal ridges are along the bottom of the burrows and in a few striae are along the sides, ranging from about 45 degrees in some to nearly vertical in others. Many burrows are inclined and, where in geometrical designs, are inclined outward. These burrows may be related to forms designated as *Cruziana.* | | | |
| A thin section at 91 feet reveals little information about the burrow itself. The rock is sandstone—very fine to coarse grained, matrix yellowish-orange to reddish-orange clay, similar-appearing material in objects up to 3 mm has faint concentric structure; grains quartz, well rounded to angular, straight to undulatory extinction, grains with bubble trains predominant; some silt, mostly feldspar, in part authigenic; a few phosphatic brachiopod fragments. | | | |
| An 83 foot section of rock below this interval is described in the section on file at the Bureau of Economic Geology. | | | |

## HICKORY CREEK AREA, LLANO COUNTY

The writer (Barnes, Dawson, and Parkinson, 1947, fig. 6) mapped part of the sandstone in Hickory Creek valley and found faulting to be prevalent; reconnaissance of the rest of the area did not reveal a measurable section even though it was obvious that a complete sequence of Hickory Sandstone beds is present. Because of the lack of a measurable section, interest in the area lagged, but finally, in order to have a map in the vicinity of this type area, additional Riley rocks were mapped in the valley of Hickory Creek ,(pl. 7, fig. 13). The nearest described section of Hickory Sandstone is in the composite Threadgill Creek section (on open file at the Bureau of Economic Geology). This section is designated as the standard section for the Hickory Sandstone Member of the Riley Formation.

The Hickory Creek area comprises 2.5 square miles and is situated within the area of the 1:24,000 scale House Mountain U.S. Geological Survey topographic quadrangle map. Rocks mapped include Precambrian Town Mountain Granite of the Enchanted Rock granite mass, Hickory Sandstone, Cap Mountain Limestone, and Quaternary alluvium.

Comstock (1890) applied the name Hickory to sandstones found in the valley of Hickory Creek, Paige (1911) retained the name as a formation name, and Bridge, Barnes, and Cloud (1947) reduced it in rank to a member of the Riley Formation. Paige's (1911) definition of the Hickory Sandstone included all sandy and silty beds now placed in the Cap Mountain Limestone, and for this reason Cap Mountain Limestone does not appear in this area on Spencer, Paige, and Kay's map (Paige, 1911). Hutchinson (1956) apparently followed Paige's usage, as he also did not map Cap Mountain Limestone in this area. A large area of the lower part of the Cap Mountain Limestone (as redefined by Bridge, Barnes, and Cloud, 1947) forms the elevated area southeast of Putnam Mountain.

Some of the boundary between the granite and the Hickory Sandstone was used as mapped by Hutchison

(1956), and the rest was placed at the actual base of the Hickory Sandstone, as was done by Spencer, Paige, and Kay (Paige, 1911), instead of at the edge of the Hickory talus, as was done by Hutchinson.

Even though a measurable section of the Hickory Sandstone is not present in the Hickory Creek area, all facies of it are well displayed on aerial photographs of this area. As is so common in the western area of its outcrop, three divisions of the Hickory are recognized. The upper one is much thinner in this area because the red zone in the Hickory to the north and northwest is calcareous in the Hickory Creek area and therefore is included in the Cap Mountain Limestone. The bench formed by the upper unit is narrow and sparsely vegetated. Because of its narrowness it is little cultivated, in contast to the preponderance of present or past cultivation where the unit is thicker.

The lower unit forms broad flat areas which, as in other areas of its occurrence, were or still are cultivated. Exposures of the lower and upper units in the Hickory Creek area are scarce.

The middle unit forms mostly a scarp covered by bee brush; exposures are fairly common, showing that the unit is argillaceous, with alternating resistant beds up to 6 inches or so in thickness and shaly zones. *Cruziana* was seen on the bottom of beds at two places (pl. 7, fig. 13).

Putnam Mountain and nearby elevated areas are capped by silica-cemented Hickory Sandstone. Where this quartzite belongs in the sequence is conjectural. Similar but mostly coarser grained quartzitic sandstone is common at the base of the Hickory Sandstone in the southern part of the area where the Riley Formation is thickest. Countering the indication that these quartzites occur in the thickest sections is an indication that these and similar high areas, such as House Mountain and Smoothingiron Mountain, capped by quartzitic sandstone, stood above their surroundings at the time of Cambrian sea encroachment. These quartzites received cursory inspection only; however, if they were studied in detail it might be possible to decide whether they belong beneath the sequence south of Putnam Mountain or at some level within the sequence.

## PONTOTOC-SLICK MOUNTAIN AREA, SAN SABA, MASON, AND LLANO COUNTIES

### Introductory Statement

The area under discussion is in the north-central part of the Llano region and includes four separate map areas, each with a measured and described section. The Riley portion of the Moore Hollow Group is measured in the Pontotoc section. The upper part of the Riley and Wilberns strata to the *Plectotrophia* Bed is measured in the mostly poorly exposed Taylor Ranch section. A few additional strata to a level in the lower part of the San Saba Member are measured in the Cold Creek section in the Cold Creek area. The Slick Mountain section and area are included mainly to round out information on sections listed by Bridge, Barnes, and Cloud (1947). Nowhere in this region was it possible to measure a complete section of the San Saba Member.

The Pontotoc area (pl. 7, fig. 9) in San Saba, Mason, and Llano Counties includes 3.2 square miles and receives its name from Pontotoc, a village in Mason County on Ranch Road 734 in the southern part of the area.

The Taylor ranch area (pl. 7, fig. 10) in Mason County includes 2.0 square miles and Ranch Road 501 passes very near the northern border of this area approximately 12 miles west of Cherokee and 7 miles northeast of Pontotoc.

The Cold Creek area (pl. 7, fig. 11) in Llano County includes 2.5 square miles and the area is crossed by Ranch Road 734 about 4.5 miles west of Valley Spring.

The Slick Mountain area (pl. 7, fig. 12) in Llano County includes about 2.5 square miles and is about 5.8 miles by road southwest of Valley Spring.

Rocks mapped in the Pontotoc area include Precambrian Valley Spring Gneiss and a few aplites; all members of the Riley Formation and the Welge Sandstone Member of the Wilberns Formation of the Moore Hollow Group; Cretaceous rocks possibly belonging to the Hensell Sand and the Edwards Limestone. The Precambrian surface in this area has considerable relief, at least 500 feet, as shown by the ridge of Valley Spring Gneiss reaching above the base of the Cap Mountain Limestone in the eastern part of the area.

Rocks mapped in the Taylor ranch area include part of the Hickory Sandstone, the Cap Mountain Limestone and Lion Mountain Sandstone Members of the Riley Formation, and the Welge Sandstone, Morgan Creek Limestone, and the basal part of the Point Peak Member of the Wilberns Formation.

Rocks mapped in the Cold Creek area include Precambrian Valley Spring Gneiss and Town Mountain Granite of the Smoothingiron Granite mass; all members of the Moore Hollow Group; the Threadgill Member of the Tanyard Formation; and Quaternary alluvium and travertine, the latter as spring-deposited masses along the east canyon wall of Cold Creek valley. It is likely that the fault zone along Cold Creek produced a zone of weakness so that the creek could cut down as rapidly as the surrounding Precambrian surface was lowered; otherwise the creek surely would have been deflected farther west.

Rocks mapped in the Slick Mountain area include Precambrian Valley Spring Gneiss, aplites, and Town Mountain Granite of the Smoothingiron granite mass; all members of the Riley Formation; the Welge Sandstone Member and most of the Morgan Creek Limestone Member of the Wilberns Formation; and Quaternary alluvium along San Fernando Creek.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Pontotoc section—description of measured section with fossil lists, heavy-mineral data, table 36, insoluble-residue data, table 37; Taylor ranch section—description of measured section with fossil lists; Cold Creek section—description of measured section with fossil lists; Slick Mountain section—description of measured section.

The structure is fairly simple with beds in most areas dipping gently. No faults occur in the Taylor ranch area; those in the Pontotoc area are of small throw and trend east-west and northwest-southeast; and those in the Cold Creek and Slick Mountain areas help outline a compound wedge-shaped graben of Paleozoic rocks forming a south-pointing finger into the Precambrian outcrop area, as shown by Spencer, Paige and Kay (Paige, 1912) and in more detail by Romberg and Barnes (1944). The Slick Mountain area includes the southern tip of this finger, and as in most similar structures in the Llano region the displacement on one side of the graben is more than on the other. In this case, the greatest displacement is along the western side of the graben where Lion Mountain Sandstone is faulted against Valley Spring Gneiss, producing a throw of at least 500 feet. Some cross-faulting is present and a subsidiary graben flanks the main graben to the east.

The Coal Creek area is along the western side of the main graben, and most of the end of one of the wedge-shaped graben segments of the main graben is within the map area. A subsidiary wedge-shaped graben embracing the sharp mountain west of Coal Creek trends southwest from the flank of the main graben. Most of the faults outlining these grabens trend north-south and northeast-southeast. One fault of small displacement trends northwest-southeast.

Vegetal patterns as expressed on aerial photographs are mostly distinct and helpful in mapping some units. There is little contrast between the vegetation of the Valley Spring Gneiss and that of the lower part of the Hickory Sandstone; both support mesquite and a few widely spaced deciduous oaks. The tripartite division of the Hickory Sandstone, very apparent in the unfaulted Taylor ranch area and its vicinity, is not as distinct in the Cold Creek and Slick Mountain areas, but even here there is some distinction. The middle unit forms a low scarp in the Pontotoc area but in the Slick Mountain area has little topographic expression; it is covered by bee brush and other stiff or thorny vegetation, whereas the upper and lower units form relatively flat areas most of which are cultivated. East of the buried ridge of Valley Spring Gneiss (eastern part of Pontotoc area, pl. 7, fig. 9), the middle unit forms a very distinct, incised, brush-covered scarp, and the outcrop belt of the lower unit is narrow, indicating that this unit is thin east of the ridge. The upper unit where not cultivated supports widely spaced clumps of deciduous oak and is very distinct from the overlying Cap Mountain Limestone with its much denser growth of scrub live oak, cedar, and other lime-loving vegetation.

Vegetation and vegetational alignments on the Morgan Creek and Cap Mountain Limestone Members and the lower calcitic part of the San Saba Member are similar except that the San Saba Member vegetation is less clumpy and not as well aligned along the bedding, thus indicating its greater uniformity in composition. The dolomitic upper part of the San Saba Member is uniformly covered by cedar.

The broad bench formed by the Lion Mountain Sandstone with its light color and widely-separated clumps of live oak is distinct from the Cap Mountain Limestone below, as well as the Welge Sandstone above, which forms a sharp scarp and is heavily vegetated. The Point Peak Member, as in the northwestern part of the Llano region, forms a thinly vegetated, light-colored scarp distinct, where facing south, from the units above and below. As in previously described areas, the vegetation is mostly stiff, thorny varieties of shrubs, but on north slopes sufficient moisture is available so that cedar can grow, producing a density of vegetation similar to that on the subjacent and superjacent units.

## Precambrian Rocks

Valley Spring Gneiss is the chief Precambrian rock mapped and occurs in three of the areas. It is a feldspathic rock varying from place to place in its resistance to erosion; because of this it formed an irregular surface at the time of the invasion of the Cambrian sea. The highest known Precambrian ridge of Valley Spring Gneiss is about 500 feet high and is in the northwestern part of the Llano region in the Pontotoc area. The Valley Spring Gneiss in this ridge is an inlier, strikes northwest-southeast, mostly dips northeast but reversals are common, and is chiefly microcline gneiss and some muscovite schist. Some malachite is near a prospect pit on the uphill side of the inlier, a quartz mass is nearby, and some boulder conglomerate is in the Hickory Sandstone near the lowest point on the inlier. Another area of even more rugged Precambrian topography extends northward from the Fly Gap area of Mason County, but no peak was seen reaching above the base of the Cap Mountain Limestone Member,

Small outcrops of coarse-grained Town Mountain Granite of the Smoothingiron granite mass are mapped in the Cold Creek and Slick Mountain area; this granite and its gravity characteristics are described by Romberg and Barnes (1944). The only other Precambrian rocks mapped are short, stubby dikes of aplite.

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone is thicker in the Pontotoc section (470 feet measured) than in any other section in the Llano region. It is 286 feet thick and very poorly exposed in the Slick Mountain section. The Hickory Sandstone varies greatly in thickness in this area because of the irregularity of the Precambrian surface. A little over 1 mile east from the line of section for a distance of about 2,000 feet along the strike, the Hickory Sandstone is interrupted by a high ridge of Valley Spring Gneiss. To the east of the ridge the average thickness of the Hickory Sandstone appears to be less than it is to the west.

The lower 157 feet of the Pontotoc section contains beds with cuneiform markings, possibly ice crystal molds, and *Cruziana* and burrows are at the level of the base of the section 1/2 mile to the west-southwest. Microcline up to granule size is found as high as 195 feet and is a common constituent below this level. This portion of the Hickory, about 43 percent covered, is mostly crossbedded, micaceous, silty, and argillaceous; some beds are essentially siltstone, and films and thin beds of sandy shale are common throughout. The grains range from very fine to very coarse, many beds contain granules, a few beds contain pebbles, and the lower 8 feet is conglomeratic with pebbles of quartz up to 2 inches and of microcline up to 3/4 inch in size. Above 35 feet, the larger quartz grains are fairly well rounded; below this level all are angular or only slightly rounded. The sandstone in this interval is yellowish to brownish gray, brownish yellow, and yellowish brown; the shale is light olive gray with an occasional streak of pale red.

A 28-foot covered interval separates the lower interval from the next overlying 117-foot interval, which is less than 8 percent covered, slightly glauconitic, and contains phosphatic brachiopods, trails, and burrows. Siltstone and shale are more abundant than in the lower interval and mica is less common. Some beds are crossbedded, intraformational conglomerate is fairly common, and beds range up to 3 feet in thickness; however, as a whole, this interval is mostly thin bedded. The sandstone, ranging in part to siltstone, is very fine to very coarse grained, granules and small pebbles are in some beds, and the larger grains are fairly well rounded and are mostly quartz. The sandstone is generally argillaceous, silty, and darker colored than in the lower unit, with colors such as moderate brown to moderate yellowish brown, dark yellowish orange to light brown, dusky yellow to dark yellowish brown, light olive gray to dark yellowish orange; a few hematitic beds are dusky red The shale in films and beds mostly less than 1 inch thick is mostly sandy, greenish gray, light brownish gray in part with a purplish tint, and in the upper part forms dusky red films.

The top 130-foot interval of the Hickory Sandstone may be divided into a lower 46-foot, somewhat less massive, siltier, more argillaceous and micaceous interval containing some intraformational conglomerate and trails, and an upper 84—foot, massive, somewhat calcareous unit. The upper 84 feet is mostly hematitic sandstone, with massive, very dusky red zones alternating with less massive, burrowed zones of various colors, such as moderate yellowish brown, grayish orange, dark yellowish orange, dark yellowish brown, and moderate brown. A 1 foot bed of shale near the middle is pale red, sandy, and fissile. The lower 46 feet is mostly very dusky red to light brown. The sand grains generally range from fine to very coarse, very fine sand is scarce, and granules are found at a few levels. The larger grains are extremely well rounded and appear polished, probably because of the hematite coating. The analytical data in table 18 by Schofield (Barnes and Schofield, 1964) give the amount of iron and some indication of the amount of carbonate (ignition loss is mostly $CO_2$ from calcite and dolomite) in the upper unit of the Hickory Sandstone. The upper 4 feet, included with the Cap Mountain Limestone, according to this analysis should have been placed in the Hickory Sandstone.

The zone of red Hickory Sandstone, so well displayed in the Pontotoc section, is continuous throughout the northwestern quadrant of the Llano region, present in the Cold Creek area, and about 66 feet thick in the Slick Mountain area, but almost entirely disappears before the Little Llano River area is reached 14 miles to the east-northeast. As the Cap Mountain is of almost identical thickness in the two areas, equivalent thicknesses of the Hickory Sandstone in the two areas should represent

**Table 18. Analytical data for red unit of Hickory Sandstone, Pontotoc section, San Saba County, Texas.**

| Position in section (feet above base) | $H_2O$- | Ignition loss | Total iron as $Fe_2O_3$ (percent) |
|---|---|---|---|
| 465–474 | 0.18 | 0.15 | 14.5 |
| 455–465 | 0.22 | 13.17 | 24.4 |
| 445–455 | 0.17 | 6 .35 | 16.4 |
| 440–445 | 0.20 | 1.74 | 10.2 |
| 430–440 | 0.19 | 1.48 | 5.3 |
| 420–430 | 0.24 | 9.86 | 14.9 |
| 410–420 | 0.24 | 10.50 | 11.4 |
| 400–410 | 0.19 | 7.39 | 8.3 |
| 380–400 | 0.24 | 8.73 | 12.2 |
| 370–380 | 0.16 | 4.43 | 4.8 |
| 360–370 | 0.23 | 2.46 | 3.5 |
| 350–360 | 0.18 | 3.01 | 4.1 |
| 340–350 | 0.10 | 1.60 | 5.9 |

approximately the same time intervals. If this is true, a facies change has taken place between the two areas, possibly caused by a rather rugged Valley Spring Gneiss area between the Cold Creek and Little Llano River areas serving as a barrier.

*Bolaspidella*-Zone fossils are in 3 collections between 279 and 326 feet, and *Cedarina-Cedaria*-Zone fossils are in 4 collections between 350 and 425 feet.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone, thickening southward, is 165 feet thick in the Taylor Ranch section, 170 feet in the Pontotoc section, and 177 feet in the Slick Mountain section. In the Pontotoc section, the best exposed section of the 3, the lower 4 feet is sandstone arbitrarily placed in the Cap Mountain because of its resistance to weathering, indicating calcite cement. However, analytical data indicate a deficiency in calcite and that this fine- to coarse-grained, moderate yellowish-brown and moderate brown, massive zone should have been placed with the Hickory Sandstone.

The next 14 feet of granular limestone, so sandy that it approaches sandstone in composition, is very silty, mottled pale yellowish brown and moderate yellowish brown, in beds 4 to 12 inches thick, and the sand is fine to coarse. This unit and the overlying 85 feet of beds constitute the silty zone of the Cap Mountain Limestone; the lower limestone unit is absent. The 85-foot interval is mostly siltstone in thick zones alternating with zones composed of siltstone and some granular limestone. This interval is mostly mottled moderate brown and pale yellowish brown, burrowed, in beds averaging 4 inches in thickness, and the upper 18 feet is slightly glauconitic.

The top 70 feet of the Cap Mountain can be divided into a lower 46-foot, boldly outcropping series of limestone strata ranging from 2 to 18 inches thick and an upper 24 feet of similar limestone alternating with recessive intervals which may be mostly greensand, forming a gradational unit below the boundary chosen for the Lion Mountain Sandstone. The limestone is fine to very coarse grained, glauconitic, silty, sandy (more so upward), in part micaceous, in part crossbedded, and various colors such as medium olive gray to pale to dark yellowish brown, moderate brown, greenish gray to yellowish brown in part mottled, and grayish orange to moderate yellowish brown and light olive gray in part mottled. The sand is mostly well rounded and polished and is bronzy in some moderate brown beds in the lower part.

*Coosella*-Zone fossils are in 3 collections between 541 and 594 feet, *Maryvillia*-Zone fossils in 5 collections between 602 and 622 feet, and *Aphelaspis*-Zone fossils in 3 collections between 636 and 639 feet.

*Lion Mountain Sandstone Member.*—In the Pontotoc section, 26 feet of Lion Mountain Sandstone was measured; this appears to be too thin when compared with 50 feet in the Taylor Ranch section, 57 feet in the Slick Mountain section, and 47 feet in the Cold Creek section. Because an offset was made to cross a fault in the Pontotoc section, it seems likely that some strata were missed and the 26-foot value is too little.

None of the sections of Lion Mountain Sandstone are well exposed; the exposures in the Pontotoc section are probably best. In this section greensand is not as prominent in the upper part of the member as in many sections; the upper half is mostly sandstone, limestone, and shale. The sandstone is medium to coarse grained with some 1/4-inch quartz grains, glauconitic, weathers brown; the lower bed is 3 feet thick, and others are 1 foot or less thick separated by thinner friable beds. The limestone, confined to the 3-foot sandstone bed, occurs as coarse-grained crossbeds of trilobite coquinite. The shale occupying the top foot and possibly some of the 3-foot covered interval beneath is olive green, glauconitic, and sandy.

The lower half is mostly greensand and limestone with greensand most abundant in the upper part and limestone abundant in the lower part. The limestone is composed of very coarse-grained crossbeds of trilobite coquinite, and is slightly sandy and glauconitic. The greensand, poorly exposed, is less than half glauconite and the remainder is mostly quartz sand, fine to very coarse grained, containing a few granules, and strongly reconstituted.

*Aphelaspis*-Zone fossils are in 4 collections between

647 and 655 feet. No post-*Aphelaspis*-Zone fossils were found, suggesting that some of the thinness of the Lion Mountain Sandstone in this section may be caused by erosion at its top.

### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone varies in thickness from 18 feet in the Slick Mountain section, 25 feet in the Taylor Ranch section, and more than 28 feet in the Cold Creek section. About 9 feet of Welge Sandstone was exposed at the time the original Pontotoc section was measured; now, after construction of Ranch Road 501, about 12 feet is exposed. The next 16-inch interval above that described in the original section consists of light greenish-gray shale, in part slightly sandy, which contains some thin-shelled, phosphatic brachiopods. The top 2 feet is sandstone similar to the sandstone beneath the shale, which is fine to very coarse grained, containing a few granules, pale to dark yellowish orange, slightly glauconitic, and crossbedded; beds are 6 inches to 2 feet, and grains are fairly well rounded and fairly rough from reconstitution.

The 25 feet of Welge Sandstone in the Taylor Ranch section is medium grained, yellowish brown, friable, limonitic, locally hematitic, slightly glauconitic, medium to thick bedded, and the grains are well sorted and rounded to subangular. In the Cold Creek section the Welge Sandstone is medium to coarse grained with some granules and small pebbles in the top bed; one pebble measures 0.45 inch. No fossils were seen in any of these sections.

*Morgan Creek Limestone Member.*—In the Taylor Ranch section the Morgan Creek Limestone Member is 126 feet thick, in the Cold Creek area it is 128 feet thick, and 102 feet was measured to the top of Slick Mountain in the Slick Mountain section. The thickness of the Morgan Creek Limestone in this area is about average; the portion beneath the *Eoorthis* Bed, about 50 feet thick, is coarse grained, slightly to very glauconitic, medium to thick bedded, sandy in the lower part, grayish red in the lower 20 feet or so, and elsewhere mostly greenish gray. The Morgan Creek Limestone above the *Eoorthis* Bed is fine to coarse grained, glauconitic, thin to medium bedded, locally silty, greenish gray, and dolomitic with dolomite replacing ooids and fossil fragments. Stromatolites are in the top 5 feet of the Slick Mountain section and the upper 28 feet of the Taylor Ranch section.

*Point Peak Member.*—The Point Peak Member in the Cold Creek section is 140 feet thick; 77 feet of Point Peak Member was measured in the Taylor Ranch section where most of it is covered. In the Cold Creek section 26 beds of intraformational conglomerate and 3 limestone beds—one hyolithid-bearing, one oolitic and trilobitic, and the other fine grained—were counted. The rest of the rock, fairly well exposed, consists of siltstone and shale. Alate *Billingsella,* elsewhere normally occurring with *Plectotrophia,* exists 113 to 119 feet above the base of the Point Peak Member in the Cold Creek area. *Plectotrophia* in the top bed of the Taylor Ranch section is 77 feet above the base of the Point Peak Member. This 40-foot discrepancy indicates that at least 1 of these fossils is distributed through more section than normal, with the distribution perhaps like that for *Plectotrophia* in the extreme northeastern part of the Llano region where it is distributed through at least 45 feet of section.

*San Saba Member.*—Most of the San Saba Member probably crops out in the Cold Creek area but only the lower 74 feet of the member could be placed in a measured section. The lower 64 feet of these strata consists of stromatolitic reef and interreef coarse-grained limestone overlain by 10 feet of very fine-grained to aphanitic, yellowish-gray, mottled limestone to the top of Cow Teat Mountain. Additional calcitic beds crop out east of Cold Creek on Lone Oak Mountain to compose perhaps half of the member; the rest of the member is dolomite and the contact between the two is in part laterally gradational.

### Cretaceous Rocks

Cretaceous rocks occur in the Pontotoc area only and consist of a thin zone of terrigenous rocks composed of conglomerate, sand, silt, and clay beneath a thin zone of bedded limestone. The terrigenous part is probably at or above the level of the Comanche Peak Limestone and is a basal unit that is probably continuous with the Hensell Sand but younger than any of the Hensell Sand mapped in Gillespie County. If this interpretation is true, then the overlying bedded limestone is Edwards Limestone.

### Quaternary Deposits

Quaternary deposits include one small patch of colluvium in the Pontotoc area, alluvium along Coal Creek and San Fernando Creek in the Cold Creek and Slick Mountain areas, and travertine in the Coal Creek area.

## LITTLE LLANO RIVER-POINT PEAK AREA, SAN SABA AND LLANO COUNTIES

### Introductory Statement

Wilberns Glen, the place from which the Wilberns Formation received its name, is in the Little Llano

River—Point Peak area. Even though all members of the Wilberns Formation are present and in part well exposed, steep dips and the possibility of undetected faulting ruled out this area for measuring and describing a section. Bridge searched for unfaulted sections nearby and found those described herein. None of these sections is completely satisfactory for a type section of the Wilberns Formation because of missing sections and poor exposures, but each adds information helpful for interpreting Moore Hollow Group rocks. In January 1960, Dempsey Montgomery Oils No. 1 Yates was completed about 1.5 miles north of the Little Llano River area, giving a good check on the accuracy of thickness data for Moore Hollow Group rocks in this part of the Llano region.

The Little Llano River—Point Peak area includes: the Little Llano River area, San Saba County (pl. 7, fig. 14), in which the Salt Branch and Little Llano River sections are situated; the Carter ranch area, Llano County (pl. 7, fig. 15), the site of the Carter Ranch section; and the Point Peak—Everett ranch area, Llano County (pl. 7, fig. 16), in which the Point Peak and Everett Ranch sections are situated.

The Little Llano area comprises 2.5 square miles and is 1.1 miles by road south from Ranch Road 501 at a point about 3.5 miles east of Cherokee. The area may also be reached from Babyhead, Llano County, in a distance of about 5.5 miles, by following a graded road east to Wilberns Glen, then north to the area (pl. 7, fig. 14).

The Carter ranch area, 1.4 square miles in size, is 3.4 miles by graded road north of Ranch Road 2241 at Lone Grove. The area may also be reached from State Highway 16 by traveling a graded road 3.4 miles east from a point 1.3 miles south of Babyhead (pl. 7, fig. 15).

The Point Peak—Everett ranch area, 2.5 square miles in size, is 2.8 miles by graded road north-northeast of Ranch Road 2241 at Lone Grove (pl. 7, fig. 16).

The Little Llano River area is situated within the area of the 1:24,000 scale Cherokee U. S. Geological Survey topographic quadrangle map and the other two areas straddle the boundary between the Indian Hills and Lone Grove quadrangles.

Rocks mapped in the Little Llano River area include Precambrian Valley Spring Gneiss and Packsaddle Schist, and all units of the Moore Hollow Group except the upper part of the dolomitic facies of the San Saba Member. Of the various sections measured in this part of the Llano region, the Little Llano River section is the best exposed except that exposures of the Point Peak Member are very poor but no worse than in other sections.

Rocks mapped in the Carter ranch area include Precambrian Valley Spring Gneiss, all members of the Moore Hollow Group; the Threadgill and part of the Staendebach Members of the Tanyard Formation; and Quaternary colluvium and alluvium. The original line of section measured by Bridge, Barnes, and Cloud (1947) is shown (pl. 7, fig. 15) as well as the slightly better exposed one measured by the present writers the same year.

Rocks mapped in the Point Peak—Everett ranch area include Precambrian Town Mountain Granite of the Lone Grove granite mass, all members of the Moore Hollow Group, part of the Threadgill Member of the Tanyard Formation, and Quaternary alluvium. Point Peak, in the southern part of the area, is the type locality of the Point Peak Member of the Wilberns Formation.

The structure is fairly simple with most beds dipping less than 10 degrees and most faults having small displacement. The rocks in the Little Llano River area form a syncline pitching east toward the Little Llano River fault, which is just beyond the area of plate 7, figure 14. The few small faults in this area mostly trend northeast-southwest, a few trend northwest-southeast, and one trends east-west.

The Wilberns Glen area is along the Little Llano River fault in which the rocks are downthrown to the east. Minor faults at a slight angle to the main fault complicate the structure, and dips up to 40 degrees or more involve the beds within 100 feet or so from the fault. The Point Peak Member is much too thin where well exposed beneath the falls, indicating that some has been cut out by strike faulting. Away from the fault, dips are very gentle and northward.

The Carter ranch area occupies part of a very blunt, wedge-shaped graben, only one of the boundary faults is shown, and this fault with a throw of about 400 feet at the eastern edge of the map dies out within the map area. The other boundary of the graben is the Little Llano River fault west of the map area. The 9- to 11-degree dip found in the line of section indicates a steepening of dip toward the end of the graben.

The Point Peak-Everett ranch area (pl. 7, fig. 16) comprises an anticline about 1 mile wide pitching northeast between much faulted synclinal areas also pitching northeast. All the faults, except one short cross fault trending northwest-southeast, are in the northeast quadrant and trend from almost north-south to northeast-southwest. Maximum displacement is probably less than 400 feet and most displacement probably does not exceed 100 to 200 feet.

The area under discussion is far enough east so that cedar, where not eradicated, forms a thick growth on all the carbonate rocks except the Staendebach Member of the Tanyard Formation, which is mainly grassland with a few widely spaced clumps of live oak. On aerial photographs the various members are not as distinct as they are to the west but still in part can be distinguished where the outcrop pattern is not complicated by faulting. The Point Peak Member forms a lighter gray scarp between the more densely vegetated limestone units, and while still retaining much of the stiff, thorny brush of the western area, also supports some luxuriant growths of mountain laurel and some cedar. The Lion Mountain bench has a steeper slope than to the east, is more densely vegetated, and the Welge Sandstone is not as sharply set off. Vegetational alignment along the bedding is distinct in the Cap Mountain Limestone, fairly distinct in the Morgan Creek and calcitic San Saba Members, and seldom seen in the Tanyard Formation. The Hickory Sandstone, with its growth of deciduous oak, is sharply set off from the Cap Mountain Limestone with its carbonate-loving vegetation, but, except for the alignment of vegetation along the bedding, is not sharply set off from the Valley Spring Gneiss. In the Little Llano River area the Hickory Sandstone on aerial photographs is fairly distinct from the Packsaddle Schist and its vegetation of brush, including much bee brush.

### Precambrian Rocks

Valley Spring Gneiss and Packsaddle Schist crop out in the Carter ranch, Wilberns Glen, and Little Llano River areas, and are similar to the rocks described by Paige (1911) in the Llano quadrangle. The Precambrian outcrop was not examined in detail in this present study; however, one band of marble was mapped in the Packsaddle Schist. Town Mountain Granite of the Lone Grove granite mass cropping out in the Carter ranch and Point Peak—Everett ranch areas is a coarse-grained granite which, within the map areas, is poorly exposed. The Dempsey Montgomery Oils No. 1 Yates drilled 775 feet of Precambrian rock, mostly Packsaddle Schist, including marble and biotite schist.

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone is 363 feet thick in the Little Llano River section, 338 feet thick in the Carter Ranch section, and 295 feet thick in the Dempsey Montgomery Oils No. 1 Yates. Only two divisions of the Hickory Sandstone remain in this area; the lower unit is missing, not having been deposited. The middle unit (basal unit in this area) forms a scarp in the Carter ranch area, and, while not producing much of a topographic feature in the Little Llano River area, is seen to be resistant to erosion when compared with the deeply eroded Precambrian rocks on which it lies.

The Hickory Sandstone is described in detail in the Little Llano River section where the lower 23 feet is conglomeratic; pebbles of quartz up to 2 inches in size exist in the lower 2 feet and microcline up to 1/4 inch is abundant, giving the coarse-grained, massive sandstone a moderate reddish-brown to moderate reddish-orange and pale reddish-brown color. The next foot is dark reddish-brown, sandy shale followed by a 171-foot interval (about 10 percent covered) of mostly medium to coarse-grained sandstone, mostly crossbedded, and mostly massive or thick bedded with granules in a few beds and two shaly intervals, one 3 feet thick and the other 5 feet thick. This shale is moderate brown and very sandy. The sandstone is of various colors—yellowish gray, pale to dark yellowish orange, pale to dark yellowish brown, and grayish orange.

The top 168 feet of the Hickory Sandstone, characterized by intraformational conglomerate containing phosphatic brachiopods, is mostly medium- to coarse-grained sandstone in party shaly and about 21 percent covered. Most of the sandstone is thin to medium bedded, thick beds are common, some beds are crossbedded, ripple marks are present, the lower part is glauconitic, and colors are mostly moderate brown, reddish brown, pale to dark yellowish orange, medium yellowish brown, greenish to dark greenish gray, and light brown. An 11-foot, very dusky-red interval in the upper part is about all that is left of sandstone comparable to the red Hickory Sandstone which is so common westward in the Llano region. One bed above the 11-foot interval contains limonitic ooids similar to those found in the red zone of the Hickory Sandstone to the west.

In the Carter ranch area only the lower part of the Hickory Sandstone is well exposed; all that is exposed compares closely to strata at equivalent positions in the Little Llano River area and the range of glauconite is about the same. In the Wilberns Glen area some Hickory Sandstone is exposed along the Little Llano River fault.

*Bolaspidella*-Zone fossils are in 1 collection at 252 feet, and *Cedarina-Cedaria* fossils are in 3 collections between 324 and 327 feet in the Little Llano River section.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone is 165 feet thick in the Dempsey Montgomery Oils No. 1 Yates, 174 feet thick in the Little Llano River section, and 239 feet thick in the Carter Ranch section, reflecting the southward thickening of this member. The upper two units of the Cap Mountain Limestone are recognized in this area; because of lateral gradation to sandstone, the lower limestone unit is absent. The middle siltstone unit (lower unit in this area), 102 feet thick, is mostly very calcareous, very slightly glauconitic, dolomitic, and micaceous siltstone ranging to very silty, fine-grained limestone. One 5-foot bed with ooids and a few thinner, medium-grained, silty, sandy limestone beds are "bronze" beds in which sand grains, spicules type B, and other objects have a bronze color caused by a very thin coating of iron oxide. The lower 3 feet of the siltstone unit is very fine to very coarse-grained, very calcareous, and slightly glauconitic sandstone. Most of the rocks in this unit are moderate brown to pale yellowish brown mottled dark yellowish orange to light brown, and grayish orange, and form massive smooth slopes exhibiting wavy bedding.

The upper 72 feet of the Cap Mountain Limestone is predominantly limestone, somewhat more silty and micaceous downward with a few siltstone beds in the lower 20 feet. The limestone is mostly coarse grained to fine and medium grained in the lower part and is various colors, such as greenish gray to light olive gray, pale to dark yellowish brown speckled by dark yellowish-green glauconite and dark yellowish-orange dolomite, and pale to dark yellowish orange to light olive gray and dark greenish gray mottled by grayish orange. Most beds range from 4 to 6 inches in thickness, a few are intraformational conglomerate, wavy bedding is common, and in the upper part some beds are oolitic and some are slightly sandy.

Cap Mountain Limestone strata in the Carter Ranch section are not as well exposed as in the Little Llano River section; however, those strata seen (mostly the coarser grained beds more resistant to weathering than the siltstone) compare closely to those in the Little Llano River section, except that 10 additional feet of very calcareous sandstone is included at the base of the Carter Ranch section. Pebbles in this sandstone are up to 1/4 inch in size.

Most Cap Mountain Limestone strata are poorly exposed in the Wilberns Glen area, and are situated along the Little Llano River fault. In the Little Llano River section *Coosella*-Zone fossils are in 4 collections between 450 and 507 feet, *Maryvillia*-Zone fossils in 2 collections at 537 and 548 feet, and *Aphelaspis*-Zone fossils in 4 collections between 557 and 560 feet. In the Carter Ranch section *Coosella*-Zone fossils are in 3 collections between 440 and 483 feet, *Maryvillia*-Zone fossils were collected at 550 feet, and *Aphelaspis*-Zone fossils are in 4 collections between 558 and 597 feet.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone varies widely in thickness in this area from 28 feet at Point Peak, to 40 feet in the Carter Ranch section, to 50 feet in the Dempsey Montgomery Oils No. 1 Yates, to 61 feet in the Little Llano River section. Whether or not this difference in thickness is due to erosion at the top of the member or to structural disturbance across the lines of section is unknown. The section on the south face of Point Peak is especially suspect because of limited exposures, the large amount of structural disturbance parallel to the section, and the wide divergence between the thicknesses of the various members measured here and their thicknesses in nearby sections. The Lion Mountain Sandstone is best exposed in the Little Llano River section, and most poorly exposed in the Wilberns Glen area.

The lower 32 feet of the Lion Mountain Sandstone in the Little Llano River section is about one-third covered and most of the rest is limestone in part coarse grained, light gray, yellowish gray, light olive gray, greenish gray, and light to dark yellowish brown, glauconitic, sandy, and trilobitic; and in part fine grained, brownish gray to pale yellowish brown, silty, argillaceous, glauconitic, and in part very sandy. The next 5-foot interval is dusky yellow shale, glauconitic, sandy, contains a few trilobite coquinite crossbeds, and is burrowed with the burrows filled by sand and glauconite, The upper 24 feet is greensand and limestone; the limestone is mainly coarse-grained crossbeds of trilobite coquinite, and the greensand is composed about equally of glauconite and quartz sand. The top 4 feet of greensand is burrowed and the burrows are in part filled by dusky-yellow shale.

*Aphelaspis*-Zone fossils are in 4 collections between 565 and 592 feet in the Little Llano River section and in 8 collections between 585 and 611 feet in the Carter Ranch section.

#### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone is about 20 feet thick in the Dempsey Montgomery Oils No. 1 Yates, 22 feet thick in the section on Point Peak, 27 feet thick in both the Carter Ranch and Little Llano River sections, and appears to be only 9 feet thick in the Salt Branch section, only 1 mile from the Little Llano River section. In the Salt Branch section 9 feet of Welge Sandstone rests on greensand typical of the Lion Mountain Sandstone, but as exposures are absent below this level it is not certain that the greensand is Lion Mountain—it could be a stray bed in the Welge Sandstone.

In the Little Llano River section the Welge Sandstone is massive, mostly medium grained, some coarse grained in the lower 2 feet, some fine grained in the lower part, pale yellowish orange, yellowish to greenish gray, moderate brown, and in the lower 7 feet pale to dark yellowish orange. The upper 3 feet and lower few inches are glauconitic, and some wavy, discontinuous shale films are in the lower part.

In the Carter Ranch section 1/4-inch pebbles are in the top surface of the Welge Sandstone. The grains are well rounded and mostly rough from reconstitution, and fossils found 12 to 13 feet above the base are trilobites and phosphatic brachiopods.

In the Wilberns Glen area the Welge Sandstone is well exposed near the Little Llano River fault, is mostly quartzitic, and small fractures are numerous. Its thickness was not measured.

*Morgan Creek Limestone Member.*—The thickness of the Morgan Creek Limestone is 121 feet in the Little Llano River section, 136 feet in the Carter Ranch section and 140 feet in the Dempsey Montgomery Oils No. 1 Yates; 165 feet was measured in the Salt Branch section, and a thickness even more out of line of 171 feet was measured on the south slope of Point Peak. The thickness found in the Carter Ranch section is about average for the thickness of the Morgan Creek Limestone, and the thickness in the Little Llano River section is below average. Considering the uniformity of thickness found for the Morgan Creek Limestone throughout the Llano region, it must be concluded that undetected duplication of beds or wrong values for dip were used in measuring the Salt Branch and Point Peak sections.

The 47 feet of limestone in the Little Llano River section beneath the *Eoorthis* Bed is coarse grained and medium to thick bedded, and it forms a scarp. It is grayish red at the base, grading upward in the lower 17 feet to pale red and pale reddish brown; in the upper 30 feet it is mostly greenish gray to very light gray, very light olive gray to yellowish gray, and pale yellowish brown mottled dark yellowish orange and grayish orange. The limestone is glauconitic, very sandy at the base; sand decreases upward in amount and is very scarce in the upper 30 feet.

The next 47-foot interval is mostly coarse- to medium-grained limestone, light olive gray, slightly glauconitic, and fossiliferous, as well as some fine-grained darker colored limestone, argillaceous, silty, slightly glauconitic and micaceous, and nodular. Dolomite patches, dark yellowish orange, are common on some bedding surfaces. The upper 24 feet of the Morgan Creek Limestone is poorly exposed, and the thinness of the member in this section may be from undetected faulting in this interval. The limestone exposed is medium to coarse grained, light olive gray to yellowish gray, some pale red in the upper 4 feet, and slightly glauconitic.

In the Wilberns Glen area the Morgan Creek Limestone is fairly well exposed and careful search might reveal a complete section not interrupted by faulting.

*Point Peak Member.*—The thickness of the Point Peak varies widely from 139 feet in the Little Llano River section, to 140 feet in the Dempsey Montgomery Oils No. 1 Yates, to 160 feet in the Carter Ranch section, and to 198 feet at Point Peak. The thickness in the Little Llano River section is substantiated by that found in the Yates well and in other sections in this part of the Llano region. The excess thicknesses in the Carter Ranch section and at Point Peak may have been caused either by duplication of beds from faulting or by the use of the wrong dip in measuring the sections. The Point Peak Member is exceedingly well displayed in the upstream James River section, which is here designated the standard section.

Exposures are very poor in all sections, only the more resistant beds crop out, and many of these are slumped below their natural level. Exposures are best in the Little Llano River section where the lower 29 feet of beds is covered, and the remaining 48 feet to the base of the 2-foot *Plectotrophia*-bearing bed contains several strata composed of limestone intraformational conglomerate and, in the upper part, dimpled stromatolites of dolomite. The *Plectotrophia* Bed (essentially one bed) is medium grained, oolitic, stromatolitic, intraformational conglomerate at the base; laterally along the strike a coquinite of silicified brachiopods cemented by silica is on the top surface.

The 60 feet of Point Peak above the *Plectotrophia* Bed crops out on a flat and consequently is little slumped. Exposures consist of about a dozen intraformational conglomerate beds, a half dozen oolitic beds or zones, and some fine-grained limestone, silty, light gray, yellowish gray and light olive gray to medium light gray scattered through 3 intervals for a total of approximately 17 feet of poorly-exposed section. Chert is in one intraformational conglomerate bed, in one bed white ooids are siliceous, in another silicifation is in patches, and in another girvanella and silicified brachiopod fragments are common.

Dolomitized stromatolites up to 3 feet in diameter in the Carter Ranch section have pitted surfaces, and stromatolites are situated about 46 feet below the top of the Point Peak Member in the Point Peak section. Other rocks in these sections are similar to those described in the Little Llano River section.

The Point Peak Member is very poorly exposed in the Wilberns Glen area except at the foot of the falls where it appears to be much too thin.

*San Saba Member.*—The 193 feet of San Saba strata measured in the Everett Ranch section is too thin when compared with the 260 feet in the Dempsey Montgomery Oils No. 1 Yates, the 230 feet in the Cherokee section of Cloud, and the 324 feet in the Tanyard section of Barnes (Cloud and Barnes, 1948, p. 28). The thinness of the member in the Everett Ranch section could be due to undetected faulting, but when the thickness data are examined it seems likely that the fine-grained—coarse-grained dolomite contact used as the boundary between the members in the various areas is not at the same stratigraphic level. The total thickness of the San Saba and Threadgill Members fluctuates only 36 feet, whereas the thickness of the San Saba Member varies 94 feet or, if the Everett Ranch section is included, 131 feet, and the thickness of the Threadgill Member varies 58 feet.

In the Little Llano River and Carter Ranch sections only the lower 46 and 75 feet, respectively, of calcitic San Saba Member beds were measured. These strata are fine grained to aphanitic, light yellowish gray in part mottled pale yellowish orange, very light olive gray to pale yellowish brown in part mottled dark yellowish orange, and girvanella are numerous. Similar beds occupy the lower 115 feet of the San Saba Member in the Everett Ranch section except that some of the girvanella in the upper half are silicified. The next 17-foot interval in the Everett Ranch section is fine- to medium-grained, light-colored, glauconitic, and thin- to medium-bedded limestone. The dolomitic facies of the San Saba Member, 61 feet thick, is medium grained, with some patches and alternations in the upper part of coarse-grained dolomite. The dolomite, which weathers gray, is mostly mottled, medium bedded, and locally fossiliferous where very cherty.

In the Wilberns Glen area the San Saba Member is composed of a lower calcitic, aphanitic to microgranular, in part mottled, in part girvanella-bearing, massively bedded limestone and an upper dolomite unit which is fine grained. One gains the impression that this member is thinner than normal in this area and probably comparable in thickness to that in the Everett Ranch section. This impression could be in part due to the narrowness of outcrop width caused by steep dips in the vicinity of the best exposures.

## Ellenburger Group

### Tanyard Formation

The Tanyard Formation is represented in the Everett Ranch section by 10 feet of medium- to coarse-grained dolomite at the base of the Threadgill Member. The dolomite is very light gray, has a sugary texture, is medium bedded, and forms a rounded outcrop with boulders and rounded ledges. Areas of calcitic and dolomitic Threadgill Member are mapped in both the Carter ranch and Point Peak—Everett ranch areas; in the Carter ranch area dolomitic Staendebach Member is also mapped. The latter is mainly fine- to medium-grained cherty dolomite.

The Tanyard Formation is 675 feet thick in the Dempsey Montgomery Oils No. 1 Yates, which is 115 feet more than in the nearby Cherokee section and only 17 feet more than in the Tanyard section. The greater thickness of Tanyard Formation strata found in the Yates well and the Tanyard section suggests that about 100 feet of beds were faulted out in the Cherokee section.

The Staendebach Member in the Yates well accounts for 440 feet of the Tanyard Formation and the remaining 235 feet belongs to the Threadgill Member. The upper 110 feet of the Staendebach Member is calcitic, compared to 176 feet in the Cherokee section; the lower 330 feet is dolomitic, compared to 124 feet in the Cherokee section. In the Yates well the upper 80 and lower 75 feet of the Threadgill Member is dolomite separated by 80 feet of limestone, whereas in the Cherokee section the Threadgill is entirely dolomite. Lateral gradation from limestone to dolomite accounts for the variation in thickness of the facies in each member; however, the total of the facies in each member should be about the same in nearby sections.

In the Wilberns Glen area the San Saba Member is overlain by the Threadgill Member, composed of upper and lower coarse-grained dolomite units separated by an aphanitic limestone unit, at least along the lines of traverse. The lower part of the Staendebach Member is present in the northern part of the area and is normal in appearance.

### Gorman and Honeycut Formations

The Gorman Formation in the Dempsey Montgomery Oils No, 1 Yates is 420 feet thick, which is very near the 426 feet found by Cloud in the Cherokee section. The calcitic facies in this well is about 130 feet thick, compared with 275 feet in the Cherokee section; the dolomitic facies (including some limestone at the base) is 290 feet thick, compared with 151 feet in the Cherokee section.

The Yates well, drilled in an outcrop area of Honeycut Formation rocks, penetrated only 60 feet of Honeycut strata before entering the Gorman Formation.

### Quaternary Deposits

Quaternary deposits include a large area of colluvium in the Carter ranch area and alluvium along most of the larger streams.

### Dempsey Montgomery Oils No. 1 Yates, San Saba County

This well, completed in January 1960, furnishes important thickness data in the portion of the Llano region near the type sections of the Wilberns and Tanyard Formations and provides a standard of comparison for measured thicknesses found in nearby surface sections. Located in San Saba County, this well is 2,000 feet from the west line and 1,200 feet from the south line of section 576, Martin Bruch survey. Sample descriptions for this well are on open file at the Bureau of Economic Geology.

Thicknesses of geologic units drilled are given in table 19.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Little Llano River section—description of measured section with thin-section descriptions and fossil lists, heavy-mineral data, table 39, insoluble-residue data, table 40; Carter Ranch section—description of measured section with fossil lists; Everett ranch—Point Peak section—description of measured section with fossil lists.

**Table 19. Thicknesses of geologic units in Dempsey Montgomery Oils No. 1 Yates well, San Saba County, Texas.**

| Stratigraphic unit | Thickness (feet) | Depth (feet) |
|---|---|---|
| Ellenburger Group | 1,155 | 0–1,155 |
| Honeycut Formation | 60 | 0–60 |
| Gorman Formation | 420 | 60–480 |
| Calcitic facies | 130 | 60–190 |
| Dolomitic facies | 290 | 190–480 |
| Tanyard Formation | 675 | 480–1,155 |
| Staendebach Member | 440 | 480–920 |
| Calcitic facies | 110 | 480–590 |
| Dolomitic facies | 330 | 590–920 |
| Threadgill Member | 235 | 920–1,155 |
| Dolomitic facies | 80 | 920–1,000 |
| Calcitic facies | 80 | 1,000–1,080 |
| Dolomitic facies | 75 | 1,080–1,155 |
| Moore Hollow Group | 1,070 | 1,155–2,225 |
| Wilberns Formation | 560 | 1,155–1,715 |
| San Saba Member | 260 | 1,155–1,415 |
| Dolomitic facies | 85 | 1,155–1,240 |
| Calcitic facies | 175 | 1,240–1,415 |
| Point Peak Member | 140 | 1,415–1,555 |
| Morgan Creek Limestone Member | 140 | 1,555–1,695 |
| Welge Sandstone Member | 20 | 1,695–1,715 |
| Riley Formation | 510 | 1,715–2,225 |
| Lion Mountain Sandstone Member | 50 | 1,715–1,765 |
| Cap Mountain Limestone Member | 165 | 1,765–1,930 |
| Hickory Sandstone Member | 295 | 1,930–2,225 |
| Precambrian | 775 | 2,225–3,000 |
| Red Mountain Gneiss(?) | 20 | 2,225–2,245 |
| Packsaddle Schist | 755 | 2,245–3,000 |

## TANYARD-MORGAN CREEK AREA, BURNET AND SAN SABA COUNTIES

### Introductory Statement

The Tanyard, Goodrich ranch, Morgan Creek, and Lion Mountain areas include most of the northeasternmost outcrops of Moore Hollow Group rocks in the Llano region. A complete, measurable section of the Moore Hollow Group could not be found in any one of these areas. To piece together a complete section it was necessary to measure the lower part in the Morgan Creek area and the upper part in the Tanyard area, resulting in a section covering a straight line distance of about 15 miles. The Goodrich ranch area (pl. 9, fig. 1), adjacent to the Morgan Creek area (pl. 9, fig. 2), was mapped by Jansen (1957), hoping that a complete section of Moore Hollow Group rocks would be found. No additional beds were found in measurable position other than those described in the Morgan Creek section.

In the vicinity of the northeastern sections where the line of correlation (pl. 2) changes from east to south, important thickness changes in the San Saba, Point Peak, and Cap Mountain Members take place The northeastern area includes the type localities and sections of two of the members of the Moore Hollow Group—the Lion Mountain Sandstone in the Lion Mountain area and the Morgan Creek Limestone in the Morgan Creek area, as well as the type area of the Tanyard Formation of the Ellenburger Group in the Tanyard area

The map of the Tanyard area (pl 7, fig 17) is a reproduction of part of plate 8 of Cloud and Barnes (1948) with the addition of a few lines of section The Tanyard area was mapped geologically by Barnes and Lincoln Warren (Cloud and Barnes, 1948, pl 8), the portion included herein (pl 7, fig 17) embraces an area of about 2 5 square miles At the time the sections were measured the area was accessible by load from the northeast by traveling about 9 miles from a point on a county road 2 miles north-northwest of Naruna in northern Burnet County The segments of sections west of Lake Buchanan (Colorado River) could then be reached from the Tanyard area by boat In event this road is now closed, the best way to reach all segments of the section is by boat from Tow, a distance of about 9 to 10 miles

The Goodrich ranch area in Burnet County, comprising about 15.6 square miles, was mapped by Jansen (1957) and includes an area of 2.7 square miles mapped by Barnes and Ellinwood in 1950 (Barnes, 1956). The northern part of the area is reached by road from Naruna, about 7 miles to the northeast, and the southern part of the area is reached from Burnet by traveling west 3.4 miles on State Highway 29, then northwest on Ranch Road 2341, about 9 miles.

The Morgan Creek area, southeast of the Goodrich ranch area, comprises about 14.9 square miles. The area, about 7 miles from Burnet, is reached over the same roads as is the southern part of the Goodrich ranch area.

The Lion Mountain area (pl. 7, fig. 18) comprises about 1.9 square miles. The area, just west of the Morgan Creek area, is about 2.6 miles west of Ranch Road 2341 at a point about 7 miles from Burnet.

The Tanyard area is situated within the area of the 1:24,000 scale Tow U. S. Geological Survey topographic quadrangle map; the Goodrich ranch area is within the area of the Tow and Buchanan Lake quadrangles; and the Morgan Creek and Lion Mountain areas are within the Council Creek quadrangle.

Rocks mapped in the Tanyard area include the topmost beds of the Cap Mountain Limestone and the Lion Mountain Sandstone members of the Riley Formation, all members of the Wilberns Formation, both members of the Tanyard Formation, and Quaternary alluvium.

Rocks mapped in the Goodrich ranch area include Precambrian Town Mountain Granite of the Lone Grove granite mass, all units of the Moore Hollow Group, both members of the Tanyard Formation, and Quaternary travertine.

Rocks mapped in the Morgan Creek area include Precambrian Valley Spring Gneiss, Packsaddle Schist, and Town Mountain Granite of the Midway sill; Paleozoic rocks including all members of the Moore Hollow Group and Tanyard Formation and part of the Honeycut Formation; and Quaternary travertine, and alluvium.

Precambrian rocks mapped in the Lion Mountain area include Packsaddle Schist and Town Mountain Granite, all members of the Riley Formation, and the Welge Sandstone Member and the basal beds of the Morgan Creek Limestone Member of the Wilberns Formation.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Tanyard sections—fossil lists, description of measured sections, description of insoluble-residues; Goodrich Ranch sections—description of measured sections with fossil lists; Morgan Creek section—description of measured section with thin-section descriptions and fossil lists, heavy-mineral data, table 41, insoluble-residue data, table 42; Lion Mountain section—description of measured section with fossil lists.

Faults are abundant in the Goodrich ranch and Tanyard areas and less abundant in the Morgan Creek and Lion Mountain areas. All faults are normal, most trend northeast-southwest, a few trend north-south, east-west, and directions in between. Faults trending northwest-southeast, common in the northwestern part of the Llano region, are absent in this part of the region. Beds are gently dipping and most dip less than 10 degrees.

The Riley and lower members of the Wilberns Formation in the Tanyard area are exposed in a narrow horst, and the fault bounding the southeast side of the fault block has a throw of about 900 feet; other faults in the area have lesser throw. One fault at the point where it passes from the Goodrich ranch area into the Morgan Creek area has at least 1,200 feet of throw and outlines the southeastern side of a graben which wedges out southwestward. A fault bounding the northwest side of another graben in the vicinity of Green Cave in the Goodrich ranch area has a throw of about 500 feet.

Vegetal patterns as seen on aerial photographs are less distinct than those to the west; however, the Hickory Sandstone retains its vegetation, dominated by dedicuous oak where sandy and mesquite where shaly, and is sharply set off from the overlying carbonate-bearing rocks with their thick growth of cedar. The Point Peak Member, in addition to cedar, supports much mountain laurel on south-facing slopes and forms a scarp. Most of the Lion Mountain bench is distinct and somewhat less vegetated than the units above and below. The abundantly cherty part of the dolomitic San Saba Member is sparsely vegetated and characterized by pimple mounds, as are portions of the Staendebach Member and cherty or spiculitic portions of the Marble Falls Limestone. The noncherty Threadgill Member where in position to receive large amounts of chert from the Staendebach Member is also covered by pimple mounds.

### Precambrian Rocks

Town Mountain Granite of the Lone Grove granite mass in the Goodrich Ranch area crops out in two places along the lake shore and forms two buried hills, one reaching as high as the Welge Sandstone and the other as high as the Lion Mountain Sandstone. In the Lion

Mountain area this granite forms low-lying outcrops partly in fault contact with Hickory Sandstone and partly in contact with Packsaddle Schist. In the Morgan Creek area a sill of Town Mountain Granite (Midway sill of Stenzel, 1934) separates Packsaddle Schist from Valley Spring Gneiss and very likely is connected with the Lone Grove mass beneath the Moore Hollow Group rocks in the Lion Mountain area. The Valley Spring Gneiss Precambrian surface was fairly hilly; one peak surrounded by Hickory Sandstone is exposed along Council Creek and another is just east of the foot of the Morgan Creek section.

### Moore Hollow Group

#### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone, 340 feet thick in the portion of the Morgan Creek section south of Potatotop, fluctuates considerably in thickness because of the irregularity of the Precambrian surface on which it was deposited. In this area, as in the Little Llano River—Point Peak area, the Hickory Sandstone is divisible into two parts, an upper flat-lying, cultivated portion and a lower wooded portion that tends to make a scarp. The Hickory Sandstone mostly crops out in the southern parts of the Goodrich ranch and Morgan Creek areas.

The lower 171 feet of the Hickory Sandstone in the Morgan Creek section is mainly fine- to very coarse-grained sandstone with some granules, conglomerate and pebbles common in the lower 25 feet, clay uncommon except in the basal few feet, and a few iron oxide ooids from 120 to 130 feet above the base. Most beds range from about 4 to 18 inches in thickness, several are crossbedded, cuneiform markings (possibly ice crystal molds or less likely burrows) are common throughout, *Cruziana* was seen in the line of section at 85 feet, and phosphatic brachiopods were in the upper 65 feet. Colors are mostly various somber shades of brown, orange, and red, such as dark yellowish brown, dusky yellowish brown, dark grayish brown, grayish brown, dusky brown, light to moderate brown, moderate yellowish brown, grayish orange, dark yellowish orange, very pale orange, grayish red, dusky red, and pale to dark reddish brown. Grains, mostly fairly well-rounded quartz, are rough from reconstitution, and microcline is locally abundant.

The upper 169 feet of the Hickory Sandstone is mostly sandstone, some silty to sandy shale, and numerous covered intervals which are probably also very argillaceous. The lower 90 feet of this interval, the least well exposed, is glauconitic, and mostly medium to coarse grained; also common is very coarse sand, granules, and finer grades of sand and silt. Colors are mostly shades of red, brown, and orange, such as grayish red, very dusky red, pale to dark yellowish brown, pale to dark yellowish orange, moderate brown, and dusky yellow. Phosphatic brachiopods are common at some levels.

Jansen measured 244 feet of Hickory Sandstone to lake level in the Hill Creek segment of the Goodrich Ranch section. The upper 152 feet is somewhat shaly and argillaceous; of this, approximately the lower 116 feet is glauconitic, comparing roughly in position with the glauconitic interval in the Morgan Creek section. Jansen found *Bolaspidella*-Zone fossils in 1 collection at 147.5 feet and *Cedarina-Cedaria*-Zone fossils in 2 collections at 207 and 230 feet.

In the Morgan Creek section Palmer found *Bolaspidella*-Zone fossils at 222 feet, *Cedarina-Cedaria*-Zone fossils in 3 collections between 283 and 322 feet, and *Coosella*-Zone fossils in 1 collection at 419 feet.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone Member, 179 feet thick in the Goodrich Ranch section and 204 feet thick in the Morgan Creek section, is only slightly thicker than in other sections in the northern part of the Llano region. Its tripartite division so well displayed in sections to the south begins to be distinguishable in the Morgan Creek section, whereas only the upper two divisions were seen in sections to the west. The Cap Mountain Limestone crops out in the southwestern half of the Goodrich ranch area, forming a faulted northwest-southeast-trending belt with important fingers following northward along Silver Creek and Beaver Creek. It crops out on Potatotop, in a belt across the middle, and in the southwestern part of the Morgan Creek area, from where it extends westward throughout much of the Lion Mountain area. The top few beds are exposed in the horst in the Tanyard area.

In the Morgan Creek section the upper half of the lower 36—foot interval is limestone, and the lower half is very calcareous sandstone in part verging on limestone. The upper part is sandy—sand medium to coarse—oolitic, and pale brown to reddish brown and moderate yellowish brown to moderate brown mottled, dark .yellowish orange. The lower half is grayish brown, dark yellowish brown, and moderate yellowish brown to moderate brownish yellow in part mottled.

The middle silty unit, 97 feet thick, in general ranges from very silty limestone to very calcareous siltstone, is slightly glauconitic, is wavy bedded, forms smooth massive outcrops in steep exposures, and some medium beds are near the top and bottom. In the upper part it is light olive gray to greenish gray and grayish orange and in the lower part mostly yellowish gray weathering pale to dark yellowish orange.

The upper 71—foot unit is mostly fine- to coarse-grained limestone, glauconitic, greenish gray to olive gray and light olive gray speckled yellowish gray and moderate yellowish brown mottled and speckled dark yellowish orange; the lower 32 feet is oolitic, the upper part slightly sandy, and some silt is found throughout. A 2-foot greensand 14 feet below the top is greenish black and contains hematite concretions and crossbeds of trilobite coquinite.

Jansen's section of the Cap Mountain Limestone in the Hill Creek segment of the Goodrich ranch area reveals a thickness of 73 feet for the upper limestone unit and about 85 feet for the middle silty unit, with no sharp boundary between it and the scarcely distinguishable lower limestone unit. He found a *Cedarina-Cedaria*-Zone fauna in 1 collection at 296.5 feet, *Coosella*-Zone fossils in 11 collections between 329 and 398 feet; *Maryvillia*-Zone fossils in 1 collection at 403.5 feet; and *Aphelaspis*-Zone fossils in 8 collections between 406 and 323 feet.

In the Morgan Creek section Palmer found *Coosella*-Zone fossils in 9 collections between 446 and 485 feet, *Maryvillia*-Zone fossils in 3 collections between 494 and 516 feet, and *Aphelaspis*-Zone fossils in 4 collections between 529 and 538 feet. In the Lion Mountain area he identified *Coosella*-Zone fossils from 2 collections 40 feet apart, and 30 and 55 feet higher *Maryvillia*-Zone fossils in the top collection 10 feet below *Aphelaspis*-Zone fossils. These collections were made by Dake, Bridge, Ulrich, and others (1930–1934) west of Lion Mountain along former State Highway 29 (before Lake Buchanan was created).

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone in this area gradually thickens southward from 35 feet in the Tanyard section to 49 feet in the type section at Lion Mountain. The thickest section measured, 69 feet, here designated the standard section, is along Squaw Creek in the opposite quadrant of the Llano region. Outcrops of the Lion Mountain Sandstone parallel those of the Cap Mountain Limestone in the Tanyard, Goodrich ranch, and Morgan Creek areas, and circle Lion Mountain in the Lion Mountain area. In the Morgan Creek section the upper boundary is difficult to recognize because of abundant glauconite in the overlying Welge Sandstone.

In the Morgan Creek section the lower 22 feet of the Lion Mountain is about two-thirds covered and the rest is mostly greensand with lenses of sandy, glauconitic, trilobite coquinite, and 1 foot of sandy, glauconitic, coarse-grained limestone. The remaining 25 feet is mostly greensand about equally glauconite and quartz sand; covered beds amount to 9 feet, and sandstone, very coarse grained arid glauconitic, 2 feet. Some intervals of the greensand contain thin beds of brown, silty shale.

The Lion Mountain Sandstone Member is very poorly exposed in the Lion Mountain section and well exposed in the Bartlett Branch segment of the Goodrich Ranch section where the upper greensand unit is thinner than in the Morgan Creek section, suggesting that erosion has removed some of the greensand in the Goodrich Ranch section. Jansen found *Aphelaspis*-Zone fossils in 3 collections between 430 and 452 feet and no post-*Aphelaspis*-Zone fossils, which helps substantiate erosion of some of the Lion Mountain Sandstone.

In the Morgan Creek section Palmer found *Aphelaspis*-Zone fossils in 2 collections at 547 and 561 feet and post-*Aphelaspis*-Zone fossils in 2 collections at 570 and 574 feet. He also identified *Aphelaspis*-Zone fossils from 4 collections in a range of 25 feet and post-*Aphelaspis*-Zone fossils 15 feet higher from collections made by Dake, Bridge, Ulrich, and others (1930–1934) in a measured section on the southwest slope of Lion Mountain. A description of the original section was not available; consequently, it has not been correlated with the stratigraphic section in Part II, and it is not known whether all the above collections are in the Lion Mountain Sandstone or if the lowest one is possibly in the Cap Mountain Limestone.

**Wilberns Formation**

*Welge Sandstone Member.*—The Welge Sandstone Member ranges from a thickness of 19 feet in the Tanyard area to 12 feet in the Goodrich Ranch section. It crops out parallel to the Lion Mountain Sandstone in all the areas and forms a rim on Lion Mountain in the Lion Mountain area.

The boundary between the Welge and the Lion Mountain Sandstone is difficult to recognize in part of the area, especially in the Morgan Creek section. It is fairly sharp in the Lion Mountain section, with the lower 4 feet of the Welge Sandstone forming a massive, slightly glauconitic bed. In the Gray Mountain segment of the Goodrich Ranch section, the Welge is coarse to medium grained, yellowish brown, slightly glauconitic, calcareous, and scarp forming. In the Morgan Creek section the bottom 3 feet is greensand, the next 7 feet is very glauconitic sandstone, and the top 5 feet is light olive-gray sandstone. The grains are well rounded and mostly rough from reconstitution.

Jansen collected *Elvinia*-Zone fossils at 468 feet.

*Morgan Creek Limestone Member.*—The Morgan

Creek Limestone ranges from 141 feet in the Goodrich Ranch section to 130 feet in the Morgan Creek section and is 131 feet thick in the Tanyard section, which is about average for its thickness in the Llano region. In the Goodrich ranch area it forms a fairly constant-width, northwest-southeast trending, faulted outcrop belt slightly southwest of center of the Goodrich ranch area and north of center of the Morgan Creek area. The Morgan Creek crops out on both sides of Colorado River in the horst in the Tanyard area, and the lower beds form the top of Lion Mountain in the Lion Mountain area.

The lower 55 feet of Morgan Creek Limestone in the Morgan Creek section beneath the *Eoorthis* Bed is mostly coarse-grained, glauconitic limestone, yellowish brown to yellowish gray to light olive gray in the upper part, grayish red to pale red in the lower part, and light brownish gray to light olive gray, yellowish gray, grayish orange pink, and pale red in the middle part. The lower 15 feet ranges from calcareous sandstone at the base to slightly sandy limestone at the top, and the sand grains are fine to very coarse and well rounded. A few beds are oolitic, dolomite patches in some beds are pale yellowish orange, a few shale films are pale olive, crossbedding is common, and beds are mostly medium to thick, the basal portion cropping out boldly.

The top 75 feet of the Morgan Creek above the *Eoorthis* Bed is mostly fine- to medium-grained limestone; coarse grained is most common near the top and bottom of the interval. Pale-olive, calcareous, argillaceous, micaceous siltstone exists in thin beds and as films around nodules of fine-grained limestone and is common throughout the interval and perhaps most abundant in the middle two-thirds. The top 15 feet is pale orange, moderate orange pink, and grayish orange pink to light brown, and the rest is mostly light olive gray to dark greenish gray, depending on the amount of glauconite. Dark yellowish-orange, dolomite patches are on some bedding surfaces, and most limestone beds range from 4 to 8 inches; some are thicker, alternating with thin-bedded and nodular zones.

In the Tanyard area 80 feet of Morgan Creek Limestone was measured above the base of the *Eoorthis* Bed, and Jansen found 73 feet in the Gray ranch segment of the Goodrich Ranch section. Beneath *Eoorthis* he found 68 feet of Morgan Creek Limestone, which appears to be an excessive thickness when compared with 51 feet in the Tanyard area and 55 feet in the Morgan Creek section.

*Point Peak Member.*—The Point Peak Member ranges in thickness from 147 feet in the Goodrich ranch area and 136 feet in the Tanyard area to 114 feet in the Morgan Creek area. This difference in thickness is mainly due to lithologic variations at the top of the member, causing the top to be placed at various stratigraphic levels. The thinning toward the Morgan Creek area may be a reflection of lateral gradation south at the top of the member from terrigenous rock to carbonate rock. The Point Peak outcrop parallels that of the Morgan Creek Limestone in the Goodrich ranch, Morgan Creek, and Tanyard areas.

The Point Peak Member is very poorly exposed in the Morgan Creek section except for the upper 15 feet, composed of glauconitic limestone, siltstone, and shale. The limestone is fine grained, light olive green to light olive gray, and thin bedded and alternates with argillaceous, micaceous, dusky yellow-green to grayish-green siltstone and silty shale. This interval also contains 3 intraformational conglomerate beds and 1 zone of 18-inch stromatolites. The lower 40 feet of the Point Peak Member in the line of section is mostly covered by siltstone float; however, in Rock Hollow 15 feet of this interval is well-exposed, glauconitic siltstone and very silty limestone, which is light olive gray and weathers yellowish gray; beds 1/4 to 1 inch are separated by thin shale films and little evidence was seen of the presence of organisms.

The remaining 97 feet of the Point Peak Member, mostly covered, is probably thin-bedded siltstone and silty limestone for the most part. The amount exposed decreases downward and that exposed consists of intraformational conglomerate beds, zones of stromatolites in part associated with intraformational conglomerate, and a few oolitic limestone beds.

In the County Road segment of the Goodrich Ranch section Jansen found that the lower 59 feet of the Point Peak Member is mostly covered and the upper 88 feet is fairly well exposed; however, intraformational conglomerate beds and stromatolitic zones appear to be scarcer than they are in the Morgan Creek and Tanyard areas. Oolitic beds are common in the upper part; in some the ooids are siliceous and in others the ooids are partly replaced by dolomite.

*San Saba Member.*—In this part of the Llano region the San Saba Member is composed of a thin, lower calcitic facies of variable thickness and a thick, upper dolomitic facies. A complete section, 324 feet thick, of the San Saba Member was measured in the Tanyard area. In the Goodrich ranch and Morgan Creek areas, even though all of the San Saba is present, suitable sections for measurement of the upper part could not be found. The lower 228 feet of the San Saba Member was measured along North Morgan Creek in the Morgan Creek area, and Jansen measured the lower 167 feet in the Lacey Creek segment of the Goodrich Ranch section.

The calcitic part of the San Saba Member forms a narrow outcrop band resting on the Point Peak Member except where interrupted by faulting, or locally in the Goodrich ranch area, by lateral gradation to dolomite. The outcrop of the dolomitic facies is broad and mostly occupies high flat areas except along streams. The San Saba Member crops out in the northern part of the Morgan Creek area, in a northwest-southeast-trending band interrupted by faulting through the central part of the Goodrich Ranch area, and in the southeastern and northwestern parts of the Tanyard area.

The calcitic facies ranges from 42 feet in the Lacey Creek segment of the Goodrich Ranch section to 59 feet in thickness in the Morgan Creek section and, as mentioned above, grades laterally in places entirely to dolomite in the Goodrich ranch area. In the Morgan Creek section the upper 11 and lower 9 feet are limestone essentially without shale, and the rest of the interval is noticeably shaly, mostly as thin films between limestone beds and around limestone nodules. The shale is light olive brown and very silty. The limestone consists of: (1) about 9 feet of stromatolites, aphanitic to very fine grained, light greenish gray to light olive gray mottled pale yellowish brown, and interreef beds, medium to coarse grained, slightly glauconitic, and in part oolitic, ripple marked, and dolomitic, the latter standing out as grayish-orange mottles; (2) about 9 feet of medium to coarse grained, oolitic, glauconitic, yellowish gray, and in part ripple marked; and (3) about 21 feet of fine to very fine grained, thinly bedded to nodular, light olive gray to yellowish gray, slightly glauconitic, and argillaceous. Chert in the basal part occurs in opaque to translucent plates parallel to the bedding.

In the Lacey Creek segment of the Goodrich Ranch section the limestone is mostly fine grained and yellowish gray; shale films are common and the lower 10 feet is pitted probably from weathering of girvanella, which are common in the basal bed.

In the Tanyard section the calcitic San Saba Member is mostly girvanella bearing, massive, and characteristically mottled by a network dolomite pattern weathering in relief; upward dolomite is more abundant until only girvanella remain calcitic. The basal beds in this section, generally glauconitic, are composed mostly of oolitic-limestone and some shale.

In the Tanyard section the basal 40 feet of the dolomitic facies is microgranular to very fine grained, brownish gray to medium gray, and purple streaked. The next 51 feet is microgranular to fine grained, purplish, mottled dark gray and brownish gray, and the lower 32 feet is cherty. The chert is opaque to semitranslucent, quartzose and dolomoldic; it forms network patterns and curved layers, indicating that the chert conformed to stromatolites not otherwise identifiable. The next 89 feet is mainly coarse-grained dolomite, light gray except that the lower 10 feet is mottled medium to dark gray. Chert in this interval is translucent to semitranslucent and in part quartzose and dolomoldic. The remainder of the dolomitic San Saba Member is fine to very fine grained, mostly mottled in grays and browns, except the top noncherty 10 feet which is pinkish gray. The chert is quartzose, mostly porous, semitranslucent, and in part dolomoldic and oolitic; it forms network aggregates.

In the Morgan Creek section the lower 18 feet of the dolomitic facies is mostly medium grained, pale yellowish brown, in part stromatolitic, and it contains some interstitial glauconite. The next 97 feet is mostly fine grained with a few medium-grained beds, pale reddish purple in the lower part and pale yellowish brown, pale red, and very light pink upward. Chert in the upper 70 feet is very quartzose and interstitial to dolomoldic. In one bed in the lower part girvanella are replaced by granular quartz. The top 55 feet is fine- to very fine-grained dolomite, pinkish gray to yellowish gray, and cherty. Translucent and interlayered with quartz druse, the chert is in part dolomoldic to interstitial and outlines elongate stromatolites 1 to 3 inches in diameter in part by following the stromatolitic structure and in part by replacing the septae between stromatolites.

In the Goodrich ranch area the dolomitic facies of the San Saba Member is composed in most places of upper and lower fine-grained zones separated by a zone of coarse-grained dolomite. These zones appear to fluctuate in thickness, and the narrowness of the San Saba outcrop southwest of Green Cave may indicate that the upper fine-grained zone has graded laterally to coarse-grained dolomite.

## Ellenburger Group

### Tanyard Formation

The Threadgill Member in the Tanyard, Morgan Creek, and Goodrich ranch areas is composed of light-gray, coarse-grained dolomite and intergradational, white, aphanitic limestone. In this part of the Llano region the limestone is in patches from a few hundred feet or less to a mile or two long surrounded by coarse-grained dolomite. For the most part in the Goodrich ranch area it was not mapped. The Threadgill Member crops out in the northern part of the Morgan Creek area, the southern part of the Tanyard area, and the northeastern part of the Goodrich ranch area.

The Staendebach Member crops out in the eastern part of the Tanyard area where it is mostly cherty, fine- to medium-grained dolomite and in the upper part cherty, aphanitic limestone. It crops out in the northeastern part of the Goodrich ranch area, and in the Morgan Creek area the member is confined to a few acres in two areas along the northern border of the map. The Tanyard Formation rocks in the Tanyard area have been described by Barnes (Cloud and Barnes, 1948, p. 244–249).

#### Gorman and Honeycut Formations

Honeycut Formation strata containing *Ceratopea*-bearing beds crop out in the northwestern corner of the Morgan Creek area and pass into the Goodrich ranch area, where a complete sequence of Ellenburger Group rocks is found in the graben containing Carboniferous rocks.

#### Quaternary Deposits

Quaternary alluvium was mapped along major streams in all areas except the Lion Mountain area, colluvium was mapped along the South Fork of Morgan Creek, small travertine deposits were mapped along both forks of Morgan Creek, and large masses in the Goodrich ranch area. One of these, known as White Bluff, can be seen for miles.

## BACKBONE MOUNTAIN-SUDDUTH AREA, BURNET COUNTY

### Introductory Statement

The Riley Formation in the Hoover Point section of the Backbone Mountain area (pl. 7, fig. 19) is near the point of the Backbone Ridge graben where faulting is common and much of the Hickory Sandstone Member is now beneath Lake Lyndon B. Johnson (Colorado River). These factors ruled out additional work on the Moore Hollow Group in this area beyond that accomplished by Bridge, Barnes, and Cloud (1947, pl. 1) and Cloud and Barnes (1948, pl. 1, p. 287–308). The thicknesses of the Wilberns units in the Hoover Point and Backbone Mountain sections determined by these authors appear to be accurate except that the Point Peak—San Saba interval is above average thickness, the excess being in the Point Peak Member, the lower part of which is poorly exposed and possibly conceals faults.

The Sudduth area (pl. 7, fig. 20) is the easternmost area of Moore Hollow Group rocks examined and, even though not very well suited for describing a section, does show very well the downward migration of dolomite of the San Saba at the expense of the Point Peak, especially when compared with the Backbone Mountain area (pl. 7, fig. 19) and the area immediately to the north of the Sudduth area. This area is also important in that the Cambrian—Ordovician boundary is at an indeterminable position in a sequence of coarse-grained dolomite.

The T. F. Murchison ranch well provides thickness data for all units of the Moore Hollow Group and Tanyard Formation not readily obtainable in the nearby outcrop of these units.

The part of the "Geologic Map of the Backbone Mountain area," mapped by Barnes and Lincoln Warren (Cloud and Barnes, 1948, pl. 11), containing Moore Hollow Group sections is revised and reproduced here as plate 7, figure 19; it includes 1.5 square miles. Rocks mapped within this area include Precambrian Town Mountain Granite of the main mass of the Granite Mountain granite mass as well as of the Kingsland lobe of this mass, all members of the Moore Hollow Group and Tanyard Formation, and Quaternary colluvium and alluvium.

The Sudduth area includes 2.5 square miles. Rocks mapped include the top of an exhumed hill of Precambrian Town Mountain Granite of the Granite Mountain granite mass, all members of the Moore Hollow Group, and part of the Threadgill Member of the Tanyard Formation.

The Backbone Mountain area is situated within the area of the 1:24,000 scale Kingsland U. S. Geological Survey topographic quadrangle map and the Sudduth area is within the area of the Longhorn Cavern quadrangle.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Backbone Mountain section—description of measured section; Hoover Point section—fossil lists; Sudduth section—fossil lists.

The T. F. Murchison ranch well, about 2 miles northeast of Sudduth, (pl. 1) drilled in 1955, started from the bottom of a previous 245-foot-deep well. Below this depth all units from near the middle of the Gorman Formation of the Ellenburger Group to Town Mountain Granite probably of the Granite Mountain granite mass were encountered.

Vegetation in the Backbone Mountain and Sudduth areas originally consisted of a thick cover of cedar on all carbonate units, but because of the accessibility of these areas, nearness to railroads, value of cedar as posts, and the effectiveness of a government-sponsored cedar eradication program, most of the cedar is now removed. The

Hickory Sandstone, where not cultivated, and the Town Mountain Granite mostly support deciduous oaks.

Structurally the Backbone Mountain area is near the point of a wedge-shaped, faulted graben with the bounding and internal faults for the most part trending northeast or east-northeast. Most beds dip from 10 to 15 degrees. In the Sudduth area the beds dip more gently and are flat in places. Faults mostly curve, form parallel fault blocks, and trend in a general northeast direction.

### Precambrian Rocks

The Town Mountain Granite in the Backbone Mountain area is low lying and deeply weathered That in the southwestern part of the Sudduth area is part of the top of a buried hill reaching to about the middle of the Cap Mountain Limestone Member. This hill and two others to the west were mapped by Barnes and Lincoln Warren in 1945 (Barnes, 1956c, p. 25; 1958, p. 23). The T. F. Murchison ranch well also reached Town Mountain Granite.

### Moore Hollow Group

#### Riley Formation

*Hickory Sandstone Member.*—In the Backbone Mountain area, because of faulting and water cover, a reasonable estimate cannot be made of the thickness of the Hickory Sandstone; also it is not in a topographic position to develop its normal expression. In the Sudduth area, however, the Hickory develops its normal topographic expression for this part of the Llano region and is divisible into an upper friable unit forming flat, cultivated areas and a lower unit forming an irregular scarp southwest of the area (pl. 7, fig. 20). In the T. F. Murchison ranch well the Hickory Sandstone is 305 feet thick.

In this well the upper 35 feet is fine- to very coarse-grained sandstone, with the upper 10 feet grayish red, and the rest light greenish gray; it is glauconitic and slightly dolomitic to calcitic. The next 50 feet downward is medium- to coarse-grained sandstone, very light yellowish gray in the upper part to almost white in the lower part, and the grains in this and the above interval are fairly well rounded and rough. The remaining interval of Hickory Sandstone is poorly represented by samples; those in the upper part are mostly fine- to medium-grained sandstone with crushed quartz probably representing coarser material, and in the lower part the samples are mostly coarse to very coarse sand.

*Cap Mountain Limestone Member.*—Cloud and Barnes (1948) estimated a thickness of 200 feet for the Cap Mountain Limestone Member in the Hoover Point section. In view of about 380 feet of Cap Mountain Limestone in Packsaddle Mountain to the west and 300 feet in the T. F. Murchison ranch well, the extreme thinness of this member in the Hoover Point section is anomalous. Its thinness in the Hoover Point section may be explained by undetected faulting, but it seems more likely that the lower limestone zone of the Cap Mountain is concealed beneath alluvium and that the base of the Cap Mountain was placed at the top of a sandstone unit which correlates with the one found just below the silty zone in the T. F. Murchison ranch well.

In the T. F. Murchison ranch well the upper limestone unit, 80 feet thick, is granular, glauconitic, in the upper 30 feet very light to light yellowish gray in part with a greenish cast and slightly sandy, and in the lower 50 feet very light olive gray and oolitic. The middle silty unit, about 80 feet thick, grades from very calcareous siltstone to very silty limestone, medium olive gray, glauconitic, and in the lower part much very fine sand and some find sand. Beneath the silty unit is 10 feet of coarsely granular limestone, very light olive gray, oolitic, and slightly glauconitic, immediately followed by 30 feet of grayish-red, fine- to medium-grained sandstone that normally would be placed with the Hickory Sandstone. However, the next 50 feet downward is sandstone, fine to very coarse grained, light olive gray to greenish gray, very calcareous, glauconitic, silty, and argillaceous; it grades to limestone, granular, brownish gray, very sandy, and glauconitic. This is followed by 40 feet of granular limestone, greenish gray with a brownish cast, somewhat silty and glauconitic, and very sandy and argillaceous in the upper part. The bottom 10 feet of the Cap Mountain is fine- to medium-grained sandstone, greenish gray, glauconitic, and very calcareous.

*Lion Mountain Sandstone Member.*—Cloud and Barnes (1948) estimated a thickness of 36 feet for the Lion Mountain Sandstone in the Hoover Point section, which is similar to its thickness in the Packsaddle Mountain section and somewhat less than the value of 53 feet found in the T. F. Murchison ranch well. The construction of Ranch Road 1431 across Hoover Point produced an excellent exposure of fresh greensand and enclosed trilobite coquinite lenses in the Lion Mountain Member; however, within a year the fresh green color of the glauconite had noticeably faded but otherwise the rock remains well exposed.

In the T. F. Murchison ranch well the upper part of the Lion Mountain Sandstone is mainly sandstone and greensand and the lower part in addition contains limestone and siltstone. The sandstone is mostly medium to coarse grained, some fine and very coarse grained, and most grains are well rounded and rough from reconstitution. The greensand, dusky green when fresh, is generally weathered blackish red and is very sandy. The limestone is granular, mostly greenish gray, sandy, and glauconitic and, in lower sample, is white and trilobitic. The siltstone is greenish gray, calcareous, and very argillaceous.

### Wilberns Formation

*Welge Sandstone Member.*—In the Hoover Point section the Welge Sandstone is about 12 feet thick and compares closely in thickness to that found in the Packsaddle Mountain area to the west and in the T. F. Murchison ranch well.

The Welge Sandstone in the T. F. Murchison ranch well is mostly medium to coarse grained, some fine grained in lower part, light brown with a reddish tint; some grains are very well rounded and others are rough from reconstitution.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone Member in the T. F. Murchison ranch well is 130 feet thick and in the Hoover Point section 136 feet thick with the *Eoorthis* Zone about 56 feet above its base. As in most other sections the basal 20 feet or so is reddish and sandy.

In the T. F. Murchison ranch well the upper 40 feet of the Morgan Creek Limestone is mostly coarsely granular, grayish red in the upper part, greenish gray to light olive gray downward, glauconitic; in the lower 15 feet some siltstone is medium olive gray with a reddish tint, very calcareous, glauconitic, micaceous, and argillaceous, and some pale-brown, aphanitic limestone in the upper part may be stromatolitic. The next 35 feet is finely granular limestone, light olive gray, greenish gray and reddish gray, glauconitic, and in the upper part argillaceous. The lower 55 feet is coarsely granular limestone, glauconitic, very light to light olive gray; the lower 20 feet is mostly reddish gray and bottom 10 feet is sandy.

*Point Peak Member.*—The 190 feet of Point Peak Member measured in the Hoover Point section appears to be an excessive value when compared with the 65 feet found in the T. F. Murchison ranch well. As measured, the basal 89 feet, mostly covered, is probably argillaceous siltstone; the next 85 feet is stromatolitic reef; and the top 16 feet is limestone and argillaceous siltstone with a zone of *Plectotrophia* and alate *Billingsella* 3 feet beneath the top. Elsewhere in this area stromatolitic reef may be entirely missing in the Point Peak or represented by scattered stromatolites or beds of stromatolites. Where reefs are absent the Point Peak Member is mostly argillaceous siltstone.

In the Sudduth area the Point Peak thickness is not accurately known but appears to be about half that in the Hoover Point section. That present is overlain by dolomite indistinguishable from the dolomite in the San Saba Member. Bridge, Barnes, and Cloud (1947, p. 116) found that the alate *Billingsella* Bed is about 80 feet above the base of the dolomite. This bed very likely represents the same stratigraphic level as the alate *Billingsella* Bed found 3 feet beneath the top of the Point Peak in the Hoover Point section, and an alate *Billingsella* Bed is also found very near the top of the Point Peak Member 3 miles to the north along the drain crossing the highway 0.5 mile south of Honey Creek (Barnes, 1953, p. 65, bed not shown). It is concluded that the base of the San Saba Member is about 80 feet lower stratigraphically in the Sudduth area than it is 3 miles to the north. An examination of this lower dolomite along the northern branch of the drain which heads east of the road (pl. 7, fig. 20) revealed stromatolitic structure, suggesting that the dolomite beneath *Plectotrophia* may be mostly dolomitized stromatolitic reef, thus giving a ready explanation of the rapid change in the position of the top and thickness of the Point Peak Member in this area.

In the T. F. Murchison ranch well the upper 15 feet of the Point Peak Member is dark greenish-gray, calcareous, micaceous shale and aphanitic limestone, probably stomatolitic. The lower 50 feet is mainly very calcareous, argillaceous siltstone grading to very silty, argillaceous limestone, dark to medium olive gray to greenish gray, and mostly micaceous; some aphanitic to microgranular limestone which may be stromatolitic is very light olive gray in part with a greenish cast, and slightly glauconitic. Coarsely granular limestone is scarce.

San *Saba Member.*—The San Saba Member in the T. F. Murchison ranch well, about 280 feet thick, is composed of an upper dolomitic facies 240 feet thick and a lower calcitic facies 40 feet thick. In the Backbone Mountain section the San Saba Member, 272 feet thick, is composed of a lower calcitic facies 48 feet thick and an upper dolomitic facies 224 feet thick. The limestone in the Backbone Mountain section is thinly bedded argillaceous units which alternate with units in part nodular and in part medium-bedded either as individual beds or groups of beds. It is mostly slightly glauconitic, yellowish gray to greenish gray, aphanitic to microgranular, and has a network of coarse-grained, brownish-gray dolomite. One bed is oolitic, and hexactinellid spicules are exposed on the surfaces of some beds. Within the Backbone Mountain area, lateral graduation from limestone to dolomite extends through about 70 feet stratigraphically, and in places the San Saba Member is dolomite to its base.

The lower 58 feet of the dolomitic facies is mostly very fine grained to microgranular and mottled various shades of brown, grayish brown, and dark greenish gray. The next 118 feet is mostly fine grained with a few medium-grained beds and in the upper part a 2-foot, coarse-grained bed grades laterally to fine-grained dolomite. This interval is mostly cherty with the chert granular, quartzose, slightly translucent, and dolomoldic; it generally forms lacy networks. At the top of the interval is some finely granular to quartzose, dark olive brown to black chert which weathers jasper red. Similar chert found in Shell Oil Company No. 1 Purcell in Williamson County influenced the placement of the San Saba—Threadgill boundary in the Purcell well (Barnes, 1959, pl. 2).

In the T. F. Murchison ranch well the calcitic part of the San Saba Member is mostly aphanitic limestone and probably stromatolitic, and some finely granular limestone and silty shale flakes exist in the lower 10 feet. The upper 170 feet of the dolomitic facies is mostly very fine-grained dolomite, mostly noncherty in the upper 30 and lower 35 feet, in the upper part light to very light gray, and downward very light olive gray, yellowish gray, very pale yellowish brown; some chips are grayish red and others are very light grayish orange pink, the latter pyritiferous. The lower 70 feet is microgranular and very fine-grained dolomite, mostly pyritiferous, very light to medium olive gray, light gray, greenish gray, and various other drab colors.

In the Sudduth area the San Saba Member is fine-grained dolomite, the lower part noncherty and the upper part cherty. The coarse-grained, noncherty Cambrian dolomite overlying the San Saba Member is continuous with and indistinguishable from the overlying coarse-grained, noncherty Ordovician dolomite assigned to the Threadgill Member of the Tanyard Formation as defined by Cloud and Barnes (1948, p. 35–36). The lower part of Cambrian age was definitely excluded from the Threadgill Member by Barnes (Cloud and Barnes, 1948, p. 350) and placed with the dolomitic facies of the San Saba Member (Barnes' Pedernales Dolomite Member of the Wilberns Formation).

With additional work by Barnes, along with adherence to a more consistent exclusion of time in mapping rock units, it became obvious that this body of coarse-grained dolomite is a mappable unit which should bear only one name. Because of its position in the stratigraphic sequence and its lithic character, the name that should be used (pl. 7, fig. 20) is Threadgill Member of the Tanyard Formation. The Threadgill Member is therefore redefined to contain Cambrian rocks in addition to Ordovician rocks in places in the eastern part of the Llano region.

However, coarse-grained dolomite is not exclusively present in the Threadgill Member. It is also present in the San Saba Member in places in the eastern part of the Llano region (*see* North Grape Creek [Rocky Creek, 1965b] quadrangle, Barnes, 1952g) and in these places is separated from the coarse-grained dolomite in the Threadgill Member by a zone of fine-grained dolomite at the top of the San Saba member, thus making the relationship clear. But even here it is unlikely that the fine-grained—coarse-grained boundary coincides exactly with the Cambrian—Ordovician boundary.

### Ellenburger Croup

All of the Threadgill Member, both dolomitic and calcitic facies, and part of the Staendebach Member of the Tanyard Formation are mapped in the Backbone Mountain area (pl. 7, fig. 19), and these rocks are described by Barnes (Cloud and Barnes, 1948, p. 304–305). Only part of the Threadgill Member is mapped in the Sudduth area, and it is coarse-grained dolomite of Cambrian age in the lower part and Ordovician age in the upper part, with the position of the Cambrian-Ordovician boundary unknown. As explained above, the Threadgill Member should be redefined to contain Cambrian rocks as well as Ordovician rocks in places in the eastern part of the Llano region.

In the T. F. Murchison ranch well the Threadgill Member, mostly coarse-grained dolomite, is about 390 feet thick and the Staendebach Member, mostly medium- to coarse-grained dolomite (310 feet) and fine-grained dolomite (120 feet) is about 433 feet thick, making a total of 823 feet of Tanyard Formation rocks. In this well 257 feet of Gorman Formation was drilled below 245 feet, of which the upper 10 feet belongs to the calcitic facies and the lower 247 feet to the dolomitic facies. If the Gorman is of normal thickness, then some Honeycut Formation rocks may be present in this well if the Cretaceous Hensell sand is a thin veneer.

### Quaternary Deposits

Quaternary rocks consist of colluvium in two large patches in the northwestern part of the Backbone Mountain area, and alluvium mapped along Colorado River in this area is now for the most part beneath water level in Granite Shoals Lake.

### T. F. Murchison Ranch Well, Burnet County

This well gives important thickness data for Moore Hollow Group and Tanyard Formation rocks in a part of

**Table 20. Thicknesses of geologic units in T. F. Murchison ranch well, Burnet County, Texas.**

| Stratigraphic unit | Murchison well Depth (feet) | Murchison well Thickness (feet) | Surface sections Thickness (feet) |
|---|---|---|---|
| Ellenburger Group | 245–1,325 | 1,080+ | 1,457+ |
| Gorman Formation | 245–502 | 257+ | 483 |
| Tanyard Formation | 502–1,325 | 823 | 572 |
| Staendebach Member | 502–935 | 433 | 481 |
| Threadgill Member | 935–1,325 | 390 | 91 |
| Moore Hollow Group | 1,325–2,470 | 1,145 | 846+ |
| Wilberns Formation | 1,325–1,812 | 487 | 610 |
| San Saba Member | 1,325–1,605 | 280 | 272 |
| Dolomitic facies | 1,325–1,565 | 240 | 224 |
| Calcitic facies | 1,565–1,605 | 40 | 48 |
| Point Peak Member | 1,605–1,670 | 65 | 190 |
| Morgan Creek Limestone Member | 1,670–1,800 | 130 | 136 |
| Welge Sandstone Member | 1,800–1,812 | 12 | 12 |
| Riley Formation | 1,812–2,470 | 658 | 236+ |
| Lion Mountain Sandstone Member | 1,812–1,865 | 53 | 36 |
| Cap Mountain Limestone Member | 1,865–2,165 | 300 | 200 |
| Hickory Sandstone Member | 2,165–2,470 | 305 | — |
| Precambrian Town Mountain Granite | 2,470–2,491 | 21+ | — |

the Llano region where sections previously measured were apt to be erroneous in thickness because of faulting and inadequate data on dip. In the Llano region the interval between the base of the Wilberns Formation and the base of the Gorman Formation is fairly constant in thickness. The thickness of 1,310 feet found for this interval in the T. F. Murchison ranch well compares favorably with a thickness of 1,268 feet found for it in the Tanyard section, whereas in the nearby Backbone Mountain and Hoover Point sections this interval is only 1,182 feet thick, including 100 feet for the probable displacement of a fault crossed in the Staendebach Member. It seems likely also that another 100 or so feet of section is missing somewhere in the Threadgill Member in the Backbone Mountain section.

In table 20, thicknesses of the stratigraphic units measured in the T. F. Murchison ranch well are compared with thicknesses of units measured in the Backbone Mountain and Hoover Point sections. Sample descriptions for this well are on open file at the Bureau of Economic Geology.

## CAP MOUNTAIN-RILEY MOUNTAINS AREA, LLANO COUNTY

### Introductory Statement

All except two of the measured and described sections of Moore Hollow Group rocks in the Llano region are marginal to the Llano basin. One of these exceptions is the Klett-Walker section in the Pedernales River basin and the other is a fault block within the Llano basin; namely, the Riley Mountain sections situated on the south limb of an eastward-tilted synclinal fault block forming the Riley Mountains. The Packsaddle Mountain section, measured but not described, and the type locality of the Cap Mountain Limestone are also within the eastern part of the Llano basin.

The type sections of the Riley Formation and the Moore Hollow Group and the standard section of the Ellenburger Group are shown in the "Geologic map of the Moore Hollow and Warren Springs area" (Cloud, in Cloud and Barnes, 1948, pl. 10). A portion of the Moore Hollow area map, including sections of the Moore Hollow Group and lowest Ellenburger Group rocks, is reproduced here as the East Canyon area (pl. 7, fig. 23). The East Canyon area comprises about 1.9 square miles mapped geologically by Cloud. The ownership within the area has been updated to 1960.

The Packsaddle Mountain area (pl. 7, fig. 21) is included principally for historic reasons. Packsaddle Mountain, a prominent topographic feature in the eastern part of the Llano basin, furnished some of the collections made by Walcott (1884) and is the site of the westernmost section of "Cap Mountain" zoned by Lochman (1938). Bridge, Barnes, and Cloud (1947) measured a section at the south end of the mountain; for the present publication little more was done except to measure the thickness of the Morgan Creek Limestone in the northern peak, try to duplicate Walcott's collections, and map the area in plate 7, figure 21, which comprises about 2.5 square miles.

The Cap Mountain area embraces the site mentioned by Paige (1911, p. 23) as a typical exposure of the Cap Mountain Limestone. The 90 feet of beds which he designated as Cap Mountain Limestone are well exposed and include at their top crossbedded, glauconitic sandstone which is now designated the Lion Mountain Sandstone Member of the Riley Formation. The remaining portion of Paige's Cap Mountain Limestone is the uppermost part of a heterogeneous unit now designated the Cap Mountain Member of the Riley Formation. South from Cap Mountain this member is at least as well and possibly better exposed than it is in the East Canyon and Packsaddle Mountain sections. A section in the vicinity of the indicated route (pl. 7, fig. 22) would have been measured and described if this area had been accessible during the earlier phases of this investigation. The Cap Mountain area comprises about 2.5 square miles.

The Packsaddle Mountain area is situated within the area of the 1:24,000 scale Cap Mountain and Click U.S. Geological Survey topographic quadrangle maps; the Cap Mountain area is within the Cap Mountain quadrangle; and the East Canyon area is within the Click quadrangle.

Rocks mapped in the East Canyon area include Precambrian Sandy and Rough Ridge Formations of the Packsaddle Schist, Red Mountain Gneiss, and metagabbro; all members of the Moore Hollow Group and Tanyard Formation; and Quaternary colluvium and soil on the upper part of the Hickory Sandstone Member.

Rocks mapped in the Packsaddle Mountain area are Precambrian Honey Formation of the Packsaddle Schist, including beds of marble and graphitic schist; all members of the Riley Formation; and the Welge Sandstone and Morgan Creek Limestone Members of the Wilberns Formation.

Rocks mapped in the Cap Mountain area include Precambrian Valley Spring Gneiss, Honey Formation of the Packsaddle Schist, Oatman Creek Granite; all members of the Moore Hollow Group; and Quaternary alluvium.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: Moore Hollow section—description of measured section and spot samples with thin-section descriptions, insoluble-residue descriptions; East Canyon section — description of measured section with fossil lists; Packsaddle Mountain section — fossil lists; Cap Mountain section — fossil lists.

The Moore Hollow Group rocks in the East Canyon area mostly dip northward between about 10 and 20 degrees and are bounded on the east by the Riley Mountain fault zone which has at least 1,500 feet of throw at the northern edge of the area. The Moore Hollow Group rocks in the Packsaddle Mountain area are generally fairly flat lying except in the vicinity of the fault zone where it passes through the "saddle" of Packsaddle Mountain. The faults are normal and trend north-south and northeast-southwest. The Cap Mountain area embraces the northern termination of the system of faults responsible for the presence of the Riley Mountains and, as in the Packsaddle area, the faults are normal and most trend north-south to northeast-southwest.

The East Canyon area, prior to the cedar eradication campaign, was thickly wooded, more so on north slopes than on south slopes, and the dominant tree was cedar. Of the Ellenburger Group rocks the dolomite of the Tanyard Formation is the least wooded, the stromatolitic reef of the Point Peak Member essentially forms a bare rock surface, and the Cap Mountain Limestone forms a scarp with a large proportion of thorny shrubs. The outcrop of the Lion Mountain Sandstone shows distinctly on aerial photographs as a narrow, sparsely vegetated bench, and all the rocks between the Hickory and the San Saba have distinct vegetational alignment along the beddings. The Hickory Sandstone with its growth of deciduous oak is distinct from the units above and fairly distinct from the Packsaddle Schist beneath with its larger proportion of mesquite and shrubs such as bee brush. The vegetation in the Packsaddle Mountain area is similar for all the units present except that the Lion Mountain Sandstone is more densely vegetated. In the Cap Mountain area all cedar has been removed, and in 1960 when the area was mapped the Cap Mountain outcrop was covered by a waist-deep mat of tasajillo and a few other types of cacti. Bee brush and some deciduous oak characterized the Hickory Sandstone and bee brush was also common on the Packsaddle Schist.

### Precambrian Rocks

Precambrian Packsaddle Schist crops out in the eastern and southern two-thirds of the East Canyon area and around much of the margin of the Packsaddle and Cap Mountain areas. The various rock types within the Packsaddle Schist have not been separately mapped except for a few beds of marble, graphitic schist, and amphibolite in the Packsaddle Mountain area. Burnt Hill in the East Canyon area, with its summit of Hickory Sandstone, appears to have received its name from a bare surface of feldspathic gneiss which is more resistant to erosion than is the Packsaddle Schist elsewhere within the map areas. Whether or not Burnt Hill is an exhumed Precambrian hill is uncertain because of the location of this feature in an area of steep dips adjacent to the Riley Mountain fault.

## Moore Hollow Croup

### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone, 330 feet thick in the East Canyon section, is composed of two units: (1) an upper friable, presumably argillaceous sandstone unit weathering to a flat area cultivated in the past, and (2) a lower, better cemented unit which forms a wooded scarp. It crops out in a northeast-southwest-trending belt in the southwestern part of the area (pl. 7, fig. 23).

The basal 10 feet is massive and conglomeratic with angular quartz pebbles and cobbles up to 8 inches in size in a coarse to very coarse sandstone matrix. The next 145 feet is sandstone, fine to very coarse grained with some granules, small pebbles, and some intraformational conglomerate, in part silty, crossbedded, massive, and mostly poorly exposed. The next 75 feet is sandstone, mostly medium grained, friable, and medium to thick bedded, and the grains are subrounded and fairly well sorted The top 100 feet of sandstone, calcareous in the upper part, is fine to coarse grained, brown, thick bedded, poorly exposed, and grains are subangular to rounded. Intraformational conglomerate is common.

The Hickory Sandstone in the Packsaddle Mountain area is 390 feet thick and similar in appearance to that in the East Canyon area except that the basal 20 or 30 feet or so is very massive, forming house-sized blocks where undermined by weathering away of Packsaddle Schist.

The Hickory Sandstone in the Cap Mountain area, as in the East Canyon area, is composed of an upper unit that disintegrates to form flats, formerly cultivated, and a lower unit generally forming steep, rocky, brush-covered slopes. The Hickory Sandstone in the Cap Mountain area appears to vary greatly in thickness. To the northeast where the Hickory rests on Valley Spring Gneiss, the width of the outcrop suggests that it is very thin, whereas to the south where it rests on Packsaddle Schist it appears to be much thicker. It is quartzitic at the base in one place in the southern area, suggesting that here it may be of about the same thickness as in Packsaddle Mountain where the basal portion is quartzitic. Shaly Hickory Sandstone is exposed in State Highway 71 cuts both west and south of the Cap Mountain area. *Cruziana* was seen near the base of the cut west of the area.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone Member, 411 feet thick in the East Canyon section, is composed of a lower medium-bedded, 260-foot unit of limestone and sandstone, a middle 70-foot silty unit, and an upper 81-foot limestone unit. It crops out in an east-northeast-trending belt in the west-central part of the area (pl. 7, fig. 23). The basal 78 feet of the lower unit is limestone, brownish yellow to yellowish brown, fine grained, glauconitic, and very sandy; followed by 137 feet of limestone and sandstone ranging from mostly brown, very calcareous sandstone in the lower part to mostly red and gray, very sandy limestone in the upper part; and an upper 45-foot limestone, yellowish brown, glauconitic, and slightly sandy and oolitic.

The middle and upper units are mostly medium to thick bedded, brownish yellow, and occur in a scarp exposure where weathering does not have a chance to bring out the marked difference between the two. The upper 48 feet contains some sand and the upper 16 feet is very sandy, glauconitic, and contains very coarse-grained trilobite coquinite.

In the Packsaddle Mountain section the Cap Mountain Limestone is 380 feet thick; much of it is well exposed in a bold bluff which is almost inaccessible for sampling and fossil collecting.

In the type locality in the Cap Mountain area the tripartite division of the Cap Mountain Limestone Member is well displayed on aerial photographs, with the middle silty zone much lighter colored than the upper zone, which in turn is lighter colored than the lower zone. The Cap Mountain in this area is closely similar to its appearance in the White Creek section which is here designated as the standard section for the member.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone Member, 33 feet thick in the East Canyon section, is not well exposed and crops out in a narrow east-west belt in the west-central part of the area (pl. 7, fig. 23). Exposures consist of coarse-grained sandstone, yellowish brown and green, very glauconitic, sand rounded; and limestone, mostly white, glauconitic lenses of trilobite coquinite. In the Packsaddle Mountain section the Lion Mountain Sandstone is about 38 feet thick and crops out at the foot of both peaks on Packsaddle Mountain. In the Cap Mountain area the Lion Mountain Sandstone is fairly well exposed in the basal part of Cap Mountain and in the saddle between Cap Mountain and the peak to the west. Other outcrops are very poorly exposed in the fault blocks forming the main part of the western peak.

### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone Member, 16 feet thick in the East Canyon section, crops out parallel to the Lion Mountain Sandstone and is medium to coarse grained, yellowish brown, slightly glauconitic, medium to thick bedded, grains rounded and well sorted, and trilobitic. In the Packsaddle Mountain section the Welge Sandstone is about 12 feet thick and crops out parallel to the Lion Mountain Sandstone in the basal part of both peaks on Packsaddle Mountain. In the Cap Mountain area the Welge Sandstone is well exposed just below the crest of Cap Mountain and on the eastern side of the slightly lower peak to the west. It is poorly exposed in the fault blocks forming the bulk of the western peak.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone, 113 feet thick in the East Canyon section, is conveniently separated into two parts by the *Eoorthis* Bed; the 39 feet of slightly to very glauconitic limestone beneath this bed is medium to thick bedded, greenish gray in the upper part and reddish gray in the lower 22 feet; the basal 25 feet is sandy, with sand increasing in amount downward. The 74 feet of medium-bedded limestone above *Eoorthis* is fine to medium grained, gray, slightly glauconitic, and stromatolitic bioherms are found 30 to 35 feet beneath the top. The Morgan Creek Limestone crops out in an east-west belt in the northwestern part of the East Canyon map area.

In the Packsaddle Mountain section 14 feet of Morgan Creek Limestone was measured to the top of the southern peak on Packsaddle Mountain. On the northern peak about 20 feet of the Morgan Creek is missing, as indicated by 55 feet of beds measured above *Eoorthis* to the top of the peak.

The eastern peak of Cap Mountain in the Cap Mountain area is topped by 35 to 40 feet of the lower part of the Morgan Creek Limestone. In the fault blocks forming most of the western peak, all of the Morgan Creek Limestone is exposed.

*Point Peak Member.*—In the East Canyon section the lower 101 feet of the Point Peak Member to the base of the stromatolitic bioherm was first measured by Cloud (Cloud and Barnes, 1948, p. 287) and later remeasured and described by Bell. The upper 115 feet above the base of the bioherm was measured and described in the Moore Hollow section (Cloud, *idem,* p. 285–286) making a total of 216 feet of Point Peak beds in this area, providing the base of the bioherm remains at the same stratigraphic level between the top of the East Canyon section and the base of the Moore Hollow section. The total thickness of the Point Peak and San Saba Members is only slightly less that that of the average total for these members in the Llano region; however, the Point Peak is thicker and San Saba thinner than in any other section, suggesting that if the stromatolitic reef were absent, the normal boundary between the members would fall within the zone now occupied by the stromatolitic reef. The Point Peak crops out in the northwestern part of the area (pl. 7, fig. 23).

Most of the lower 101 feet is covered and exposures consist of limestone and siltstone. The limestone, mostly intraformational conglomerate, is fine grained, gray, silty, glauconitic, thin bedded, platy. The siltstone weathers yellowish brown and is calcareous, glauconitic, thin bedded, and most occurs as float.

The upper 115 feet of the Point Peak Member is mainly aphanitic to fine-grained, massive stromatolitic reef, some covered, and a few granular limestone beds, most of which are located in the upper 14.5 feet. The stromatolites are clouded to mottled greenish to brownish to olive gray, with streaks of brownish yellow where dolomitic and duller dusty green where argillaceous films are present. Interreef granular limestone may form beds or pockets, and most of the septae between stromatolite heads are coarser grained than the heads and may in part be composed of fragmental stromatolitic material difficult to distinguish from that in normal growth position.

The Point Peak Member is very poorly exposed in the Cap Mountain area in the fault block forming the northwestern part of the broad peak west of Cap Mountain. Stromatolitic limestone is common as float.

San *Saba Member.*—The San Saba Member, 217 feet thick in the Moore Hollow section, is the thinnest section of these rocks measured in the Llano region. It is composed of a lower 144-foot-thick limestone interval and an upper 73-foot dolomite interval. Cloud (Cloud and Barnes, 1948, p. 283–285) described the limestone as aphanitic to medium grained with the granularity mostly in dolomitic portions, light brownish to greenish gray grading to very light to light gray with mottles and streaks of brownish yellow to yellow and pinkish brown where dolomitic, intermittently girvanella-bearing, and thin to thick bedded. Dolomite is somewhat more abundant in the upper 23 feet, glauconite is absent to very scarce throughout, and oolitic beds are very scarce.

Cloud found that the dolomite is mostly very fine grained to microgranular, yellowish to brownish gray, olive gray, and various shades of pink and purple; beds are indistinct and mostly medium to thick and interstitial glauconite is exceedingly scarce. Chert is fairly common as excrescences and as plates that are slightly translucent to chalky or subgranular, in part very finely dolomoldic, in part finely drusy, and mostly white to yellowish weathering rough and dirty white.

The San Saba Member crops out in the northwestern part of the area (pl. 7, fig. 23); the calcitic and dolomitic facies are in part laterally gradational and locally the dolomitic facies has collapsed where solution of the calcitic facies has taken place.

Cloud noted hexactinellid sponge spicules 10 to 15 feet above the base of the San Saba Member, *Billingsella* 79 to 81 feet above the base, *Finkelnburgia* sp., 148 feet above the base, "*Hyolithes*" sp. 150 feet above the base, and elsewhere saw little except fossil fragments, one calcitic trilobite, and one cherty free cheek of a large trilobite.

In the Cap Mountain area 50 feet or more of calcitic San Saba Member strata crop out in the northwesternmost fault block on the broad peak west of Cap Mountain. This aphanitic to microgranular limestone is slightly off white and mottled medium yellowish orange.

### Ellenburger Group

#### Tanyard Formation

The Threadgill Member, composed mostly of dolomite surrounding islands of limestone, crops out in the northwesternmost part of the East Canyon area. In the line of section light to very light gray, coarse- to medium-grained dolomite comprises the lower 78 and upper 96 feet of the Threadgill Member and in between is 76 feet of massive, yellowish-gray to very light-gray, aphanitic limestone. The lower part of the Staendebach Member crops out within the map area, and both members of the Tanyard Formation are described in Cloud's Moore Hollow section (Cloud and Barnes, 1948, p. 276–283).

### Quaternary Deposits

Quaternary deposits mapped by Cloud are regolith mostly confined to the outcrop of the upper friable part of the Hickory Sandstone, colluvium at the base of the Cap Mountain scarp, and a travertine deposit astride the Riley Mountain fault zone.

## WHITE CREEK AREA, BLANCO COUNTY

### Introductory Statement

The White Creek section is the southeasternmost section marginal to the Llano basin and most of it is well exposed, including the normally poorly exposed friable zone of the Hickory Sandstone. The Cap Mountain Limestone is thicker in this section than in any other surface section, and the Point Peak Member is intermediate in thickness between that found in the East Canyon and Klett-Walker areas.

The White Creek area comprises 3.7 square miles and is situated within the area of the 1:24,000 scale Blowout U. S. Geological Survey topographic quadrangle map. The location of the section is shown on the planimetric Blowout quadrangle of Barnes (1952a). The White Creek area (pl. 7, fig. 24) may be reached from Round Mountain by traveling Ranch Road 962 about 7.5 miles, turning west (left) along a graded road for about 5.5 miles, then south on a ranch road 0.5 mile to the north edge of the area.

Rocks mapped in the White Creek area include Precambrian Click Formation of the Packsaddle Schist, Valley Spring Gneiss, Red Mountain Gneiss, and Town Mountain Granite of the North Grape Creek granite mass; all members of the Moore Hollow Group; and Quaternary alluvium.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: White Creek section — description of measured section with fossil lists, heavy-mineral data, table 43, insoluble-residue data, table 44.

The Moore Hollow Group rocks generally dip northward 5 to 9 degrees and terminate against an irregular fault zone against which they are sharply upturned, with dips southward of about 20 degrees, producing a syncline with a steeply-dipping north limb and a gently-dipping south limb.

Cedar grows thickly on all the carbonate units except the Lion Mountain Sandstone, which is rather sparsely vegetated, and the Cap Mountain Limestone, which has a fair proportion of thorny shrubs. The Hickory Sandstone is characterized by deciduous oak, which sharply sets it off from the overlying Cap Mountain with its carbonate-loving shrubbery. The vegetation on the underlying Town Mountain Granite is similar to that on the Hickory but is very sparse, and the characteristic rilling of the decomposed granite shows very well on aerial photographs. The rest of the Precambrian, except the inclusion of Valley Spring Gneiss in the Town Mountain Granite, is low lying, develops a deep soil, and for the most part supports clumps of bee brush with narrow, open areas of grassland between.

### Precambrian Rocks

An inclusion of Valley Spring Gneiss in Town Mountain Granite is located along Zigzag Creek at the south boundary of the map (pl. 7, fig. 24). Packsaddle Schist and Red Mountain Gneiss, very poorly exposed, crop out in the northern part of the area only a short distance south of the type locality of the Red Mountain Gneiss (Romberg and Barnes, 1949, fig. 1; Barnes, Shock, and Cunningham, 1950, p. 7). The coarse-grained Town Mountain Granite cropping out in the southern part of the White Creek area is part of the large, irregularly shaped North Grape Creek granite mass, mostly covered by Paleozoic and Mesozoic sedimentary rocks. The shape of the granite mass is indicated by gravity data (Barnes, Romberg, and Anderson, 1952, 1954, 1956) and by outcrops in the Blowout (Barnes, 1952a), North Grape Creek (Barnes, 1952g; Rocky Creek, 1965b), Willow City (Barnes, 1952k), Crabapple Creek (Barnes, 1952b), Gold (Barnes, 1952c; Cave Creek School, 1967), Johnson City (Barnes, 1963, 1969) and Howell Mountain (Barnes in preparation d) quadrangles.

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone Member.*—The Hickory Sandstone Member, 276 feet thick in the White Creek section, forms a broad east-west outcrop band in the southern part of the area and narrow fault blocks in the northern part. It is divisible into an upper 61—foot, slightly glauconitic interval and a lower 215-foot, nonglauconitic interval, the latter divisible into 3 lithologically different zones. The lower one, 80 feet thick, is mostly sandstone, fine to very coarse grained; granules abundant; grayish orange to grayish orange pink to pale reddish brown to yellowish brown to light brown, grayish pink to pale red, and moderate reddish orange. Grains are rounded to spherical, in upper part rough from reconstitution, somewhat more angular in lower part; microcline common in lower 20 feet; mica in upper part; crossbedding common; and burrows, trails, and cuneiform markings common in upper part.

The next 70-foot zone is sandstone and siltstone. The sandstone is mostly medium to very coarse grained, some fine grained; yellowish gray to grayish yellow, some grayish orange pink and pale yellowish brown in upper part, and grayish red to pale red in lower part; silty and argillaceous. Grains are rounded and rough from reconstitution; cuneiform markings and burrows(?) are common. The siltstone is generally pale red, sandy, argillaceous, and micaceous.

The upper 40-foot zone is sandstone, medium to very coarse grained, grayish orange to dark yellowish brown, very dusky red to blackish red, and grayish red and massive; some intraformational conglomerate and a few ripple marks are present.

The 61-foot, slightly glauconitic interval at the top of the Hickory Sandstone consists of alternations of sandstone and siltstone. The sandstone is very fine to medium grained in upper part, coarser grained toward base, with some granules in lower 8 feet; colors are yellowish brown to moderate yellowish brown to dark yellowish brown in lower 8 feet; a 2-foot, grayish red, ripple-marked bed is at the top; ripple marks trend N. 20° E., 1 foot between crests; grains are mostly well rounded and rough from reconstitution. The siltstone is dark yellowish brown, argillaceous, in part micaceous, and sandy.

*Bolaspidella*-Zone fossils are in 3 collections between 247 and 270 feet.

*Cap Mountain Limestone Member.*—The Cap Mountain Limestone Member, 497 feet thick, crops out in a broad east-west band near the center of the White Creek area and in narrow fault blocks in the northern part. It is divisible into an upper limestone unit, a middle siltstone unit, and a lower limestone unit grading downward into calcareous sandstone and siltstone.

The lower 124 feet of the lower unit is mainly calcareous sandstone, sand very fine to fine and some medium to coarse, mostly yellowish to dark yellowish brown, in part mottled, glauconitic, in part crossbedded; some siltstone, light grayish orange; and in the upper part some limestone, fine to coarse grained, very light to light olive gray and pale to dark yellowish brown mottled moderate yellowish brown and dark yellowish orange, sandy, slightly glauconitic. An oolitic limestone bed is near the middle.

The upper 186 feet of the lower unit is mostly limestone, the lower 22 and upper 26 feet mostly coarse grained and some fine grained, and the middle part fine grained with oolitic and sandy beds common; the upper third is mostly yellowish gray to light olive gray mottled yellowish to dark yellowish orange and grayish orange; the rest, in part mottled, is of somber colors: pale brown to pale yellowish brown to dark yellowish brown, grayish brown, and grayish orange; glauconite is common throughout, some silt is present, and the sand is mostly fine to medium, with some very fine and coarse in the lower part.

The middle unit, 66 feet thick, is mostly siltstone, very calcareous, mottled, yellowish gray to light olive gray, greenish gray, grayish orange to grayish orange pink, light brown, moderate yellowish brown, and reddish orange. The siltstone in part grades to very fine grained and very silty limestone; a 2-foot, coarse-grained, oolitic limestone zone is near the middle.

The upper unit, 121 feet thick, is mostly fine- to medium-grained limestone, some coarse grained in upper third, very light to light olive gray to yellowish gray, some greenish gray in upper third, glauconitic, in part oolitic, slightly dolomitic, and sand and silt are scarce.

*Bolaspidella*-Zone fossils are in 1 collection at 341 feet; *Cedarina-Cedaria*-Zone fossils in 2 collections at 365 and 460 feet; *Coosella*-Zone fossils in 9 collections between 365 and 695 feet; *Maryvillia*-Zone fossils in 3 collections between 704 and 725 feet; and *Aphelaspis*-Zone fossils in 6 collections between 744 and 771 feet.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone Member, 41 feet thick, crops out in a narrow east-west band just north of center of the area (pl. 7, fig. 24) and is composed of greensand, sandstone, and limestone. The dusky-green to grayish-green greensand is more than half quartz and the rest is mainly glauconite. The sandstone in the upper 10 feet is medium to very coarse with a few granules up to 1/4 inch in the lower part; in the lower 31 feet it is mostly fine to very coarse grained, light gray to very light olive gray where slightly glauconitic to grayish green where approaching greensand in composition, quartz grains well rounded and rough from reconstitution. The limestone, confined to the lower 31 feet and most abundant in the lower 15 feet, is generally coarse grained, light olive gray and greenish gray, glauconitic, sandy; in part it is crossbeds of trilobite coquinite.

*Aphelaspis*-Zone fossils are in 1 collection at 775 feet, and post-*Aphelaspis*-Zone fossils are in 5 collections between 779 and 808 feet.

### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone, 11 feet thick, parallels the outcrop of the Lion Mountain Sandstone and is mostly medium to coarse grained, grayish orange to moderate yellowish brown near the middle and elsewhere greenish gray and glauconitic. It is calcareous throughout, massive, grains well rounded to spherical, mostly rough from reconstitution, and some show crescentic impact marks.

Trilobites and linguloid brachiopods are common.

*Morgan Creek Limestone Member.*—The glauconitic Morgan Creek Limestone Member, 143 feet thick, forms a fairly broad east-west outcrop band just north of center of the area shown in plate 7, figure 24, and can be conveniently divided into 2 parts at the level of the *Eoorthis* Bed. The 64 feet of limestone beneath the *Eoorthis* Bed is mostly thicker bedded and coarser grained than that above. The lower 25 feet is very coarse grained, very sandy at the base to slightly sandy at the top, in the lower 10 feet moderate red to moderate brown speckled dark yellowish orange, and in the upper 15 feet pale to dark yellowish brown speckled and mottled grayish red and light brown. The upper 39 feet is mostly coarse grained, some medium and fine grained, light to very light olive gray, yellowish gray, and pale yellowish brown speckled dark yellowish orange and moderate yellowish brown; the finer grained portions are silty and slightly micaceous.

The 79 feet of limestone above *Eoorthis* is mostly coarse grained with some medium- and fine-grained beds, yellowish gray, very light gray, very light olive gray, and light greenish gray, mottled and speckled by dark yellowish-orange and grayish-red dolomite, and dolomite patches are common; the lower half contains beds of very silty, fine-grained limestone ranging to micaceous, very calcareous siltstone; some stromatolite zones exist in the upper 20 feet.

*Point Peak Member.*—The Point Peak Member, 111 feet thick, crops out on both flanks of a syncline in the northern part of the area shown in plate 7, figure 24, and is composed of an upper 38-foot interval of aphanitic to microgranular stromatolitic reef and a lower 73-foot interval of mainly siltstone and some limestone. The reef, if viewed only in the line of section, could just as well be placed with the San Saba Member, but laterally the outcrop pattern suggests the presence of interbeds of siltstone and therefore this interval should be placed with the Point Peak.

In the lower 73 feet of the Point Peak Member a few stromatolite zones are mostly in the upper part, intraformational conglomerate beds are fairly well distributed throughout, and some fine- to coarse-grained limestone beds are located mostly in the upper 14 and lower 7 feet with an 8-inch oolite bed 3 feet above the base. The limestone is yellowish gray to light olive gray, in upper part mottled yellowish orange to light brown, and in lower part speckled grayish red and dark yellowish orange. The siltstone is very light olive gray to greenish gray, very calcareous, glauconitic, thinly bedded, and in part micaceous.

San *Saba Member.*—About one-third of the San Saba Member, all dolomite, occupies the middle of an east-west syncline in the northern part of the area (pl. 7, fig. 24). Only the lower 56 feet, to the level of the alate *Billingsella* Bed, is sufficiently well exposed to measure and describe. The lower boundary is arbitrarily placed at the point of change from dolomite to stromatolitic limestone. Within 100 feet of the line of section, this point of change varies stratigraphically as much as 10 feet.

The dolomite in the lower 19 feet and most of the upper 27 feet is medium grained, somewhat argillaceous, and in part slightly calcitic; in the upper part it is yellowish gray to light brownish gray in part with a pinkish cast and mottled and speckled by grayish red, and in the lower part it is yellowish gray with a greenish cast and greenish gray and mottled. The rest of the dolomite is fine to very fine grained and weathers blocky, whereas the medium-grained dolomite weathers to rounded boulderlike forms and very likely replaces stromatolitic limestone.

### Quaternary Deposits

Quaternary alluvium is mapped along White Creek near the northern border of the map area.

## PEDERNALES RIVER-SANDY POST OFFICE AREA, BLANCO COUNTY

### Introductory Statement

Barnes (Cloud and Barnes, 1948, p. 341–343, pls. 3, 12) measured a section of Wilberns rocks in the Scott Klett Ranch section and upstream Pedernales River section in the Klett-Walker and Johnson City areas. The Wilberns measured was much thinner than elsewhere in the Llano region; as the part missing appeared to be the top portion of the San Saba Member, it was surmised that the thinness was attributable to erosion or nondeposition at the Cambrian-Ordovician boundary.

During 1955, the Stratoray Oil Corporation No. 1 Stribling well was completed just west of U. S. Highway 281, 4.5 airline miles north-northeast of Johnson City and about 3 miles northeast of the upstream Pedernales River section. About 310 feet of San Saba Member strata was measured in this well, and the outcrop pattern around it suggests that at least another 140 feet of San Saba strata is present in the area.

This total amount is more than twice the 195 feet of San Saba Member measured in the upstream Pedernales River section. It is obvious that a fault cuts out about 250 feet of the uppermost San Saba beds in the upstream Pedernales River section. The thickness of the San Saba Member, as indicated by Stratoray Oil Corporation No. 1 Stribling, is substantiated by the thickness of 615 feet for the San Saba found still farther southeast in the Roland K. Blumberg No. 1 Wagner well in plate 3 (Barnes, 1959, pls. 1, 3).

The area in the vicinity of the Scott Klett Ranch section was mapped in detail and a better line of section than the original one was located (pl. 7, fig. 25). The new section, designated the Klett-Walker section, extends from 98 feet below the top of the Cap Mountain Limestone Member at a point along Pedernales River flanking an exhumed granite dome to a point 121 feet above the base of the San Saba Member. The rest of the San Saba Member crops out on a flat but cannot be accurately measured.

Beneath the upstream Pedernales River section the rest of the Moore Hollow Group crops out over a distance of about 9 miles upstream, in part along Pedernales River and in part along Hickory Creek. Measurement of a section along this route was not attempted because of gentle dips, a fault, and poor exposures in places. However, to obtain some outcrop data for rocks below those exposed in the Klett-Walker section, J. C. Wise, one of Bell's students, was assigned the Sandy P. O. area to map in an attempt to find a measurable section. Wise (1964) measured and described a portion of the sequence and collected fossils from it in sections designated "Gipson Ranch Section," "Hickory Creek Section," "Sandy Post Office Section," and "Rosa Ranch Section." The approximate location of the sections described by Wise are shown on the "Geologic map of the Johnson City quadrangle, Blanco County, Texas" (Barnes, 1969); except that the "Rosa Ranch Section" is mislabeled "Sandy Post Office Section." The "Sandy Post Office Section" is a short distance to the northwest just across the Hog Thief Bend fault.

A complete surface section would have been very helpful in this part of the Llano region, but since none was found it is fortunate that Stratoray Oil Corporation No. 1 Stribling gives thickness data for all units beneath the San Saba Member. Unfortunately, the complete thickness of the San Saba Member is not penetrated in the Stribling well, and in surface sections the San Saba is either faulted or not accurately measurable. However, interpolating from figure 7, the Wilberns Formation should be about 650 feet thick in the vicinity of the Stribling well. Only 485 feet of Wilberns Formation rocks was penetrated; therefore, it is judged that the well entered the San Saba about 165 feet beneath its top.

The Klett-Walker area (pl. 7, fig. 25) mapped geologically by Lincoln Warren and Barnes in 1943, comprises 2.5 square miles. Rocks mapped in the area include Precambrian Town Mountain Granite, all members of the Moore Hollow Group except the Hickory Sandstone, the basal portion of the Threadgill Member of the Tanyard Formation, Cretaceous Hensell Sand and Glen Rose Limestone, and Quaternary alluvium. This map, originally published in a report on lead deposits in the Upper Cambrian of Central Texas (Barnes, 1956c), covers an area astride the boundary of the North Grape

Creek quadrangle (Barnes, 1952g; Rocky Creek quadrangle, 1965b) and the Johnson City quadrangle (Barnes, 1963, 1969).

The Paleozoic rocks in the Klett-Walker area mostly dip south-southeastward except in the northern part where they dip quaquaversally about the granite dome. One northeast-southwest fault downthrown to the west crosses the northwestern part of the area, and a minor fault downthrown to the south is along the south side of the granite dome. The Cretaceous rocks appear horizontal to the eye, but elevation observations on the *Corbula* Bed throughout Blanco County show that these beds dip gently eastward.

The carbonate units in this area were originally thickly overgrown by cedar, much of which has disappeared during a cedar-eradicating campaign. The Glen Rose Limestone, in addition, supports much Spanish oak and the Hensell sand is in part cultivated. The Lion Mountain Sandstone and the Oatman Creek Granite have relatively sparse vegetation.

## Precambrian Rocks

The granite cropping out in the Klett-Walker area is fairly silicic and resistant to weathering and because of these properties, even though the grain size is abnormally large, originally was thought to be a late differentiate of the Town Mountain Granite (Barnes, Dawson, and Parkinson, 1947, p. 52). Also influencing this decision was the presence of a series of Oatman Creek Granite hills north of Hye trending toward this area (Barnes, North Grape Creek quadrangle, 1952g; Rocky Creek quadrangle, Barnes, 1965b). Such differentiated masses are either marginal to or away from but not within Town Mountain Granite masses.

It was found by Barnes, Romberg, and Anderson (1956) that this outcrop is near the lowest point in the gravity trough caused by the North Grape Creek granite mass and that very likely it is an exfoliation dome of Town Mountain Granite within this mass. Such an assignment is more nearly compatible with the grain size; also, several outcrops of Town Mountain Granite, especially those forming exfoliation domes, are as silicic.

It is judged that this granite dome stood about 750 feet above its surroundings at the time of the incursion of the Cambrian sea. This figure is based on the thickness of the Riley Formation indicated for this area in figure 3, and from an estimate that the dome reached the level of the top of the Cap Mountain Limestone.

The Stratoray Oil Corporation No. 1 Stribling bottomed in fresh Town Mountain Granite just east of the postulated boundary of the North Grape Creek granite mass estimated from gravity data (Barnes, Romberg, and Anderson, 1956). In view of finding Town Mountain Granite in this well and the presence of a gravity trough extending through this area, it is believed that the North Grape Creek granite mass should have been shown following the gravity trough several miles farther east.

## Moore Hollow Group

### Riley Formation

*Hickory Sandstone* Member.—The nearest Hickory Sandstone crops out about 2.5 miles northwest of the Klett-Walker area (Barnes, North Grape Creek quadrangle, 1952g; Rocky Creek quadrangle, Barnes, 1965b). The only thickness data for the Hickory in this part of the Llano region is from Stratoray Oil Corporation No. 1 Stribling, in which it is about 240 feet thick. Wise (1964) measured the upper 65 feet of the Hickory in the Rosa Ranch section.

In Stratoray Oil Corporation No. 1 Stribling, the upper 60 feet of the Hickory Sandstone is greenish-gray to grayish-red, silty, argillaceous shale, fine- to very fine-grained sandstone, and medium- to coarse-grained sandstone. The lower 180 feet of the Hickory Sandstone is mostly fine- to very coarse-grained sandstone, coarser toward the base, and in the lower 50 feet crushed quartz indicates the presence of pebbles. Microcline fragments in the lower 40 feet indicate granite at no great distance laterally, and the freshness of the granite penetrated suggests that the well bottomed on the side of a low granite dome.

*Cap Mountain Limestone Member.*—In Stratoray Oil Corporation No. 1 Stribling, the Cap Mountain Limestone Member is 510 feet thick. The upper 120 feet of limestone is granular, mostly oolitic, very light olive gray, and some light brownish gray in lower part; some of the limestone in the lower part is finely granular, silty, argillaceous, and slightly micaceous.

The next 100 feet corresponds to the silty zone of the Cap Mountain Limestone and is mainly limestone, in part finely granular, silty, argillaceous, glauconitic, slightly micaceous grading to siltstone; in part it is coarsely granular.

The lower 290 feet of the Cap Mountain Limestone is further subdivisible into 3 limestone zones, the upper one, 30 feet thick, granular, oolitic, light olive gray, glauconitic, and slightly silty; the middle one, 160 feet thick, finely granular, pale to dark yellowish brown, silty, and slightly glauconitic; and the lower one, 100 feet thick, finely granular, dark yellowish brown, glauconitic, very sandy and silty in the upper 40 and lower 10 feet, granular, mostly greenish gray to olive gray, silty, and very glauconitic in the middle 50 feet. In the lower 20 feet some noncalcareous shale is greenish gray to grayish red, silty, and micaceous.

In the Klett-Walker section only the top 98 feet of the Cap Mountain Limestone is present above a point on the flank of the granite dome in the northern part of the Klett-Walker area. The dome is surrounded by quaquaversally-dipping Cap Mountain Limestone.

In the Klett-Walker section the lower 53 feet of strata is dolomite, mostly fine grained, some very fine grained, mostly greenish gray to light olive gray and yellowish gray, mottled, mostly slightly silty and glauconitic, and in part oolitic. The next 17-foot interval is alternating beds of fine- to medium-grained dolomite and granular limestone; the dolomite pale orange to pale yellowish brown and the limestone moderate yellowish brown, slightly glauconitic, and in part oolitic.

The top 28 feet is mainly limestone, fine grained in the lower part to coarse grained in the upper part, yellowish gray to light olive gray to greenish gray, glauconitic, dolomitic, and in part trilobitic; dolomite forms a moderate yellowish-brown, raised network in lower 4 feet. A 3-foot siltstone zone 4 feet above the base is dark yellowish brown, dolomitic, and glauconitic.

*Lion Mountain Sandstone Member.*—The Lion Mountain Sandstone Member in Stratoray Oil Corporation No. 1 Stribling is about 35 feet thick and in the Klett-Walker section 31 feet thick.

In the Klett-Walker area the Lion Mountain Sandstone forms a circular outcrop surrounding the Cap Mountain Limestone except to the northwest where faulted out. In the Klett-Walker section the Lion Mountain Sandstone is mostly greensand, limestone, sandstone, and shale. The greensand, constituting the upper third and interbedded in rest of member, is about equally quartz and glauconite, silty, argillaceous, grayish olive green to dark grayish green where fresh but mostly weathered moderate yellowish brown; the quartz sand is fine to very coarse, well rounded to subrounded, and in part reconstituted, and impact marks are common on larger grains. The limestone, mostly confined to the lower two-thirds of the member, is sandy, in part crossbeds of trilobite coquinite, glauconitic, yellowish gray to greenish gray to brownish gray; and in part beds, moderate yellowish brown to dark yellowish brown, and light olive gray to greenish gray and dark greenish gray depending on the amount of glauconite; some beds are crossbedded.

A bottom, 2—foot bed is sandstone, very fine grained, light olive gray weathering dark yellowish brown, and glauconitic. The top 2 feet is shale, moderate olive brown weathering pale brown to moderate brown, glauconitic, and silty.

### Wilberns Formation

*Welge Sandstone Member.*—The Welge Sandstone is 10 feet thick in both the Stribling well and the Klett-Walker section where it parallels the outcrop of the Lion Mountain Sandstone. In the Klett-Walker section it is very fine to very coarse grained, finer grained upward, pebbles up to 1/2 inch in basal 6 inches, crossbedded, dark yellowish brown to pale yellowish brown, calcitic, in part glauconitic and shaly, grains angular to well rounded, in part reconstituted, and impact marks common. In the line of section no fossils were seen; however, trilobites exist in the Welge Sandstone just north of Pedernales River about 4 miles to the northeast.

*Morgan Creek Limestone Member.*—The Morgan Creek Limestone is 135 feet thick in Stratoray Oil Corporation No. 1 Stribling and 126 feet thick in the Klett-Walker section. In the Klett-Walker area it parallels the outcrop of the Welge Sandstone and also crops out northwest of the main fault. The lower 18 feet of the Morgan Creek Limestone is coarse grained, pale yellowish brown to grayish orange pink with some pale red and light olive gray, and is very abundantly sandy in the lower few feet to sparsely sandy at the top. In the next 40 feet fine-grained and coarse-grained limestone alternates with coarse-grained more abundant in the lower part. The coarse-grained is light olive gray to greenish gray and medium gray speckled by dark yellowish orange dolomite, and in part is oolitic; the fine-grained limestone is mostly light olive gray to greenish gray, silty, glauconitic, and burrowed. The top 68 feet is alternating fine-grained and coarse-grained zones, light olive gray to greenish gray, light brownish gray, yellowish gray, speckled by pale yellowish-orange dolomite, glauconitic. In the upper part 3 zones of stromatolites and some oolitic beds are present.

*Point Peak Member.*—The Point Peak Member is 25 feet thick in the Klett-Walker section and about 30 feet thick in the Stribling well. Near the middle of the Klett-Walker area it crops out in a narrow belt parallel to the Morgan Creek Limestone and in the northwestern part of the area it crops out in a broader belt and appears to be thickening. In the Klett-Walker section the Point Peak Member is mostly very thinly bedded siltstone and

**Table 21. Thicknesses of geologic units in Stratoray Oil Corporation No. 1 Stribling well, Blanco County, Texas.**

| Stratigraphic unit | Thickness (feet) | Depth (feet) |
|---|---|---|
| Cretaceous–Hensell Sand | 70 | 0–70 |
| Moore Hollow Group | 1,270 | 70–1,340 |
| Wilberns Formation | 485 | 70–555 |
| San Saba Member | 310 | 70–380 |
| Point Peak Member | 30 | 380–410 |
| Morgan Creek Limestone Member | 135 | 410–545 |
| Welge Sandstone Member | 10 | 545–555 |
| Riley Formation | 785 | 555–1,340 |
| Lion Mountain Sandstone Member | 35 | 555–590 |
| Cap Mountain Limestone Member | 510 | 590–1,100 |
| Hickory Sandstone Member | 240 | 1,100–1,340 |
| Precambrian–Town Mountain Granite | 15 | 1,340–1,355 |

some limestone and dolomite. The siltstone is greenish gray, very calcareous, glauconitic, and micaceous, and it grades to very silty limestone. Limestone intraformational conglomerate is common, and two zones of stromatolites in interreef granular limestone are microgranular and greenish gray to light olive gray. The top 2 feet of the Point Peak is dolomite, fine grained, very thinly bedded, silty, and contains a 4-inch, cherty, oolite bed.

San *Saba Member.*—The full thickness of the San Saba Member has not been measured in this part of the Llano region but is thought to be about 450 feet. In Stratoray Oil Corporation No. 1 Stribling, 310 feet of dolomite belonging to the San Saba Member was drilled, and in the Klett-Walker section 121 feet of dolomite was described. The portions of the San Saba Member described in the upstream Pedernales River section (Cloud and Barnes, 1948, p. 341–342) match very closely an equivalent amount of the lower part of the San Saba Member described in Stratoray Oil Corporation No. 1 Stribling. This suggests that the fault responsible for the loss of section crosses the section at the point used as the San Saba—Threadgill boundary. The San Saba Member in the Johnson City area is all dolomite and in the Klett-Walker area mostly dolomite.

So far as could be determined, a complete sequence of San Saba strata crops out in the southern part of the Klett-Walker area and is fairly well exposed in a flat area where accurate measurement could not be made. The various grain sizes and rock types were mapped east of Pedernales River. A fine-grained zone at the base of the San Saba Member, 87 feet thick in the line of section, persists laterally to where it passes beneath the Cretaceous. It corresponds closely to 86 feet measured in the upstream Pedernales River section and 100 feet in Stratoray Oil Corporation No. 1 Stribling. A similar, somewhat thinner zone occurs at the top of the member in the Klett-Walker area. Between these rather persistent zones is a belt nearly 1 mile wide of mostly coarse-grained dolomite, but near the middle, islands of fine-grained dolomite and aphanitic limestone are somewhat obscured by overlapping Cretaceous rocks. Both the limestone and the fine-grained dolomite grade laterally to coarse-grained dolomite.

In the Klett-Walker section the lower 87 feet of the San Saba Member is fine-grained dolomite, mostly yellowish gray, in the upper third ranging to light olive gray speckled by grayish orange and slightly glauconitic; near the middle, 12 feet of beds are abundantly oolitic and the top 9 feet contains some hexactinellid spicules. The top 34 feet is dolomite, coarse grained, and yellowish gray.

In the Stribling well the San Saba Member is all dolomite; the lower 100 feet is mostly very fine grained and some fine grained, very light to medium gray and very light yellowish gray, mostly pyritiferous, slightly glauconitic in the lower 20 feet, and with abundant interstitial chert in the top 20 feet. The next 100 feet is coarse grained, white to pinkish gray. The remaining 110 feet is mostly fine and very fine grained with 20 feet of coarse grained starting 20 feet above the base of the interval, is various shades of yellowish gray, yellowish brown, and pinkish gray in lower part, and is cherty, chert mostly opaque, white, dolomitic to interstitial and granular quartzose ranging to quartz druse.

## Ellenburger Group

The Ellenburger Group rocks in the Johnson City area are described by Barnes (Cloud and Barnes, 1948, p. 320–341). The Threadgill Member of the Tanyard Formation is composed of coarse-grained dolomite with islands of aphanitic limestone and is exceedingly difficult to distinguish from similar rocks in the San Saba Member except in undisturbed sequences. In the upstream Pedernales River section the boundary between the two was placed at the top of a 5-foot, microgranular dolomite zone, but it seems likely now that this contact may be a fault contact.

In the Klett-Walker area fine-grained dolomite of the San Saba Member is in contact with coarse-grained dolomite of the Threadgill Member, and a short distance to the south of the area (pl. 7, fig. 25) some aphanitic limestone of the Threadgill Member is exposed just short of the Cretaceous overlap (Barnes, North Grape Creek quadrangle, 1952g; Rocky Creek quadrangle, Barnes, 1965b).

### Cretaceous Rocks

The Paleozoic rocks in this part of the Johnson City quadrangle (Barnes, 1963, 1969) are overlapped by Cretaceous Hensell Sand and Glen Rose Limestone (Cloud and Barnes, 1948, pl. 3). In the Klett-Walker area (pl. 7, fig. 25) Hensell Sand rests mainly on the older rocks; however, just beyond the border of the area Glen Rose Limestone rests directly on Threadgill Member rocks.

### Quaternary Deposits

Much of the alluvium shown in plate 7, figure 25, along with a stand of pecan trees, was removed by the flood of 1952. During a 24-hour period, 26 inches of rain was recorded at Hye just upstream from this area.

### Stratoray Oil Corporation No. 1 Stribling, Blanco County

The Stratoray Oil Corporation No. 1 Stribling, 4.5 airline miles north-northeast of Johnson City and just west of U.S. Highway 281, gives important thickness data for all Moore Hollow Group rocks in the Johnson City area except for the total thickness of the San Saba Member (Barnes, 1963, 1969).

Sample descriptions for this well are on open file at the Bureau of Economic Geology.

Thicknesses of units in this well and insoluble-residue data are given in tables 21 and 22 respectively.

Data in Parts II and III on open file at the Bureau of Economic Geology are as follows: upstream Pedernales River section—description of measured section; Klett-Walker section—description of measured section with thin-section descriptions and fossil lists, insoluble-residue data, table 45; Sandy P. O. sections—description of measured sections with fossil lists.

**Table 22. Insoluble-residue data for a portion of the Stratoray Oil Corporation No. 1 Stribling well, Blanco County, Texas (Wise, 1964).**

| Interval (feet) | Percent insoluble |
|---|---|
| 70–80 | 14.2 |
| 80–90 | 28.7 |
| 90–100 | 32.3 |
| 100–110 | 35.3 |
| 110–120 | 32.2 |
| 120–130 | 30.5 |
| 130–140 | 21.5 |
| 140–150 | 27.7 |
| 150–160 | 27.6 |
| 160–170 | 26.0 |
| 170–180 | 20.6 |
| 180–190 | 34.4 |
| 190–200 | 13.9 |
| 200–210 | 26.0 |
| 210–220 | 16.9 |
| 220–230 | 15.9 |
| 230–240 | 12.0 |
| 240–250 | 6.3 |
| 250–260 | 9.1 |
| 260–270 | 11.5 |
| 270–280 | 15.3 |
| 280–290 | 17.6 |
| 290–300 | 18.8 |
| 300–310 | 10.5 |
| 310–320 | 5.3 |
| 320–330 | 4.8 |
| 330–340 | 4.8 |
| 340–350 | 4.6 |
| 350–360 | 4.4 |
| 360–370 | 9.5 |
| 370–380 | 13.6 |
| 380–390 | 38.0 |

# SUBSURFACE DATA

## Data on Moore Hollow Group Wells

The present subsurface study coincides with part of the area previously covered in the publication on pre-Simpson Paleozoic rocks by Barnes (1959). The prime reason for that publication was to show how Ellenburger Group rocks could be subdivided in the subsurface, and wells which did not contribute chiefly to the understanding of the Ellenburger Group were excluded from the pre-Simpson study.

Prior to the examination of well samples for this report, David L. Amsbury compiled a list of Cambrian wells other than those used for the pre-Simpson publication, and made a generalized description of the samples. From the wells examined only those which penetrated at least the full thickness of one member were chosen for detailed study.

In table 23 data for wells, including location, elevation, depth, and depth to the top of the Moore Hollow Group, is given for wells involved in this study. Isopach maps (figs. 2–11) and correlation sections (pls. 2–5) were prepared from thickness data given in table 24.

Sample descriptions for these wells are given in Part III of this report, which is on open file at the Bureau of Economic Geology.

**Table 23. Data on Moore Hollow Group wells in Texas arranged by companies.**

| Company | Lease | County | Location: Survey | Location: Blk. | Location: Sec. | Location: Dist. from lines | Elev. (feet) | Total Depth | Top of Moore Hollow |
|---|---|---|---|---|---|---|---|---|---|
| *Amerada Petroleum Corporation | No. 2 Hickman | Reagan | H.E.&W.T. Ry. Co. | | 4 | 2,016 FNL & 685 FEL | 2,767 | 10,077 | 9,965 |
| *American Republics Corporation | No. 1 Bradford | Menard | J. W. Massey | | 29 | 467 FS & WL | 2,054DF 2,043GL | 2,745 | 1,230 |
| *The Atlantic Refining Company | No. 1 Noelke | Irion | Tom Green County School Land No. 1 | | | 4,471 N of NW corner of sec. 1,147, H&O.B. survey, thence 3,329 E | 2,326DF (est.) | 7,960 | 7,500 |
| *The Atlantic Refining Company | No. 1 Roberts | Schleicher | H.E.&W.T. Ry. Co. | A | 175 | 1,980 FN & EL | 2,405DF 2,395GL | 7,751 | 7,090 |
| *W. F. Bilsky | No. 1 D. F. Mitchum | Eastland | S.P. R.R. | | 476 | | 1,587DF | 5,426 | 4,770 |
| **Roland K. Blumberg | No. 1 Wagner | Blanco | Henry Manton League No. 17 | | | 1,980 FWL of lge & 1,320 FSEL of 265.52-acre lease | 1,250 (est.) | 3,318 | 1,825 |
| Brady | No. 3 city water well | McCulloch | | | | 4 blks ESE of Courthouse | 1,675 (est.) | 2,075 | 940 |
| *Tommy Brook | Water well | McCulloch | | | | 2.4 miles ENE of Camp San Saba | | | 560 |
| *Carpenter Exploration Company | No. 1 Bradshaw | Mason | Indianola RR. | | 46 | 330 FS&EL of lease | 1,614 (est.) | 1,095 | 290 |
| **Carpenter Exploration Co. | No. 1-A McCollum | McCulloch | E. Greene (Gruene) | | 957 | 150 FS & EL | | 2,559 | 1,860 |
| **Continental Oil Company | No. 1 Wiley | Erath | W. B. Whittaker | | | | 1,416DF | 6,069 | 5,510 |
| *Deep Rock Oil Corporation | No.1 Bevans | Menard | G.H.&S.A. RR. Co. | A | 31 | 660 FN & WL | 2,218DF 2,212GL | 5,148 | 3,810 |
| **Fish Production Company | No. 1 Postell | Kinney | S. Bank | | 602 | 3,600 FNL, 4,620 FEL. | 1,571DF | 5,374 | 4,440 |
| **Forest Oil Corporation | No. 1 Stapp | Kimble | G.H.&S.A. RR. Co. | N | 682 | 660 FNL & 1,866 FWL | 1,975 | 4,090 | 2,550 |
| **Fredericksburg | City water well No. 9 | Gillespie | | | | S of city | | 1,250 | 160 |
| **N. D. Gallagher and O. G. Lawson | No. 1 Mrs. Bobbie I. Terry | Comanche | N. H. Kuykendall | | | | 1,334DF | 5,259 | 4,535 |
| **Garland-Anthony | No. 1 Hammons | Parker | J. Johnson | | | | 877DF | 7,798 | 6,890 |
| **General Crude Oil Company | No. 1 Anderson | Bandera | G.H. & S.A. RR. Co. | | 21 | 3,245 FNWL & 300 FNEL | 1,843DF 1,833GL | 10,626 | 9,120 |

* See: correlation charts, plates 1-6, Barnes (1959).

** See: correlation charts, plates 2-5, this publication.

(Table 23 continued.)

| Company | Lease | County | Location: Survey | Blk. | Sec. | Dist. from lines | Elev. (feet) | Total Depth | Top of Moore Hollow |
|---|---|---|---|---|---|---|---|---|---|
| **Gilcrease Oil Company | No. 1 Feril | Comanche | Vina Campbell | | 19 | 330 FE & SL | 1,562 | 4,278 | 3,620 |
| **Gregg et al. (Danewood Oil Co. et al.) | No. 1 M. L. Smith | Brown | J.F. (J.W.) Crawford | | 1 | 1,660 FNEL, 1,170 FSEL | 1,487 | 3,427 | 2,700 |
| **Harvey | No. 1 Giesecke | Runnels | Heirs of James Hughes | 132 | 227 | 660 FSL, 330 FWL | 1,678 1,680DF | 4,238 | 3,740 |
| *Honolulu Oil Corporation | No. 2 Whitaker | Nolan | T. & P. RR. Co. | 20 | 35 | 2,173 FSL & 467 FEL | 2,040DF | 5,705 | 5,520 |
| **Humble Oil & Refining Co. | No. 1 Autry | Comanche | Chas Sargent | | 73 | 710 FEL, 3,537 FNL | 1,115GL | 6,299 | 5,315 |
| *Humble Oil & Refining Company | No. 1 Bolt | Kimble | Mary Toliver | | 134 | 1,400 FS & EL | 2,025DF | 4,171 | 2,510 |
| *Humble Oil & Refining Company | No. 1 Farris | Lubbock | E.L. & R.R. RR. Co. | P | 29 | 1,980 FSL & 660 FWL | 3,350 | 11,775 | 11,660 |
| **Humble Oil & Refining Co. | No. 1 Millican et. al. | San Saba | L. Kessler | | 600 | 330 FSWL, 150 FSEL | nd | 2,170.5 | 1,425 |
| Humble Oil & Refining Company | No. 1 White | San Saba | | | | | | 1,680 | 895 |
| *Humble Oil & Refining Company | No. 1 Woodard | Kimble | T.W.N.G. RR. Co. | 15 | 5 | 1,980 FN & EL | 2,115DF 2,105GL | 3,033 | 2,610 |
| *R. A. Irwin | No. 1 G. R. Kothman | Kimble | T.W.N.G. RR. Co. | | 37 | 660 FS & WL | 2,193DF 2,188GL | 3,964 | 2,570 |
| *J. B. Jameson | No. 1 Webb | Taylor | Lunatic Asylum | | 46 | 1,170 FN & EL | 1,905 | 6,396 | 5,325 |
| *Magnolia Petroleum Company | No. 1 Below | Kendall | B. Ficklin Irr. Co., A-87 | | 881 | 2,786 F most S'ly SWL & 1,085 FSEL | 1,724DF 1,712GL | 6,512 | 5,490 |
| Magnolia Petroleum Co. & Western Natural Gas | No. 1 Brown and Bassett | Terrell | TCRR | Y | 218 | | 2,448 | 15,556 | 15,365 |
| *Magnolia Petroleum Company | No. 1 Shannon Hospital | Crockett | E.L. & R.R. RR. Co. | BB | 5 | 660 FS & EL | 2,476DF 2,466GL | 8,623 | 8,550 |
| **Demsey Montgomery Oils | No. 1 Yates | San Saba | Martin Bruch | | 576 | 2,000 FWL, 1,200 FSL | 1,495 (est.) | 3,005 | 1,155 |
| **T. F. Murchison | Ranch well | Burnet | | | | 4.7 mi. S of Burnet | 1,160 (est.) | 2,491 | 1,325 |
| **H. M. Naylor | No. 1 Lloyd Mitchell | Edwards | H. E. & W. T. | E | 87 | 1,650' FSL, 337.2' FWL | 2,260 | 7,811 | 6,280 |
| **Naylor | No. 1 Stone | Coleman | Childress | | 73 | | 2,129DF | 5,348 | 4,620 |
| *Phillips Petroleum Company | No. 1 Callan | Schleicher | J. F. Wilhelm | | 311 | 660 FN & WL | 2,306DF | 6,065 | 5,165 |
| *Phillips Petroleum Company | No. 1 Meta | Menard | J. W. Bradford | | 501 | 660 FS & EL | 2,335DF | 3,939 | 2,530 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Phillips Petroleum Company | No. 1 Spiller | Kimble | W. A. Choice | | 10 | 1,980 FEL & 765 FSL | 2,227DF | 4,264 | 2,820 |
| **Phillips Petroleum Company | No. 1-A Towson | Hamilton | | | | | | 6,390 | 5,250 |
| *Richardson & Bass | No. 1 Schwartz | Tom Green | John Cherry | | 155½ | 2,246 F most N'ly SL & 3,451 FEL | 1,849DF 1,837GL | 7,168 | 6,350 |
| *L. U. Rowntree | No. 1 Richard Kott | Gillespie | Michael Erskin | | 154 | 1,200 FWL & 400 FSL | 2,067 | 3,189 | 1,830 |
| *G. L. Rowsey | No. 2 Fee | Bandera | J. M Shipp, A-1062 | | 13 | 6,500 FNL & 1,120 F most N'ly EL | 1,809DF 1,798GL | 6,970 | 5,730 |
| *G. L. Rowsey | No. 2 Nowlin | Kerr | J. Corono | | 570 | 3,170 FWL & 3,865 FNL | 1,680DF 1,670GL | 7,902 | 6,280 |
| *Scherck & Chizum | No. 1 D.C.O. Wilson | Schleicher | W. H. Moulden | V-14 | 9 | 660 FN & EL | 2,237DF 2,229GL | 7,155 | 6,460 |
| *Seaboard Oil Company | No. 4 Upshaw | Stonewall | H. & T.C. RR. Co. | D | 61 | 780 FSL & 467 FWL | 1,767DF 1,759GL | 6,340 | 6,115 |
| **Shaw | No. 1 Jordan | San Saba | AB & M | | 1 | 467 FSL, 1,400 FEL | 1,386DF | 1,355 | 1,880 |
| *Shell Oil Company | No. 1 Purcell | Williamson | Wm. H. Magill | | | 1,196 FWL of survey & 1,196 FSL of Purcell tract | 1,074DF | 9,479 | 8,960 |
| **Stratoray Oil Corporation | No. 1 Stribling | Blanco | | | | 4.5 mi. NNE of Johnson City | 1,245GL | 1,355 | 70 |
| **The Superior Oil Company | No. 1 J. E. McDowell | Runnels | T. & N.O. RR. Co. | | 80 | 1,980 FWL & 660 FNL of NW/4 of section | 1,900DF | 6,307 | 5,530 |
| *Taylor Oil and Gas Company et al. | No. 2 Sheen | Schleicher | E.L. & R.R. RR. Co. | | 66 | 660 FS & WL of SE/4 of section | 2,295DF 2,284GL | 5,584 | 5,180 |
| *Tucker Drilling Company | No. 1 Boyd | Schleicher | B.S. & F. | C | 7 | 660 FEL & 467 FSL | 2,389DF 2,379GL | 5,970 | 5,280 |
| **Tucker Drilling Company | No. 1 Dr. Roy E. Perkins | Kerr | W. S. Long | | 31 | 660 FWL & 1,499 FNL of survey | 1,544 | 3,355 | 1,560 |

Table 24. **Thickness data for Moore Hollow Group rocks in Texas wells arranged by companies.**

| | Moore Hollow Group | Wilberns Formation | San Saba Member | Point Peak Member | Morgan Creek Limestone | Welge Sandstone | Riley Formation | Lion Mountain Sandstone | Cap Mountain Limestone | Hickory Sandstone | Depth to top of Moore Hollow |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amerada No. 2 Hickman | 110 | 110 | 110 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9,965 |
| American Republics No. 1 Bradford | 1450 | 690 | 435 | 145 | 90 | 20 | 760 | 60 | 200 | 500 | 1,230 |
| Atlantic No. 1 Noelke | 460+ | 255 | 155 | 50 | 50 | 0 | 205+ | 60 | 0 | 145+ | 7,500 |
| Atlantic No. 1 Roberts | 630± | 450± | 320± | 50 | 80 | 0 | 180 | 70 | 0 | 110 | 7,090± |
| Bilsky No. 1 Mitchum | 465 | 465 | 465 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,770 |
| Blumberg No. 1 Wagner | 1500+ | 730 | 620 | 0 | 100 | 10 | 770+ | 45 | 600 | 125+ | 1,825 |
| Brady water well | 1100 | 500 | 230 | 120 | 110 | 40 | 600 | 45 | 145 | 410 | 940 |
| Tommy Brook water well | 605+ | 555 | 340 | 100 | 90 | 25 | 50+ | 50+ | | | 560 |
| Carpenter No. 1 Bradshaw | 805+ | 560 | 340 | 75 | 120 | 25 | 245+ | 50 | 155 | 40+ | 290 |
| Carpenter No. 1 McCollum | 700+ | 560 | 320 | 100 | 120 | 20 | 140+ | 65 | 70 | 5+ | 1,860 |
| Continental No. 1 Wiley | 540 | 540 | 540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,510 |
| Deeprock No. 1 Bevans | 1330 | 610 | 320 | 170 | 90 | 30 | 720 | 90 | 110 | 520 | 3,810 |
| Fish No. 1 Postell | 935+ | 935+ | 645 | 160 | 105 | 25+ | | | | | 4,440 |
| Forest No. 1 Stapp | 1540+ | 725 | 400 | 170 | 130 | 25 | 815+ | 70 | 290 | 455+ | 2,550 |
| Fredericksburg No. 9 water well | 1080+ | 150+ | 0 | 0 | 130+ | 20 | 930 | 75 | 555 | 300 | 160 |
| Gallager & Lawson No. 1 Terry | 640 | 640 | 445 | 40 | 120 | 35 | 0 | 0 | 0 | 0 | 4,535 |
| Garland-Anthony No. 1 Hammons | 770 | 730 | 565 | 0 | 140 | 25 | 40 | 40 | 0 | 0 | 6,890 |
| General Crude No. 1 Anderson | 1505+ | 1130 | 880 | 130 | 110 | 10 | 375+ | 50 | 325+ | | 9,120 |
| Gilcrease No. 1 Feril | 660+ | 565 | 355 | 80 | 95 | 35 | 95+ | 65 | 0 | 30+ | 3,620 |
| Gregg and others No. 1 Smith | 695 | 390 | 180 | 70 | 115 | 25 | 305 | 60 | 20 | 225 | 2,700 |
| Harvey No. 1 Giesecke | 420 | 415 | 230 | 130 | 60 | 0 | 0 | 0 | 0 | 0 | 3,740 |
| Honolulu No. 2 Whitaker | 165 | 140 | 30 | 20 | 80 | 10 | 25 | 25 | 0 | 0 | 5,520 |
| Humble No. 1 Autry | 965 | 695 | 465 | 110 | 110 | 10 | 270 | 80 | 0 | 190 | 5,315 |
| Humble No. 1 Bolt | 1540 | 750 | 360 | 260 | 110 | 20 | 790 | 90 | 215 | 485 | 2,510 |
| Humble No. 1 Farris | 60 | 60 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,660 |
| Humble No. 1 Millican | 745 | 485 | 260 | 105 | 100 | 20 | 260 | 80 | 140 | 40 | 1,425 |
| Humble No. 1 White | 785+ | 570 | 360 | 65 | 110 | 35 | 215+ | 60 | 110 | 45+ | 895 |
| Humble No. 1 Woodard | 425+ | 425+ | 305 | 120+ | | | | | | | 2,610 |
| Irwin No. 1 Kothman | 1380 | 680 | 350 | 170 | 140 | 20 | 700 | 70 | 200 | 430 | 2,570 |
| Jameson No. 1 Webb | 485 | 315 | | | | | 170 | | | | 5,325 |
| Magnolia No. 1 Below | 1020+ | 870 | 705 | 0 | 140 | 25 | 150+ | 35 | 115+ | | 5,490 |
| Magnolia No. 1 Brown-Bassett | 77 | 77 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15,365 |
| Magnolia No. 1 Shannon Hospital | 50 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8,550 |
| Montgomery No. 1 Yates | 1070 | 560 | 260 | 140 | 140 | 20 | 510 | 50 | 165 | 295 | 1,155 |
| Murchison ranch well | 1145 | 485 | 280 | 65 | 130 | 10 | 660 | 55 | 300 | 305 | 1,325 |
| Naylor No. 1 Mitchell | 1530+ | 835 | 430 | 155 | 215 | 35 | 695+ | 45 | 420 | 230+ | 6,280 |
| Naylor No. 1 Stone | 720 | 570 | 280 | 150 | 120 | 20 | 150 | 50 | 0 | 100 | 4,620 |
| Phillips No. 1 Callan | 785 | 500 | 210 | 130 | 130 | 30 | 285 | 110 | 0 | 175 | 5,165 |
| Phillips No. 1 Meta | 1335 | 640 | 320 | 190 | 110 | 20 | 695 | 75 | 115 | 505 | 2,530 |
| Phillips No. 1 Spiller | 1430 | 695 | 340 | 240 | 95 | 20 | 735 | 75 | 130 | 530 | 2,820 |
| Phillips No. 1 Towson | 1130 | 865 | 540 | 185 | 130 | 10 | 265 | 75 | 0 | 190 | 5,250 |

* Allowances made for faults: 230 feet in the San Saba Member and 320 feet in the Cap Mountain Limestone Member.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Richardson & Bass No. 1 Schwartz | 720 | 450 | 180 | 140 | 100 | 30 | 270 | 120 | 0 | 150 | 6,350 |
| Rowntree No. 1 Kott | 1355 | 710 | 360 | 225 | 110 | 15 | 645 | 75 | 335 | 235 | 1,830 |
| Rowsey No. 2 Fee | 1790+ * | 950* | 720* | 45 | 165 | 20 | 840+ * | 70 | 520* | 250+ | 5,730 |
| Rowsey No. 2 Nowlin | 1620+ | 900 | 640 | 80 | 160 | 20 | 720+ | 55 | 535 | 130+ | 6,280 |
| Scherck & Chizum No. 1 Wilson | 650 | 560 | 340 | 140 | 80 | 0 | 90 | 90 | 0 | 0 | 6,460 |
| Seaboard No. 4 Upshaw | 225+ | 225+ | 225+ | | | | | | | | 6,115 |
| Shaw No. 1A Jordan | 820+ | 420 | 220 | 80 | 100 | 20 | 400+ | 80 | 40 | 280+ | 1,880 |
| Shell No. 1 Purcell | 480 | 480 | 420 | 20 | 40 | 0 | 0 | 0 | 0 | 0 | 8,960 |
| Stratoray No. 1 Stribling | 1270+ | 485+ | 310+ | 30 | 135 | 10 | 785 | 35 | 510 | 240 | 70 |
| Superior No. 1 McDowell | 650 | 430 | 150 | 150 | 105 | 25 | 220 | 35 | 0 | 185 | 5,530 |
| Taylor No. 2 Scheen | 405+ | 405+ | 335 | 70+ | | | | | | | 5,180 |
| Tucker No. 1 Boyd | 690+ | 490 | 220 | 130 | 120 | 20 | 200+ | 100 | 0 | 100+ | 5,280 |
| Tucker No. 1 Perkins | 1795+ | 970 | 790 | 20 | 140 | 20 | 825+ | 50 | 650 | 125+ | 1,560 |

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