# GEOLOGY OF THE BEE BRANCH - MILL CREEK AREA
# MASON COUNTY, TEXAS

A THESIS

BY

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Submitted to the Graduate
School of the Agricultural and
Mechanical College of Texas in partial
fulfillment of the requirements for the
degree of MASTER OF SCIENCE

August, 1957

MAJOR SUBJECT: GEOLOGY

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(Chairman of Committee)

(Head of Department)

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ILLUSTRATIONS

ACKNOWLEDGEMENTS

The geologic map of the Bee Branch - Mill Creek Area, Mason, County, Texas, and this accompanying thesis are the results of two months of mapping in Mason County, Texas. Mr. H. R. Blank was helpful in obtaining permission from the ranchers for access to the thesis area and in helping the author to start the investigation. Sincere thanks is here given for the friendly cordial manner in which the author was treated by the ranchers. The assistance of Messrs. Bill Barton, Melvin Capps, and W. W. White in locating roads, land marks, and property line boundaries is appreciated.

The writer is under particular obligation to Mr. M. C. Schroeder whose cooperation and suggestions aided in an understanding of many of the problems encountered in mapping the Ellenburger dolomite and calcite. The author hereby gratefully acknowledges the suggestive criticism given by Messrs. M. C. Schroeder, H. R. Blank, Clay L. Seward, and S. A. Lynch, before this thesis reached its final form.

Mr. Kenneth Sliger helped measure the Point Peak and San Saba sections given in the appendix. The Marble Falls group and the Smithwick shale sections were measured and painted every five feet by Messrs. Don Winston, Pete Rose, and the author, These sections were described by Winston who is writing his doctor's dissertation on the Pennsylvanian strata of Mason County, Texas.

## ABSTRACT

The Bee Branch - Mill Creek Area contains approximately twenty square miles on the extreme southwest flank of the Llano uplift. The surface rocks consist of limestones, dolomites, shales, siltstones, and sandstones that range in age from Late Cambrian to Pennsylvanian in age. The Morgan Creek member of the Wilberns formation is the oldest rock unit exposed in the area. The youngest rock unit exposed is Early Pennsylvanian in age. The carbonates of the Ellenburger group make up the thickest composite rock unit in the area.

The Honey Creek fault transverses the area in a northeast-southwest direction. This normal fault has a throw of over 1200 feet. Less prominent normal faults branch from the Honey Creek fault.

Associated with the faulting in the area is a structural depression referred to as the Bee Branch depression. Drag due to fault movement, tectonic folding, and solution collapse are discussed as three possible theories for the origin of this structural depression. The Bee Branch Depression, which is apparently a continuation of the Honey Creek Syncline, is believed to be purely a structural feature of tectonic origin. The axial alignment of this fold is almost due east in the Bee Branch - mill Creek Area. The axes of the Honey Creek Syncline mapped in the adjacent Bear Springs Area of Cloud and Barnes (1948) apparently changes to north-northeast.

# GEOLOGY OF THE BEE BRANCH - MILL CREEK AREA

# MASON COUNTY, TEXAS

## INTRODUCTION

### STATEMENT OF PROBLEM

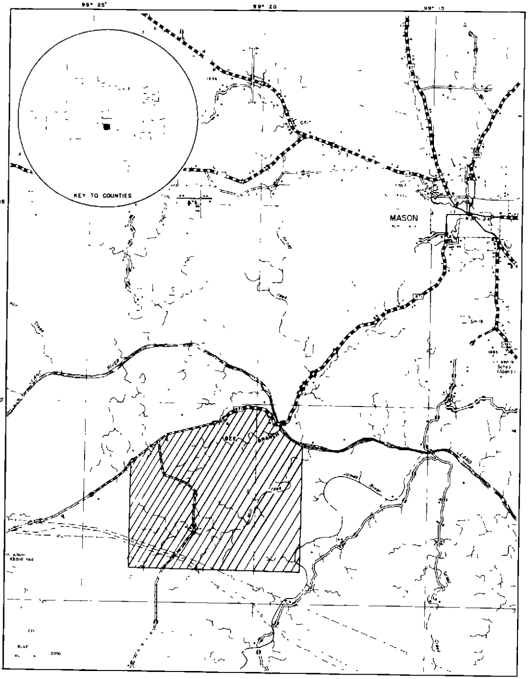
The problems involved in this investigation were as follows: (1) to make a detailed geologic map of the area, ( ) to describe the geologic formations mapped, (3) to interpret the structure and geologic history of the area mapped, and (4) to explain the occurrence of the Carboniferous strata found in structural depressions.

### LOCATION AND ACCESSIBILITY

Mason County is located in Central Texas. The Bee Branch - Mill Creek area lies approximately seven miles southwest of Mason, Texas. White's Crossing on the Llano river adjoins the northeast corner of the area. The boundary of the area approaches a rectangle with sides that extend about five miles west and four miles south. Thus, it contains an area of approximately twenty square miles as shown in Figure 1. This rectangle contains the Bee Branch and the Mill Creek drainage basins.

Two all-weather roads give access to the area. Ranch-to-Market Road 1871 runs east and west and forms the northern boundary of the area, while the western part of the area is crossed by the north-south trending Mill Creek Road. An unimproved ranch road, called a "Dim" road by the natives, intersects Ranch Road 1871. Although this term, Dim road, is commonly used in the area to describe any faint road or trail, it is used throughout this report for the aforementioned road.

FIGURE 1




**LOCATION MAP OF THE BEE BRANCH — MILL CREEK AREA, MASON COUNTY, TEXAS**

REPRODUCED FROM HIGHWAY MAP OF MASON COUNTY, TEXAS, PREPARED BY THE TEXAS STATE HIGHWAY DEPARTMENT, 1954

SCALE

This sinuous, narrow, rough road gives access to the central part of the thesis area.

## FIELD WORK

The field work on which this thesis is based was done during the summer of 1956. Seven vertical aerial photographs (series DFZ-Numbers 14, 15, 16, 17, 23, 24, and 25) made for the United States Department of Agriculture in 1948 were used as a base on which to map the surface geology. The photographs used were nine inches square with a scale of about three inches to the mile, 1:20,000. A stereoscope was used to identify topographic expressions on the aerial photographs.

Strikes and dips were taken on the limestone and dolomite beds with a Brunton compass at places where the bedding was exposed. Bedding planes are obscure in many of the surface exposures of shale and dolomite found in the area.

## PREVIOUS INVESTIGATIONS

The first important work on the geology of the Central Mineral region of Texas was done by Roemer who visited Texas from 1845 to 1847. Four papers were published giving the results of his studies. Two of these papers by Roemer (1846, 1848) were published in the American Journal of Science. The titles of the German papers by Roemer (1849, 1852) have been translated as "Texas, with Especial Reference to German Emigration and the Physical Conditions of the Country, Based on Personal Observations", and "The Cretaceous Formation of Texas and Their Organic Remains".

The next significant observations were made by two brothers, G. G. Shumard and B. F. Shumard. A general outline of leading geologic features along the route through San Saba Valley, Fort Mason, and Fredericksburg was made by G. G. Shumard. G. G. Shumard's report is contained within the 1886 report of B. F. Shumard, the state geologist.

B. F. Shumard's paper of 1859 gave an account of the Primordial (Cambrian) rocks discovered in Burnet County, Texas. The Primordial zone of Texas was described by Shumard (1861, p. 214):

> "...As a series of light-colored, pure and impure dolomites, limestone, chert, calcareous and siliceous sandstone, gritstones and conglomerates, presenting an aggregate thickness of from eight to ten hundred feet, and separable into two well-marked divisions, of which the superior represents the calciferous sand group and the inferior, the Potsdam sandstone of the northwest."

S. B. Buckley classified all of the igneous rocks in the Central Mineral region as Azoic. Apparently Buckley (1847, p. 15) believed that the igneous intrusions were not all of Precambrian age, for he stated:

> "Some of the Azoic rocks are the oldest known, and others not, for there are granites in Texas, in Burnet, Llano, and San Saba counties, which have been thrown up during the formation of the rocks of the older Silurian."

In 1883 Walcott (1884) made a study of the Cambrian and collected fossils from the Texas Potsdam horizon. He established the Late Cambrian age of the Texas Potsdam group and proposed the name of Llano group for the Lower Cambrian. He believed that the granites were in part contemporary with the deposition of the Llano group, but that most of the igneous rocks were the results of extrusions at or near the close of the erosion of the Llano group and before the deposition of the Potsdam. Walcott (1884) estimated the thickness of the Lower Silurian (Ordovician) rocks to be 1145 feet.

In his review of Texas geology, Hill (1887) briefly mentioned the Llano area. Hill (1889) believed that the granite classified by Walcott (1884) as Cambrian in age was younger. The lowest or encrinital limestone strata of the Carboniferous was thought by Hill to have been thrust up almost vertically by the great granite mass exposed a few miles east of Marble Falls, in the southwest corner of Burnet County. On the basis of this exposure Hill (1889) assigned a late Carboniferous or post Carboniferous age to the granite and metamorphic rocks of the area. Hill (1889) was the first to use the name "Marble Falls" for the Carboniferous limestone in the area. He was of the opinion that the alleged Devonian of B. F. Shumard was identically the Carboniferous limestone of North Texas, which had been intensely metamorphosed by igneous contact in the southwest corner of Burnet County. Hill (1890) gave a brief classification of the topographic and geologic features of Texas. This report contains a map that divides the state into twelve topographic and geologic regions. Mason County is included in the Coal, Iron, Marble, Granite Region of the Grand Prairie on this map.

In 1890, Dumble presented the <u>First Annual Report of the Geological and Mineralogical Survey of Texas</u> for the year 1899. Comstock was appointed geologist for the Central Mineral District in 1889 by Dumble, state geologist. In his <u>Preliminary Report on the Geology of the Central Mineral Region of Texas</u>, Comstock (1890) confined his study to the rocks of pre-Carboniferous age. Comstock (1890, p. 264) stated on the age of the igneous iruptions:

> "It need only be said here that both Buckley and Walcott have been partly correct and partly wrong.

> There are granites of various ages, intrusive and perhaps extrusive; but they are not all later nor are they all earlier than the beginning of the Potsdam epoch."

Comstock divided the Archean and Eparchean metamorphic and igneous rocks into the (1) Burnetan, ( ) Fernandan, and (3) Texas. Comstock (1890) proposed the name "Hickory Series" for the Lower Cambrian, "Riley Series" for the Middle Cambrian, and "Katemcy (Potsdam) Series" for the Upper Cambrian. Comstock provisionally classified the beds overlying the Katemcy Series as "Lower Silurian". He divided the Lower Silurian into (1) the Leon Series (Canadian?) and (2) the San Saba Series composed of strata of slabby character, containing large quantities of sponge-like fossils, probably Stromatopora concentrica.

Cummins (1890) wrote a paper on the general geology of the Carboniferous with special emphasis on the economic geology of the Carboniferous in Central Texas.

Tarr (1890) wrote two papers on the superimposed drainage system that originated on the Cretaceous strata in Tertiary time in Central Texas. Tarr brought out the fact that, since the Colorado in Central Texas flows with a general course at right angles to the strike of the Carboniferous rocks in an opposite direction to the dip, the Colorado River selected its course on a structure that is no longer present. He believed that this earlier structure was present on Cretaceous strata because the Paleozoic region of Central Texas is only partially uncovered and the denudation of the Cretaceous is still in progress.

The mineral resources of Texas were given special attention in the Second Annual Report of the Texas Geological Survey, Dumble (1891). Dumble (1898) included the Granite Highlands of Central Texas in his discussion of the geologic history of Texas.

Hill (1901) wrote a comprehensive report on the Black and Grand Prairies of Texas that was based on his study of the area since 1882. He pointed out that the drainage valleys of the Llano and Colorado in Llano, Mason, Gillespie, and Burnet counties exposed Precambrian rocks because the younger sediments had been stripped away by erosion; he discredited the hypothesis that the Precambrian granites were the remnants of primeval mountains that had stood exposed since the earliest geologic time. Walcott (18?4), in his discussion of the Llano group, was given credit by Hill (1901) for first pointing out the true relation of Precambrian metamorphic rocks. Hill further states:

> "There may be other granites of post-Cambrian age in the Burnet region, as has been asserted by Comstock, but their existence has not been demonstrated."

The alleged Devonian of Shumard (1860, and Comstock (1890) were determined, by fossils sent to the Smithsonian institute by Hill, to be of Carboniferous age. In this same paper by Hill (1901), there is a discussion of the Cretaceous that is accompanied by numerous maps and geologic sections.

Paige (1911) gave an account of the field work that was done in 1908 and 1909 in the preparation of the Llano quadrangle map. The Llano quadrangle includes portions of Llano, Mason, and San Saba counties. Paige's first paper treats in detail the Precambrian geology and the minerals of the Llano quadrangle. In his brief discussion of the Paleozoic of this area, Paige (1911) named the Wilberns, Cap Mountain, Ellenburger, and Smithwick formations. He also redefined Comstock's Packsaddle schist and Valley Springs gneiss; these rocks were regarded as Algonkina in age by Paige. Paige refers to Comstock's Hickory Series as the "Hickory Sandstone". The Llano-Burnet folio was published in 1912, Paige (1912) by the U.S. Geological Survey.

A Review of the Geology of Texas was published by the University of Texas under the direction of Udden (1916). This report contains the first comprehensive geologic map of Texas. The Ellenburger, Wilberns, Cap Mountain, and Hickory are included in one unit and the Precambrian as another unit on the map, which has a scale of 1 : 1,500,000.

Girty (1919) discussed the importance of the unconformity within the Bend formation. This unconformity separated the rocks of Mississippian and Pennsylvanian age. The Bend formation, as defined by Girty (1919), consisted of two shales separated by a limestone. The lower shale was not named by Girty, but he named the limestone and the overlying shale, respectively the "Marble Falls" and the "Smithwick".

Plummer and Moore (1922) called the shale below the Marble Falls the "Barnett" in their study of the Pennsylvanian Formations of North-Central Texas. Roundy, Girty, and Goldman (1926) established the lower Mississippian age of the crinoidal limestone underlying the Barnett. The name "Chappel" was applied to this crinoidal limestone by Sellards (1933).

Dake and Bridge (193-) were the first to recognize and report on the similarity of the fauna of the Ellenburger formation to fauna of rocks of the Ozark region of Missouri:

> "Of these, the Potosi and Eminence equivalents seem to be limited to the northeast portion of the uplift, in the general vicinity of [illegible]. Beds of Proctor and Van Buren age have not been identified with certainty, but the Gasconade equivalent is typically represented and has proved to be much more widespread than the older units. Strata of Roubidoux age are excellently developed and widely distributed throughout the uplift."

In addition, Dake and Bridge (19--) indicated that there are certain zones represented in the Ellenburger formation that do not occur in the Missouri section. They also believed that the Ellenburger had a thickness of approximately 2,000 feet instead of the previous estimates of 1,000 feet.

The Valley Spring gneiss and the Packsaddle schists were reinvestigated and redefined by Stenzel (1932). The Precambrian, Paleozoic, and Mesozoic systems of the Llano region were reviewed by Sellards (1932) in his report on the stratigraphy of Texas. A discussion of the structure and paleogeography of the Precambrian, Paleozoic, and Cretaceous rocks of the Llano region is included in Sellards' (1934) report on the structure and economic geology of Texas. Stenzel (1934, 1935) presented one paper on the Precambrian structural conditions in the Llano region and another paper on the major Precambrian unconformities.

The general geologic setting of the Llano area is shown on the geologic map of Texas by Darton, Stephenson, and Gardner (1937).

Bridge (1937) made a tentative correlation of Upper Cambrian rocks of the upper Mississippi Valley, Missouri, and Central Texas, and named the Lion Mountain sandstone member of the Cap Mountain formation. Bridge and Girty (2937) redescribed Ferdinand Roemer's Paleozoic fossils and type localities.

On the basis of numerous localities where dreikanters were observed in the basal Hickory sandstone of Central Texas, it was conjectured by Barnes and Parkinson (1939) that wind deposits are more common in the basal part of the Upper Cambrian than have hitherto been recognized.

Plummer (1943) described a new quartz sand horizon found in the Wilberns formation (Cambrian) of Mason County.

The Ellenburger limestone was elevated in rank to the Ellenburger group and restricted to beds of Early Ordovician age by Cloud, Barnes, and Bridge (1945). They divided the Ellenburger group into the following formations: the Tanyard formation at the base, containing the Threadgill and Standeback members; the Gorman formation; and the Honeycut formation at the top. Their paper contains two charts that show correlations within the Llano region and with southern Oklahoma and Missouri. The Riley series was reduced to formation rank, having in ascending order the following members: Hickory sandstone, Cap mountain limestone, and the Lion Mountain sandstone. Thus, the Upper Cambrian sediments were divided into the Riley formation and the overlying Wilberns formation.

In his report on the water resources of Texas, Plummer (1946) discussed the important Central Texas aquifers, the Hickory sandstone, and the Ellenburger limestone.

Both the Wilberns and Riley formations are described and redefined in a comprehensive paper on the Upper Cambrian by Bridge, Barnes, and Cloud (1947).

A complete, forthright dissertation of the Ellenburger rocks, which gives the final results of continuous, cooperative work of many geologists on the stratigraphy of the Ellenburger group and its correlation with other Lower Ordovician strata, was presented by Cloud and Barnes (1948).

<u>Carboniferous Rocks of the Llano Region of Central Texas</u>, Plummer (1950) is a progress report that supplements Plummer and Moore's report (1922). This report contains the most detailed geologic map of

the Llano region yet published and serves as the basic reference for the Carboniferous interpretations in the area.

# PHYSIOGRAPHY

## CLIMATE

A semi-arid climate exists in Mason County, Texas. The county has an average annual precipitation of about 22 inches, occurring mostly in the winter and spring months. The mean-average temperature is 70.5°F. The summer months are hot and dry with the temperature often reaching 110°F or slightly higher, whereas the winters are rather mild with temperatures only occasionally going below freezing.

## VEGETATION

The vegetation is similar to the vegetation found in other semi-arid parts of the Western United States and consists of several varieties of cactus, small thorny bushes, mesquite, cedar, and some oak. The vegetation, including the grasses, is sporadically distributed in the thesis area except where the surface rocks have weathered to soil and silt, and where shale crops out. Abundant vegetation, mostly mesquite, oak, catsclaw, and cactus, is found on the Barnet shale and the alluvium deposited by Mill Creek and Bee Creek. The only abundant growth of grass is found on the silt of a Cretaceous outlier in the northwest part of the area mapped, although grass would probably be more common elsewhere except for the drought.

## PHYSICAL FEATURES

The Llano region comprises a topographic basin with Precambrian igneous rocks in the center and younger Paleozoic and Cretaceous rocks forming the outer periphery. From the topographic high to the enterior there is a difference in elevation of approximately 600 feet.

The Bee Branch-Mill Creek area is located on the southwest flank of the Llano uplift. The thesis area consists of a plateau that has been dissected by Mill Creek, Bee Creek, and the Llano River. The area west of the upper reaches of Bee Creek and Mill Creek is relatively flat. Bee Creek has cut into Ellenburger carbonates throughout its drainage basin. The V-shaped Valley formed by Mill Creek exposes Pennsylvanian, Mississippian, Ordovician, and Cambrian strata. In the western part of the thesis area an isolated area of Cretaceous and the underlying Ellenburger dolomite form a flat surface. This isolated Cretaceous outlier is approximately two miles east of the resistant Cretaceous rocks of Blue Mountain.

## DRAINAGE

The Llano region is drained by the San Saba, Colorado, Pedernales, and Llano rivers. The thesis area is south of the Llano River. Bee Creek and Mill Creek, flowing into the Llano River, have cut deep, canyon-like valleys in order to enter the main stream at grade and as a result, a very rugged topography is found in the lower reaches of the two intermittent creeks. The Southeast corner of the area is drained by the James River which in turn empties into the Llano River east of the area.

The outcrop pattern of the formations is determined by these smaller streams, but the geologic structure has had only a minor influence in determining the present stream pattern on the area mapped.

## STRATIGRAPHY

### GENERAL STATEMENT

The surface rocks in the Bee Branch - Mill Creek area of southern Mason County consist of limestones, dolomites, shales, siltstones, and sandstones that range in age from Late Cambrian to Pennsylvanian. The Cambrian system is represented in the Llano area by the Wilberns and the Riley formations. The Morgan Creek limestone member of the Wilberns formation is the oldest rock unit exposed in the Bee Branch - Mill Creek area. A columnar section of the surface rock units of the area is as follows:

CENOZOIC
- Quaternary System
  - Recent

MESOZOIC ERA
- Cretaceous System
  - Lower Cretaceous
    - Cretaceous Silt

PALEOZOIC ERA
- Pennsylvanian System
  - Bend Series
    - Marble Falls Group
      - Smithwick Formation
      - Big Saline Formation
- Mississippian System
      - Barnett Formation
      - Chappel Formation
- Ordovician System
  - Lower Ordovician
    - Ellenburger Group
      - Gorman Formation
      - Tanyard Formation
        - Staendebach Member
        - Threadgill Member
- Cambrian System
  - Upper Cambrian

Wilberns Formation
San Saba Limestone Member
Point Peak Shale Member
Morgan Creek Limestone Member

CAMBRIAN SYSTEM

The Upper Cambrian strata of the Llano area has been redefined and redescribed by Bridge, Barnes, and Cloud (1947). This paper is generally accepted as the standard reference for the two formations and the eight members that comprise the Upper Cambrian series. The Riley formation consists of the Upper Cambrian sequence of rocks underlying the Wilberns formation. The Riley formation is not exposed in the area but crops out a few miles to the southeast in the adjacent Lower James River Area of South Mason County, Texas of Sliger (1957). In bluffs along the Llano River, the Morgan Creek limestone member of the Wilberns formation is exposed below the Point Peak shale member. The Morgan Creek limestone is the oldest rock unit exposed in the area. Rocks of Cambrian age comprise only a small per cent of the surface rocks in the area mapped.

## Wilberns Formation

The Wilberns formation was named by Paige (1911, p. 23) for Wilberns Glen in the Llano quadrangle where it is typically exposed. The lower boundary as defined by Paige is still recognized, but his indefinite Cambro-Ordovician boundary has been redefined and is placed between the top of the Cambrian Wilbern formation and the overlying Ellenburger group by Cloud, Barnes, and Bridge (1945). In ascending order, the members of the Wilberns formation are the Welge sandstone member, the Morgan Creek limestone member, the Point Peak shale member, and the San Saba limestone member. According to Barnes and Bell (1954), the Wilberns formation ranges in thickness from 360 to 619 feet. The average thickness is 500 feet. Cloud and Barnes (1948, p. 28) show a thickness of 575 feet for the Wilberns formation on the Bear Spring area. This section in the Bear Spring area is approximately two and one-half miles northwest of White's Crossing.

Virgil Barnes named the Welge sandstone, the Morgan Creek limestone, and the Point Peak shale, members of the Wilberns formation in an unpublished manuscript.

### Welge Sandstone Member

The Welge sandstone is not exposed in the area. It was named by Barnes from the Welge land surveys between Threadgill and Squaw creeks, Gillespie County, where it is typically exposed. The Welge sandstone is a yellowish brown sandstone that averages 18 feet in thickness in the Llano area. Its contact with the underlying Riley formation is abrupt, but the Welge sandstone grades into the overlying Morgan Creek limestone.

### Morgan Creek Limestone Member

The Morgan Creek limestone at its type locality on the north and south forks of Morgan Creek in Burnet County was described by Barnes (1944). At the type section it is 110 feet thick and averages about 120 feet in thickness in the Llano area.

The beds at the base of the Morgan Creek limestone are slightly sandy and are a reddish color. These basal beds grade upward into a grey to greenish grey, medium- to coarse-grained, glauconitic limestone. Thin beds of shales and zones of stromatolitic bioherms one to two feet thick occur toward the top of the Morgan Creek limestone. The small size and limited thickness of the Morgan Creek bioherms distinguish them from those found between the Point Peak shale and the San Saba limestone members.

In the Bee Branch-Mill Creek area the Morgan Creek limestone and the overlying Point Peak shale is exposed in bluffs along the Llano River. The limestone grades stratigraphically upwards into the shales and siltstones of the overlying Point Peak member.

### Point Peak Shale Member

In the type locality, Point Peak in Llano County, the Point Peak member is 270 feet thick, according to Bridge, Barnes, and Cloud (1947, p. 115). Barnes and Bell (1954, p. 37) estimate the average thickness in the Llano region to be 130 feet. Included in the above thickness of the Point Peak shale member is a zone characterized by sub-lithographic limestone formed by stromatolitic bioherms. In the Bee Branch-Mill Creek area this bioherm zone is mapped separately as a zone at the top of the Point Peak shale.

In this area the lower contact of the Point Peak has been located at the base of the first shale bed stratigraphically above the small bioherms of the Morgan Creek limestone. The upper contact is placed at the bottom of the large bioherms.

The thickness of the Point Peak shale was measured at a place approximately 1000 feet west of the mouth of Bee Branch. In this section the Point Peak shale is 145 feet thick.

In the measured section shale slopes alternate with ledges composed of dark gray siltstone, thinly-bedded limestone, and flat-pebbled, intraformational conglomerate. Glauconite and limonite are dispersed in varying amounts throughout the section, sometimes in individual grains and sometimes in irregular masses.

The dense growth of vegetation on the shale slopes of the Point Peak member shows up as exceedingly dark areas on the aerial photographs.

### Bioherm Zone of the Point Peak Shale Member

The bioherms occur as a distinct zone in the uppermost part of the Point Peak shale in the Bee Branch-Mill Creek area. The zone is characterized by stromatolitic limestones (calcareous algae secretions) that form distinct massive structures of sublithographic limestone called "bioherms". These reef structures obtain a thickness of over 50 feet and exceed 75 feet in length where they are exposed along the Llano River. These huge bioherms have compressed the shale that lies directly beneath them, thus causing the adjacent shale beds to bend beneath the bioherms. Differential compaction has caused the overlying strata to bend around the bioherms. In the basal portion of the zone, thin shales alternate with massive limestones between the individual bioherms. In the upper portion, massive granular limestones bend around the reef structures. Cloud and Barnes (1948, p. 155) explain this occurrence of exposed bioherms in the bluffs of the Llano River approximately one mile southeast of White's crossing as follows:

> "The interbioherm beds contain more limestone than shale, but the latter is a conspicuous lithic element and there is no doubt that the bioherms are properly associated with the Point Peak shale at this place. The bioherms extend upward from a floor of Point Peak strata, commonly with compaction basins beneath them. Apparently they grew considerably above the sea-floor of their

> time, for peripheral beds about them are wholly within the Point Peak shale member, others extend upward into the stratigraphic level of the San Saba limestone member, with San Saba beds deposited against them and over them."

Where the bioherm zone is mapped in the thesis area, the reefs either cap the shale slopes and form almost vertical cliffs, or weather out as fragments and subcircular reticulated masses on top of the Point Peak shale. The stromatolitic bioherms consist of very hard, light- to- dark gray, microgranular-to-sublithographic limestones.

### San Saba Limestone Member

The Bioherm zone is overlain by the San Saba limestone member of the Wilberns formation. The San Saba limestone member was named by Bridge (1947, p. 117) for exposures along the Mason-Brady Highway. The term "San Saba Series" was originally used by Comstock (1890, p. 301) for a portion of these beds.

The lower few feet of the San Saba limestone in the Bee Branch-Mill Creek area contain beds abundant in trilobite and other fossil fragments, forming a "hash" in some beds and making up only a small per cent of a medium-to-coarse-grained limestone in others. Intraformational conglomerates composed of flat, well-rounded pebbles are found in the upper 200 feet. These pebbles are composed of glauconite or limestone. The exposed limestone of the San Saba in the Bee Branch-Mill Creek area weathers to various shades of a brownish gray and yellowish gray with a few greenish-gray beds.

The first yellowish-gray bed occurs 78 feet above the top of the Bioherm zone in the measured section of 290 feet. Quartz sand is found in this buff-colored limestone and other yellowish-gray beds in the upper 212 feet. Cloud and Barnes (1946, p. 156) recognize an upper zone of arenaceous limestone 28 to 35 feet below the Cambrian-Ordovician boundary in the Bear Spring area. This, or a similar sandy limestone, is found at approximately the same stratigraphic position throughout the outcrop area of the San Saba limestone in the Bee Branch-Mill Creek area. This and other sandstone beds of the San Saba limestone are indicated on aerial photographs by a dark band due to the black persimmons that grow on the sandy beds.

A graditional contact exists between the San Saba limestone member of the Wilberns formation and the overlying Ellenburger group. The Cambrian-Ordovician boundary was picked by paleontology and lithology. The fossil Lytospira gyrocera is tightly coiled in the upper San Saba limestone; on the other hand, the Lytospira gyrocera is "open" in the Threadgill member of the Tanyard formation (Lower Ordovician). The "open" Lytospira gyrocera, however, was found to occur consistently above the last bed containing abundant glauconite and one to ten feet above distinctive buff-colored limestones. The upper contact of the most prominent buff-colored limestone coincides with the faunal boundary of the Cambrian-Ordovician and the top of the San Saba in the thesis area.

## ORDOVICIAN SYSTEM

### Ellenburger Group

The Ellenburger formation was named by Paige (1911, p. 24) for exposures of chert-bearing limestones and dolomites in the Ellenburger

Mills in the Burnet quadrangle. Cloud, Barnes, and Bridges (1945, p. 139) elevated the Ellenburger formation to group status.

The Lower Ordovician is represented by the Ellenburger group in the Llano uplift. The Ellenburger group is divided into three formations. Beginning with the oldest, they are the Tanyard formation, the Gorman formation, and the Honeycut formation. The Tanyard formation is divided into the Threadgill member and the Staendebach member. Both of these members are divided into dolomite and calcite facies. The Gorman and the Honeycut are also divided into dolomite and calcite facies. in the Llano area. H. R. Blank (Personal Communication) suggested that the Ellenburger group be mapped as dolomite and limestone, because it appeared that individual formations of the Ellenburger group could not be readily differentiated. By mapping the Ellenburger group in this manner, a suggestion of the stratigraphic position of the dolomite and calcitic facies was obtained. The dolomite and limestone sequence shown on the map includes the Tanyard and Gorman formations. These two formations were recognized by their gross lithologic differences and the presence of Lytospira gyrocera in the Tanyard formation. No attempt was made to trace the obscure graditional boundary between these two formations. According to Cloud and Barnes (1948, p. 159), the Honeycut formation is missing west of San Saba County due to pre-Devonian truncation. In the Bear Spring area a thickness of 973 feet of carbonate rocks of the group was measured by Cloud and Barnes (1948, p. 28). The outcropping Ellenburger rocks are predominately limestone where the Bear Spring area overlaps the thesis area; on the contrary, the total surface area of the entire Bee Branch-Mill Creek area consists of over 50 per cent Ellenburger dolomite.

PLATE II

ELLENBURGER LIMESTONE

Figure 1

Figure 2

Figure 1.....Ellenburger limestone (Tanyard)
Figure 2.....Ellenburger limestone (Gorman)

PLATE III

TYPICAL ELLENBURGER TOPOGRAPHY SHOWN LOOKING NORTH FROM RANCH ROAD 1871 (SMITH HOLLOW)

The limestones are sparingly fossiliferous, hard, predominately sub-lithographic, and non-glauconitic. They are grey to white on both weathered and fresh surfaces and are commonly stromatolitic. To the naked eye, the limestones appear very pure. Chert is found in some of the limestone beds, especially in the upper limestone (Gorman limestone).

The dolomites are light grey, dark grey, tan, yellowish brown, reddish brown; in part vuggy, and fine-to-medium-grained. The bedding of the dolomites is either thin-bedded, indistinguishable, or slabby. Typically, the exposed surface bedding is covered with boulders of dolomite, chert, and/or soil produced by weathering. The soil derived from the dolomite is typically red but often grey. Chert is found as nodules, concretions and inclusions in the dolomites, and as small fragments to boulders on weathered surfaces. In places, chalk-textured chert with alternating brown and white bands one-eight inch thick are characteristic. The chert, however, is mostly porcelaneous and either grey or reddish brown. A few sand grains have been found in some of the chert.

The perennial-flowing Llano River has cut steep cliffs along the northeast boundary of the thesis area. The intermittent streams have cut deep canyon-like valleys throughout the Ellenburger carbonates to enter the Bee Branch-Mill Creek area. The Ellenburger rocks support very little vegetation, whereas denser vegetation is found on the underlying Wilberns formation and the overlying Carboniferous rocks. Aerial photographs show a dense growth of chaparral and mesquite growing on the outcrop of the Barnett shale of Mississippian age, as a very prominent narrow black band. Plate IV shows the tree line on the Barnett shale and the underlying Ellenburger limestone.

## MISSISSIPPIAN SYSTEM

The first published description of Mississippian strata in Texas was made by Roundy, Girty, and Goldman (1926). Discovery of Mississippian strata near White's Crossing on the Llano River seven miles southwest of Mason was made by Dake and Bridge (1932, map). Cloud and Barnes (1948, p. 160) described the Mississippian rocks of the Bear Spring area which overlaps the north corner of the thesis area. In the thesis area the Chappel and the Barnett formations are found collapsed into the Ellenburger group and outlining the major structural depression in the Bee Branch-Mill Creek area. The Chappel and the Barnett formations outcrop almost continuously on the north side of a structural depression along the Honey Creek fault that transverses the area in an east, northeast direction. The surface exposures of this depression consist of Pennsylvanian limestones and shales. Similar smaller collapsed structures occur in the Bee Branch-Mill Creek area (Plate I).

### Chappel Formation

The Chappel formation was named by Sellards (1933, p. 91) for exposures on Chappel Road six miles northwest of the town of Chappel.

The Chappel limestone consists of large crinoid fragments embedded in a fine, granular matrix which is usually pure white but occasionally rose-colored. The Chappel limestone is from a fraction of a foot thick to over 50 feet thick. At one locality green chert was found associated with the Chappel limestone.

Don Winston (Personal Communication) believed that this green chert is reworked Devonian chert. This suggests that the Caballos novaculite probably extended east of the Pecos River at one time because it is the probable source of the chert. This occurrence of green chert may represent a trace of the basal Mississippian Ives Breccia.

## Barnett Shale

The Barnett shale overlies the Chappel limestone unconformably. The name "Barnett" was applied to this formation by Plummer and Moore (1922, p. 24) from excellent exposures just north of Barnett Falls and Barnett Springs in San Saba County.

The Barnett formation is composed of shales and subordinate limestone, having an average thickness of approximately 25 feet in the thesis area. Caliche overlying Barnett shale is exposed in a pit approximately one and one-half miles south of the intersection of Ranch Road 1871 and Mill Creek Road.

The outcrop of the Barnett shale forms a narrow dark band on aerial photographs due to the dense growth of mesquite, blue brush, agarita, and thorny bushes on the outcrop. This band of dense vegetation is found consistently outlining the major structural depression which is adjacent to the Honey Creek fault. Where the Chappel limestone has been eroded away, the Barnett rests on the Gorman formation of the Ellenburger group. The Barnett shale is also found outlining the outer periphery of numerous smaller synclinal depressions in the thesis area.

PLATE IV

BARNETT FORMATION

Figure 1

Figure 2

Figure 1.....Shows the thick growth of vegetation on the Barnett formation and the sparse growth of vegetation on the underlying Ellenburger limestone.

Figure 2.....Barnett caliche pit approximately one mile south of Ranch Road 1871 along Mill Creek Road.

## PENNSYLVANIAN SYSTEM

In the Llano area the Pennsylvanian System consists of the Marble Falls group and the Smithwick shale. Hill (1889, p. 289) used the term "Marble Falls" for exposures of "encrinital" limestone near Marble Falls on the Colorado River. Paige (1911, p. 55-56) gave the name "Smithwick" to the shales in the upper part of the type section of the Marble Falls. Plummer's (1950, p. 47) classification of the formations of Early Pennsylvanian age is as follows:

| SERIES | GROUP | FORMATION |
|---|---|---|
| BEND | | SMITHWICK |
| | MARBLE FALLS | BIG SALINE |
| MORROW | | SLOAN |

In the thesis area the Marble Falls group was mapped as one unit and the overlying Smithwick shale as another.

### Marble Falls Group

In the Bee Branch-Mill Creek area the Marble Falls limestone is easily recognized on aerial photographs due to its stratigraphic position below the dark, narrow band that is distinctive of the Smithwick contact in the area. The Smithwick is present only along the synclinal depressions that are adjacent to the Honey Creek fault in the thesis area. The center of the smaller structural sinks in the Bee Branch-Mill Creek area often consists of Marble Falls limestone.

PLATE V

MARBLE FALLS LIMESTONE DIPPING TOWARD AXIS OF ELONGATED STRUCTURAL DEPRESSION ABOUT A QUARTER OF A MILE WEST OF "DIM ROAD" ON MELVIN CAPPS' RANCH.

The limestone is mostly dark grey, fine-grained, and stratified in beds one foot or less in thickness. A detailed, measured section is given in the appendix. Occasional nodules and thin beds of chert are found. In the upper part of the Marble Falls limestone a few thin shale beds are present. Fossils are found in great abundance in many of the limestone beds. There are a great number of corals, brachiopods, fusulinids, and crinoid fragments.

## Smithwick Formation

The Smithwick formation includes the black shale beds above the Marble Falls formation and below the sandstones and shales of the Strawn group (Middle Pennsylvanian), according to Cheney (1940, p. 80). Paige (1911) states that the type section includes the black shales and lenticular sandstone strata exposed in the Burnett quadrangle stratigraphically between the Marble Falls formation and the overlying Cretaceous deposits east of Marble Falls.

The Smithwick shale occurs in the center of the structural depressions surrounded by the Marble Falls limestone. The structural depressions are associated with the Honey Creek fault. Recent alluvium deposited by Bee Branch-Mill Creek has covered much of the shale. In the Bee Branch Depression the highest topographic bench caused by outcropping of shale was selected as the Marble Falls-Smithwick contact. From this contact down to the bottom of the structural depression there is a slope resulting from the weathering and erosion of shale with a few thin beds of limestone exposed.

It is questionable as to whether this shale is equivalent to the Smithwick shale of Paige and Cheney or is equivalent to the upper part of the Marble Falls group. Blank (Personal Communication) believed that this shale is the Smithwick shale. He pointed out that it contained several prominent buff-colored beds that were characteristic of the Smithwick shale. Don Winston (Personal Communication) pointed out that the top of the Marble Falls consists of a shale in this region. He correlated this shale with other upper Marble Falls shales on the bases of fossils and prominent limestone beds. Smithwick shale of the measured section listed in the appendix is included in the Marble Falls limestone by Don Winston.

Showing this shale as a separate rock unit on the geologic maps (Plates I and II) brings out the structure of the Bee Branch Depression. Although there is some uncertainty about the identification of this unit, it is arbitrarily placed in the Smithwick. The outer rim of the depression is composed of Ellenburger, Chappel and Barnett limestone, with the younger Marble Falls and Smithwick sediments composing the center of the structural low.

The approximate line of the measured section of 140.5 feet of the shale is shown on Plates I and VII. A lithologic description of the Smithwick shale in the measured section is given in the appendix. The thickness of the formation is not known because the section terminates at a fault.

## CRETACEOUS SYSTEM

With the exception of the recent stream deposits, the Cretaceous sediments are the youngest exposed in the area. The Cretaceous sediments in the Bee Branch-Mill Creek area are exposed in one small outlier approximately one and one-half miles east of the northeast edge of the Blue Mountains. The Lower Cretaceous sediments making up this outlier consist of red and black residual soil derived from the Cretaceous limestone. These sediments are only a few feet thick and rest unconformably on Ellenburger dolomite.

This section of the thesis area is relatively flat and contains the only cultivated field in the Bee Branch-Mill Creek area.

On aerial photographs the prolific growth of grass on this outlier is lighter in color than the sporadic vegetation that is on the surrounding Ellenburger dolomite.

QUATERNARY SYSTEM

In the thesis area the recent stream deposits are found along the Llano River, Bee Branch, and Mill Creek. The recent alluvium consists mostly of black soil derived from the Ellenburger dolomites and limestones.

PLATE VI

SILTY SOIL OF WEATHERED CRETACEOUS OUTLIER (BOTH IN THE FOREGROUND AND THE DARK-COLORED CULTIVATED FIELD IN THE CENTRAL PART OF THE PHOTOGRAPH)

# STRUCTURAL GEOLOGY

## REGIONAL STRUCTURE

Considered as a unit, the structure of the Llano uplift is an elongated dome. Precambrian granite is in the exposed center of the topographic basin. The exposed rocks surrounding the Precambrian core consist of more resistant Paleozoic and Cretaceous carbonates.

The distinctive structural characteristic of the Llano region is the great number of faults striking northeast-southwest. These nearly vertical normal faults with a throw ranging from a few feet to 1800 feet are most abundant on the western side of the uplift.

Cheney (1929, 1940) described the area as a stable region which consistently occupied a position slightly below or above sea level. Cheney (1929, p. 582) contended that the influence of the Precambrian core has been overemphasized in the development of regional structures. Cheney (1929) and Plummer and Moore (1921) considered the structure found in the Central Mineral region the result of isostatic adjustment. The folding that produced the Ouachita folded belt is believed by Barnes (1956, p. 13) to have been contemporaneous with the formation of the normal faults in the Llano region. The major late Paleozoic faulting took place before Canyon time, according to Cloud and Barnes (1948, p. 121).

## LOCAL STRUCTURES

### General Relations

The most prominent structure in the Bee Branch-Mill Creek Area is the northeast-trending Honey Creek fault. Numerous steeply dipping normal faults branch from the Honey Creek fault. Geographically associated with the faulting in the area is a structural depression referred to as the "Bee Branch Depression" in this thesis. Flat-lying Cretaceous strata have not been affected by faulting or folding in the area.

## Faults

The Honey Creek fault transverses the Bee Branch-Mill Creek Area in a northeastern direction. This major fault was called the "Mason" fault by Plummer (1950) on his Geologic Map of the Carboniferous Formations in the Llano Region, Texas. On the geologic map of the Bear Spring Area, Mason County, Texas by Cloud and Barnes (1948) this fault was called the "Honey Creek" fault. Although Plummer's map is dated 1943, it was not issued until 1950, after the map of Cloud and Barnes issued in 1948. The name "Honey Creek" has priority because it was first used in published literature. The detailed map of the Bear Spring area on which this fault was first named overlpas the thesis area.

Most of the faults in the Bee Branch-Mill Creek Area are found in the northern half, as shown on Plates I and VII.

The San Saba and the Point Peak members of the Wilberns formation are faulted against the Gorman formation and the Marble Falls group in the northeastern section of the area, where they occur along the Honey Creek fault. This relationship indicates a throw of approximately 1200 feet for the Honey Creek fault. In the vicinity of Capps' pond (see Plate VII) a belt 30 yards wide and 200 yards long composed of boulders of Tanyard limestone separates the Marble Falls limestone from the San Saba limestone. The Honey Creek fault and the faults that branch from this major fault are high-angle, normal faults. Topography does not affect the rectilinear trace of the major faults. Four faults branch from the Honey Creek fault in a northeastern direction, and two faults leave the main fault in a sourthwestern direction.

The field criteria for mapping the faults consisted of first locating rectilinear lines of vegetation on aerial photographs and then determining if there were two different formations in juxtaposition on sides of the line of vegetation. The determination of a fault was simple when limestone was faulted against shale or dolomite, or when the sandy limestone beds of the San Saba were adjacent to the sublithographic limestone of the Ellenburger group; but where limestone of the Ellenburger group is brought against another limestone member of Ellenburger, the problem is more difficult. The problem of determining a fault trace separating on the one side Ellenburger dolomite from Ellenburger limestone on the other is almost as difficult, particularly where the limestone and dolomite are both laterally and vertically gradational. The fault trace on the map with question marks represents what is believed to be a fault that is obscured in the field because the Ellenburger carbonates on both sides grade laterally and vertically from dolomite to limestone, and limestone to dolomite.

## Bee Branch Depression

### Explanation of Terms

Cloud and Barnes (1948, p. 51) call the collapse or solution features that have the structure, but not the topographic expression of sinks, "structural sinks". This usage is followed in this thesis. The area where both a topographic and structural depression exists is referred to as the "Bee Branch Depression". The eastern half of the Bee Branch

Depression is referred to as a "syncline" since it contains two limbs that dip toward each other.

### General Relations

The Bee Branch Depression is both a topographic and a structural low with its center approximately two miles west-southwest of White's crossing on the Llano river (see Plates I and VII). The long axis of this depression extends for two and a half miles in a general east-west direction. The Bee Branch Depression is outlined by a thin band of Barnett shale on the north side and on the south by the Honey Creek andthe Mill Creek faults.

### Eastern Half of the Bee Branch Depression

The eastern half of the Bee Branch Depression is a syncline whose structure has been complicated by faulting. On the north side of the Honey Creek fault Mississippian and Pennsylvanian beds dip from 15 to 50 degrees toward the south. The attitude of the Ellenburger limestone adjacent to the syncline is slightly erratic. The dips in the Ellenburger dolomite 1000 feet north of the syncline are very erratic. However, the bedding of the dolomite has been obscured or completely destroyed by weathering or by dolomitization; therefore, the dips obtained on the Ellenburger dolomite are not as reliable as those of the Ellenburger limestone. Furthermore, some of the irregular strikes and dips found in the dolomite are undoubtedly due to the slumping of dolomite into solution cavities in other Ellenburger carbonates or due to dolomitization.

The Ellenburger dolomite mapped to the north of the thesis area by Cloud and Barnes (1948) indicates that the dolomite and the limestone

PLATE VIII

SYNCLINE COMPOSED OF MARBLE FALLS LIMESTONE

Figure 1

Figure 2

Figure 1.....Shows Marble Falls limestone dipping 40 degrees to the south. This photograph was taken about 100 yards west of "Dim Road" on Melvin Capps' Ranch.

Figure 2.....Shows Marble Falls limestone dipping 15 degrees to the north. Figure 2 was taken about 30 feet north of Figure 1.

in this adjoining area has a prevailing dip toward the southeast. In the thesis area the prevailing dip of all the formations is toward the southeast. Where strike and dip measurements were taken a few tens of feet on either side of a fault, the dips obtained were from two to six degrees toward the southeast. The Mississippian and Pennsylvanian strata dip to the south at 15 to 60 degrees on the south side of the Barnett shale. These relations of strikes and dips taken on the Ellenburger limestone exposed on the north side of the Bee Branch Depression and the Carboniferous strata strongly suggest that the strata north of the outcrop of the Barnett formation have not been involved in the movements that caused the steeply dipping altitude of the Carboniferous strata south of the exposure of Barnett formation.

Two parallel faults, one approximately 200 feet and the other 400 feet north of the Honey Creek fault, dissect the syncline. Another small fault terminates the south side of the syncline. In plan view the northern fault is the most prominent. The curving outcrop pattern of the Smithwick shale ends abruptly at this fault. The small throw of this fault is shown by Marble Falls limestone being brought against Smithwick shale. This fault is further distinctive when observed in plan view because it has the only fault trace in the thesis area that shows apparent offset. The fact that the topography has offset this fault trace indicates that its fault plane is not dipping as steeply as the rest of the fault planes in the area.

The fault, intermediate between the Honey Creek fault and the previously described northern fault, is not as obvious as it appears on the map, because the Marble Falls limestone is faulted against Marble Falls limestone. In the field this fault is expressed by a very prominent fault line scarp. This fault scarp shows up equally well when viewed on aerial photographs with a stereoscope. The two exposures of Marble Falls limestones brought against each other are believed to be of different ages because there appears to be beds missing that are in the Marble Falls' section by Don Winston (Personal Communication). A geologic section of the Pennsylvanian strata found in this syncline is given in the appendix. This section was measured, painted, and described in conjunction with Don Winston. Winston (Personal Communication) planned to measure at least two more sections of the well-exposed Marble Falls limestone in the Bee Branch Depression.

On the south side of the Honey Creek fault, the Barnett shale, the Chappel limestone, and the Ellenburger carbonates have a dip of from 20 to 40 degrees to the east-northeast, north, and west-northwest. These folded strata can be traced almost continuously on the surface. They are the remains of the south side of the syncline. The folded strata of this syncline are terminated by a fault. South of this fault the San Saba limestone is not folded.

### Western Half of the Bee Branch Depression

The Carboniferous strata in the western half of the Bee Branch Depression dip to the south, toward the Honey Creek fault, at angles varying from 20 to 50 degrees. The western part of the Carboniferous exposure lies completely to the north of the Honey Creek fault. Small synclinal undulations are found within the Marble Falls part of the exposure, as shown by the strike and dip symbols on Plate VII and the symbols showing the plunge of the synclinal axis. Apparently the western part of the Bee Branch Depression had strata dipping in toward the major fault on both sides before the south side was uplifted and eroded. This is suggested by the half-circle formed by the Chappel limestone where it is terminated by the Mill Creek fault (see Plate VII).

## Theories on the Formation of the Bee Branch Depression

### General Statement

There seem to be only three theories that can explain the origin of the Bee Branch Depression. The theories are as follows:

(1) Drag due to fault movement
(2) Tectonic folding
(3) Folding due to solution

### Summary of Data

The data that must be considered in determining the origin of the depression are as follows:

(1) Plummer's (1950) map of 1943 shows the Bee Branch Depression and another depression, named the "Honey Creek syncline" by Cloud and Barnes (1948, p. 121) extending from White's Crossing six and a half miles northeast along the north side of the Honey Creek fault.

(2) The southwestern two miles of the Honey Creek syncline is mapped in detail on the Bear Spring Map of Cloud and Barnes (1948, plate 5).

(3) The synclinal nature of both depressions is indicated by the outcrop pattern shown on Plates I and VII and on the maps of Plummer and Cloud and Barnes and as previously described in detail for the Bee Branch Depression.

(4) The regional dip of the Limestones of the Ellenburger group on the north side of the Bee Branch Depression is 2 to 6 degrees to the southeast. On the north side of the Honey Creek syncline, the dip of the Ellenburger

group is about the same to the south.

(5) The dips of the beds of the Ellenburger group on the north side of the Bee Branch Depression near the Carboniferous outcrops are about 10 degrees, although the attitude of the beds is slightly erratic. A similar attitude of the Ellenburger beds is shown on Cloud and Barnes' map for a portion of the Honey Creek Syncline.

(6) The Carboniferous on the north side of the Honey Creek fault in both depressions dips 15 to 50 degrees toward the fault.

(7) On the south side of the eastern end of the Bee Branch Depression both the beds of the Ellenburger group and the Carboniferous formations dip from 35 to 45 degrees toward the Honey Creek fault.

(8) The axial alignment of the fold in Fuller and Wilson's (Personal Communication) thesis area is north-northeast. In Sweet's (Personal Communication) area the direction of alignment of the fold axis is north. In Grote's thesis area the anticlinal axis is apparently northeast.

(9) About five miles west of White's Crossing on the Llano River, one north and one south of the river, two areas of carboniferous rocks are located as determined by Plummer (1950, Plate I). The outcrop pattern as determined by Plummer is such that it may be due either to topography or to structure. If it is controlled by structure, there is a synclinal structure which has a north-south axis which, when followed north, changes strike to northeast and adjoins the anticlinal structure found by Grote.

(10) According to Cloud and Barnes (1948, p. 121), the axes of many of the folds in the Llano area are aligned in a northwest-southeast direction although alignments in other directions also occur.

(11) The Bee Branch Depression is doubly plunging elongated basin fold

with canoe-shaped ends that has been faulted. The inferred location of the axis and its indicated direction of plunge, as shown on Plate VII, indicates that the axis undulates with three minor basins and two minor domes.

(12) The location of the Honey Creek fault coincides with the southern side of both the Bee Branch Depression and the Honey Creek syncline.

### Drag Due to Fault Movement Theory

Drag along the Mill Creek and Honey Creek faults has been suggested as one of the possible theories for the formation of the Bee Branch Depression.

On the north side of the depression the strata dip to the south. The strata on the south side of the fault are on the down-thrown side of these two major normal faults. The drag expected on this type of faulting would produce dips toward the north. The observed dips to the south are between 20 and 50 degrees. Since the folding is truncated by faulting, the Bee Branch Depression and the Honey Creek syncline are older than the Honey Creek fault. The fact that the curved contact of the Chappel limestone and the Smithwick shale are found only on one side of a fault, also indicates that folding was done prior to faulting. Furthermore it is difficult to develop two canoe-shaped ends by this theory. Normally, drag does not extend out far enough from a fault to account for the depressions.

### Tectonic Folding Theory

There is a possibility that the slightly warped areas observed in other parts of the Llano uplift and the steeply-folded Bee Branch depression are associated. Cloud and Barnes (1948, p. 121) apparently believed that small pronounced folds they have seen are of tectonic origin, but they are uncertain as to their relationship to the uplift of the Llano area. Although Cloud and Barnes (1948, p. 121) noted and named the Honey Creek Syncline, they did not definitely state the origin of the fold or the minor structures on its northwest limb.

Grote (1954, p. 35) described what appeared to be an anticline plunging to the southwest. A synclinal fold is suggested by the outcrop pattern of the Lion Mountain sandstone and the Hickory sandstone, where the thesis areas of Wilson (1957) and Fuller (1957) overlap about five miles south of Mason. The dips observed by Wilson and Fuller (Personal Communication) and by Grote (1954, p. 35) are erratic on the limbs of the proposed folds. However, they state that the trend of the dips suggests the presence of the folds. Sweet has found a gentle synclinal fold within a graben-like fault block in the Katemcy-Voca area north of Mason. Sweet (Personal Communication) indicates that there is a lack of a definite pattern of the dips on the eastern limb of the fold. Dr. H. R. Blank (Personal Communication) pointed out on a mosaic of the Llano uplift that numerous outcrop patterns also suggest the presence of numerous small, warped areas.

The tectonic fold theory offers an explanation of the Bee Branch Depression, but does not fully explain the following characteristics of the depression and the adjacent structures: (1) The folds attributed definitely to tectonic development have generally had very gentle dips. (2) Such steeply double-plunging folds as the Bee Branch Depression and the Honey Creek Syncline resemble some Appalachian folds and adjacent folds of similar development would be expected. (3) The unusual undulation of the axis of the Bee Branch Depression with frequent change in direction of plunge is difficult to explain by this theory alone. (4) The beds of the Ellenburger group adjacent to the folds appear to be involved only locally in the folding.

On the other hand, a tectonic origin for the fold originating on the site of a prior collapse due to loss of some support as a result of solution of some of the underlying strata offers an adequate explanation of the structure. Barnes (Personal Communication, March, 1957) has stated that the Honey Creek syncline is purely a structural feature of tectonic origin. He further stated that while in a sense it is a collapsed area, it is not an area of collapse from solution of underlying rocks.

## Solution Theory

A concise account of the solution structures that developed in the Gorman formation is given by Cloud and Barnes (1948, p. 51). Part of their explanation and description of these structures is given below:

> "The Chappel limestone of the eastern areas overlaps the Honeycut formation, whereas that of the western areas overlaps limestone of the Gorman formation. The limestones of the Gorman are characteristically the most readily soluble part of the Ellenburger sequence. Throughout the Llano region their area of outcrop is more commonly marked by solution crevasses and small caves than any other part of the section, and the only large caves known in the Llano region (Longhorn Cavern and Richland Spring Cavern) are in the upper limestone of the Gorman formation.....It is evident from their lithic character attitudes, and distribution that these limestones were not deposited as detrital fillings of ordinary sinks. Rather they have been let down from an original subhorizontal attitude, concomitantly with solution, or have fallen into caves that developed by solution,

mainly before Barnett time, of the limestone of the Gorman formation below."

Beginning at Capps' pond and extending east for at least two hundred yards along the Honey Creek fault trace, there is a zone approximately thirty yards wide where boulders of Tanyard limestone separate the Marble Falls limestone from the San Saba limestone. This indicates that the Honey Creek fault created a fractured zone that was partially open.

Barnes (1948, p. 51) stated that the solution structures developed prior to Barnett time. This is shown where the Chappel limestone is found in the sinks but is absent immediately adjacent to these sinks. In the Bee Branch Depression the Chappel limestone is found only sporadically outside of the Barnett shale.

From the above discussion of the Bee Branch Depression the following hypothesis for the formation of the Bee Branch Depression is given:

(1) A solution cavity with a length of over three miles and a width of over a mile was formed on the Gorman formation before the deposition of the Chappel limestone. (2) The Chappel limestone was deposited over the Llano region. Erosion removed the Chappel limestone that was not deposited in the Gorman sinks in the western part of the uplift. (3) Later Carboniferous strata were deposited on the Chappel limestone. According to Cloud and Barnes (1948, p. 52), the limestones have been let down from an original subhorizontal attitude, concomitantly with solution. Cloud and Barnes were referring to the Chappel limestone where it has been folded down into "structural sinks". In the Bee Branch Depression the Barnett formation, the Marble Falls limestone, and the

Smithwick shale would have been let down into the depression. (4) The Bee Branch Depression was displaced by the Honey Creek fault after the deposition of the Smithwick shale and before the Cretaceous was deposited. (5) It follows that if the Gorman limestone and dolomite were susceptible to the action of surface waters in forming sinks on its exposed surface, circulating ground water would have a similar effect. The sublithographic limestone of the Gorman is not jointed; its permeability is very low. The presence of boulders of Tanyard limestone containing "open" Lytospria gyrocera shows that free circulation of water could have taken place along the Honey Creek fault. This open fracture probably extended the length of the Bee Branch Depression. The circulation of ground water along this "open" fracture could have dissolved the Gorman limestone where-ever it could circulate. This was between the Chappel limestone and the Gorman limestone. As the Gorman limestone was dissolved, the overlying strata sank down into it. This process would have to be slow enough to allow the strata to fold rather than shear. (6) The strata are now dipping from 30 to 50 degrees toward the Honey Creek fault. The steep dip of the strata and the fact that the three small faults are gravity faults due to slumping. On the other hand, these small faults probably are associated with the Honey Creek fault.

The undulations of the axis of the Bee Branch Depression might have been more easily formed by solution and slow slumping than by tectonic force. The structure is older than the faulting since it is truncated by faults. This relationship is also true for the structures found in the Bear Springs Area, and in theris areas of Sweet, Grote, and Wilson and Fuller. If the structures found in these areas are all part of a large structure, the major force involved in the formation of this structure was undoubtedly tectonic. The minor folds on the flank of the Honey Creek syncline are more logically of tectonic formation than of solution and slumping origin. The tectonic origin of the c folds and the Honey Creek syncline makes it likely that the Bee Branch Depression is of similar origin and should therefore be called the Bee Branch syncline.

# GEOLOGIC HISTORY

## GENERAL STATEMENT

The geologic history of the twenty square miles in the Bee Branch-Mill Creek area is contained in the more ample record of the Llano region. The processes that have operated in the thesis area are apparently the same as those that have affected the overlapping Bear S ring's area of Cloud and Barnes (1948). Therefore the geologic history is discussed both in terms of the Llano uplift and more specifically in the thesis area and the overlapping Bear Spring area.

## PALEOZIC ERA

The geologic history of the Bee Branch-Mill Creek area is recorded in approximately 1500 feet of exposed strata. According to Cloud and Barnes (1948, pp. 28, and 186) the Bear Springs area exhibits the following thickness of strata:

| | Thickness in feet |
|---|---|
| Lower Ordovician | |
| Ellenburger group (total) | 973 |
| Honeycut formation (total) | - |
| Gorman formation (total) | 450 |
| Calcitic facies | 237 |
| Dolomitic facies | 213 |
| Tanyard formation (total) | 523 |
| Staendbach member | 229 |
| Calcitic facies | - |
| Dolomitic facies | 229 |
| Threadgill member (total) | 294 |
| Dolomitic facies | - |
| Calcitic facies | 294 |
| Upper Cambrian | |
| Wilberns formation (total) | 561 |
| San Saba limestone | 260 |
| Stromatolitic Bioherms | 41 |
| Point Peak shale | 115 |
| Morgan Creek limestone | 120 |
| Welge sandstone | 25 |

In the thesis area the Welge sandstone and the lower part of the Morgan Creek limestone are not exposed.

The great abundance of Paleozoic carbonates, the present of bioherms, intraformational conglomerates, glauconite, and chert all suggest that the strata were deposited in shallow seas. These deposits became consolidated by cementation and compaction.

## Cambrian Period

At the beginning of the Paleozoic Era the surface upon which the sediments were deposited had a relief of about 800 feet, according to Barnes (1956, p. 8). This erosional surface was developed throughout Lower and Middle Cambrian time. The oldest Paleozoic sediment found in the Llano region is the Hickory sandstone. The Hickory sandstone is comparable to the LaMotte or basal sands and quartzites that separate the Upper Cambrian from the Precambrian in the Ozarks. The deposition of the Hickory sandstone was followed by deposition of the Cap Mountain limestone. The calcareous deposits of the Cap Mountain limestone grades upward into the Lion Mountain sandstone. These three members of lowermost Upper Cambrian (Riley formation) are not exposed in the area mapped. The various authors that have described these deposits are referred to in the "Previous Investigations".

The Riley formation is overlain by the Wilberns formation. This formation of Late Cambrian indicates a continuation of the shallow sea deposition that began in the Riley formation. The abundance of glauconite granules that characterized the Riley formation became more abundant during the deposition of the Wilberns. The intraformational conglomerates contained in both the Point Peak shale and the San Saba formation and the presence of both small and huge bioherms all suggest that the Wilberns sea was shallow in the Llano area.

## Ordovician Period

According to Cloud and Barnes (1948, p. 32), the Ellenburger group is 970 feet thick in the Bear Spring area of western Mason County. Its maximum thickness of approximately 1820 feet is in the southeastern corner of the Llano uplift. Cloud and Barnes (1948, p. 32) attributed the thinning of the Ellenburger to pre-Devonian truncation that appears to have completely removed the Honeycut formation west of western San Saba County.

Glauconite is essentially absent in the Ellenburger limestone and dolomites. Chert is plentiful. The presence of ripple marks and stromatolitic limestone indicates a shallow water environment for the Ellenburger group of Early Ordovician Age.

## Silurian and Devonian Periods

No rocks of Silurian age have been recognized in the Llano region. Barnes, Cloud, and Warren (1945, 1947) recognized three formations of Devonian age. They arethe Zesch formation, Bear Springs formation, and Pillar Bluff limestone. The Zesch and the Bear Springs formations occupy a portion of a collapse structure in the Bear Springs area, Cloud and Barnes (1948, p. 159). A green chert found in the Bee Branch depression mixed with Chappel limestone was believed by Don Winston (Personal Communication) to be reworked Devonian chert. A wide spread unconformity separates the Devonian and Mississippian.

## Pennsylvanian Period

During Pennsylvanian time, it is believed by Barnes (1948, p. 118) that the faulting in the Llano region accompanied the folding of the Ouachita trough. The combined thickness of Cambrian, Ordovician, Silurian, and Devonian sediments in this trough is approximately 3,000 feet. During the Lower Pennsylvanian at least 34,000 feet of sediments were deposited in the subsiding Ouachita trough or geosyncline.

The Marble Falls and the Smithwick shale comprise the Pennsylvanian strata deposited in the Llano uplift. The Marble Falls limestone has a thickness of at least 1625 feet in the thesis area and grades upward into the Smithwick shale.

The Marble Falls limestone and Smithwick shale are of Bend age. They have been faulted, but according to Barnes (1956, p. 9), the Canyon rocks in the northwestern part of the uplift are not faulted. This indicates that the orogency occurred between Bend and Canyon time, chiefly during the Strawn. It was during this time that the folds were probably formed in the thesis areas of Wilson and Fuller, Sweet, and Grote as well as in the Honey Creek syncline and the Bee Branch Depression.

# MESOZOIC ERA

## Cretaceous Period

The Cretaceous outlier found in the Bee Branch-Mill Creek area has not been affected by either folding or faulting. Apparently the essentially horizontal attitude of deposition is still maintained in the Cretaceous strata. Stream channels were established on the Cretaceous and were superimposed on the Paleozoic.

## REFERENCES

Alexander, W. L. (1952) Geology of the South Mason Area, Texas, M.S. Thesis, Agricultural and Mechanical College of Texas, August, 1952, pp. 48.

Barnes, V. E. (1956) Lead Deposits in the Upper Cambrian of Central Texas, Texas Univ., Bur. Econ. Geology Pub. Inv., No. 26, pp. 1-68.

__________, Cloud, P. E., and Duncan, Helen (1953) Upper Ordovician of Central Texas, Amer. Assoc., Petrol. Geol. Bull. Vol. 37, pp. 1030-1043.

__________, (1944) Gypsum in the Edwards Limestone of Central Texas, Texas Univ., Bur. Econ. Geology Pub. 4301, pp. 35-46.

__________, and Parkinson, G. A. (1939) Dreikanters from the Basal Hickory sandstone of Central Texas, Texas Univ., Bur. Econ. Geology Bull. 3945, pp. 665-670.

Bridge, Josiah (1937) The correlation of the Upper Cambrian sections of Missouri and Texas with the section in the upper Mississippi Valley, U.S. Geol. Survey Prof. Paper 186-L, pp. 233-237.

__________, and Girty, G. H. (1937) A Redescription of Ferdinand Roemer's Paleozoic types from Texas, U.S. Geol. Survey Prof. Paper 186-M, pp. 239-271.

__________, and Barnes, V. E., and Cloud, P. E., Jr. (1947) Stratigraphy of the Upper Cambrian, Llano Uplift, Texas, Geol. Soc. Am. Bull., Vol. 58,, pp. 109-124.

Buckley, S. B. (1847) First annual report of the Geological and Agricultural Survey of Texas, Houston.

Cheney, M. G. (1940) Geology of North-Central Texas, Amer. Assoc., Petrol. Geol. Bull., Vol. 24, pp. 65-118.

Cloud, P. E., Barnes, V. E., and Bridge, Josiah (1945) Stratigraphy of the Ellenburger Group of Central Texas, progress report, Texas Univ., Bur. Econ. Geology Pub. 4301, pp. 133-161.

__________, and Barnes, V. E. (1948) The Ellenburger Group of Central Texas, Texas Univ., Bur. Econ. Geology Pub. 4621, 473, pp., 8 figs., 45 plates.

Comstock, T. B. (1890) A preliminary report of the geology of the Central Mineral Region of Texas, Texas Geol. Survey, 1st Ann. Rept. (1889), pp. 235-391.

Cummins, W. F. (1890) The southern border of the central coal field, Texas, Texas Geol. Survey 1st Ann. Rept. (1889), pp. 143-182.

Dake, C. L., and Bridge, J. (1932) Faunal Correlations of the Ellenburger Limestone of Texas, Geol. Soc. Am. Bull., Vol. 43. pp. 725-748.

Darton, N. H., Stephenson, L. W., and Gardner, Julia (1937) Geologic Map of Texas, U.S. Geol. Survey.

Deen, A. H. (1931) Cambrian Algal reefs of Texas, (Abst.), Geol. Soc. Am. Bull., Vol. 42, p. 368.

Dumble, E. T. (1890) Report of the State Geologist for 1889, Texas Geol. Survey, 1st Ann. Rept. 1889, pp. XVII-LXXV.

__________, (1890) Physical geography, geology, and resources of Texas, in Wooten, D. G., A comprehensive history of Texas, Vol. 2, pp. 471-516.

Girty, G. H. (1919) The Bend formation and its correlation, Amer. Assoc. Petrol. Geol. Bull., Vol. 3, pp. 71-81.

__________, and Moore, R. C. (1919) Age of the Bend series, Amer. Assoc. Petrol. Geol. Bull., Vol. 3, pp. 418-420.

Grote (1954) Structural Geology of the Central Bluff Creek Area, Mason County, Texas, M.S. Thesis, Agricultural and Mechanical College of Texas, pp. 1-44.

Hill, R. T. (1889) A portion of the geologic story of the Colorado River of Texas, Am. Geol., Vol. 3, pp. 287-299.

__________, (1890) Classification and origin of the chief geographic features of the Texas region, Am. Geol., Vol. 5, pp. 9-29, 68-80.

Keppel, D. (1940) Concentric patterns in the granites of the Llano-Burnet Region, Texas, Geol. Soc. Am., Bull., Vol. 51, No. 7, pp. 971-999.

Liddle, R. A., The geology of the San Saba Reservoir, Texas State Board of Water Engineers, 40 pp., (unpublished).

Marcou, Jules (1855) Le Terrain Carbonifere Dans L'Amerique du Nord, Tire de La bibl. Universelle de Geneve, pp. 1-23.

Paige, Sidney (1911) Mineral resources of the Llano-Burnet region, Texas, with an account of the pre-Cambrian Geology, U.S. Geol. Survey, Bull., Vol. 450, 103 pp., 22 figs., 5 plates, maps.

__________, (1912) Description of the Llano and Burnet Quadrangles, U.S. Geol. Survey, Geol. Atlas, Llano-Burnet folio No. 183, 16 pp.

Plummer, F. B., (1943) A new quartz sand hori on in the Cambrian of Mason County, Texas, Texas Univ., Bur. Econ. Geology, Circ. 22.

__________, (1946) Texas water resources, Texas Univ., Bur. Econ. Geology Bull. 4310, pp. 310-312.

__________, (1950) The Carboniferous rocks of the Llano Region of Central Texas, Texas Univ., Bur. Econ. Geology Bull. 4329, 117 pp., 14 figs., 22 plates, 4 charts.

__________, and Moore, R. C. (1922) Stratigraphy of the Pennsylvanian formations of North-Cent al Texas, Texas Univ., Bur. Econ. Geology Bull. 2132, 236 pp., 19, figs., 27 plates.

Roemer, Ferdinand (1946) A sketch of the geology of Texas, Am. Journ. Sci. (2), Vol. 2, pp. 358-365.

__________, (1848) Contributions to the geology of Texas, Am. Jour. Sci. (2), Vol. 2, pp. 21-28.

__________, (1849) Texas, mit besonderer Rucksicht auf deutsche Auswanderung und die physichen Verhaltnisse des Landes, 464 pp., Bonn.

__________, (1852) Die Kreidelbildungen von Texas und ihre organischen Einschlusse, 110 pp., 11 plates, Bonn. Adolph Marcus.

Roundy, P. V., Girty, G. H., and Goldman, M. I. (1926) Mississippian formations of San Saba County, Texas, U.S. Geol. Survey Prof. Paper 146, 63 pp., 1 gig., 33 plates.

Sellards, E. H. (1932) The pre-Paleozoic and Paleozoic systems in Texas, in The geology of Texas, Vol. 1, Stratigraphy, Texas Univ., Bur. Econ. Geology Bull. 3232, pp. 15-238.

__________, (1934) Major structural features of Texas east of Pecos River, Texas Univ., Bur. Econ. Geology Bull. 3401, pp. 11-136.

Shumard, B. F. (1861) The Primordial Zone of Texas, with descriptions of new fossils, Am. Jour. Sci., (2) Vol. 32, No. 95, pp. 213-221.

__________, (1863) Descriptions of new Paleozoic fossils, St. Louis Acad. Sci. Trans., Vol. 2, pp. 108-113.

__________, (1886) A partial report on the geology of western Texas, 145 pp., State Printing Office, Austin, Texas.

Sliger, K. L. (1957) Geology of the Lower James River Area, Mason County, Texas, M. S. Thesis, Agricultural and Mechanical College of Texas, (in preparation).

Stenzel, H. B. (1932) Pre-Cambrian of the Llano Uplift, Texas, Geol. Soc. Am., Bull., Vol. 43, pp. 143-144.

________ (1935) Pre-Cambrian Unconformities in the Llano Region, Texas Univ., Bur. Econ. Geology Bull. 3501, p. 115.

Tarr, R. S. (1890) Origin of some topographic features of Central Texas, Am. Jour. Sci. (3), No. 239, art. 39, pp. 306-311.

________ (1890) Superimposition of the drainage in Central Texas, Am. Jour. Sci. (3), No. 239 art. 40, pp. 359-362.

Udden, J. A., Baker, C. L., and Bose, Emil (1916) Review of the geology of Texas, Texas Univ., Bur. Econ. Geology Pub. 44, 164 pp.

Walcott, C. D. (1884) Notes on Paleozoic rocks of Central Texas, Am. Jour. Sci. (3), Vol. 28, pp. 431-433.

# APPENDIX

MEASURED SECTION OF SMITHWICK FORMATION AND MARBLE FALLS LIMESTONE IN THE BEE-BRANCH DEPRESSION

The Marble Falls group and the Smithwick formation were measured, painted, and described in conjunction with Don Winston and Pete Rose. Don Winston is making a study of the Carboniferous for his doctor's dissertation at the University of Texas.

The approximate line of the section is shown on the map, Plate I.

PENNSYLVANIAN SYSTEM

| Smithwick formation: | Thickness In Feet |
|---|---|
| 16. Limestone, deep-tan, homogeneous, microgranular, breaks with conchoidal fractures, probably silty, weathering deep-tan . . . . . . | 1.0 |
| 15. Covered, probably shale . . . . . . . . . . . . . | 23.0 |
| 14. Limestone, medium-grey, earthy, thin-bedded, up to three inches, microgranular, weathers to olive-grey; contains Goniatites . . . . . . . . | 2.0 |
| 13. Covered, probably shale . . . . . . . . . . . . . | 12.0 |
| 12. Limestone, tannish-grey, fine-grained, weathering dark grey, contains reddish-tan, elongated grains. . . . . . . . . . . . . . . . . . . . | 2.0 |
| 11. Covered, probably shale . . . . . . . . . . . . . | 8.0 |
| 10. Limestone, tan, fine- to medium-grained, weathering dark greyish-tan . . . . . . . . . . . | 1.0 |
| 9. Shale . . . . . . . . . . . . . . . . . . . . . | 18.5 |
| 8. Limestone, dark grey, yellowish-tan splotches, microgranular, weathers buff-grey . . . . . . . | 0.5 |
| 7. Covered, probably shale . . . . . . . . . . . . . | 6.0 |
| 6. Calcareite, dark-grey, massive, coarse-grained, weathers dark-tan with rough surface; contains abundant brachiopods and fusulina . . . . . . . | 1.0 |
| 5. Covered, probably shale . . . . . . . . . . . . . | 25.0 |

| | | Thickness In Feet |
|---|---|---|
| 4. | Limestone, medium-grey, bedding planes weather smoothly, fine-grained weathers to tannish-grey. . . . . . . . . . . . . . . . . . . . . . | 1.0 |
| 3. | Covered, shale float. . . . . . . . . . . . . . . | 4.5 |
| 2. | Limestone, dark-grey with tan splotches, very fine-grained to microgranular, weathering olive-grey. . . . . . . . . . . . . . . . . . . . | 0.5 |
| 1. | Covered, probably shale, forms a prominent bench . . . . . . . . . . . . . . . . . . . . . . | 34.5 |
| | Total Thickness. . . . . . . . . . . . . . . | 140.5 |

Marble Falls group:

| | | |
|---|---|---|
| 42. | Limestone, medium- to dark-grey, beds six inches to one foot thick, very fine-grained, weathering dark-grey with olive cast; Goniatites, corals, and snails. . . . . . . . . . | 3.0 |
| 41. | Covered . . . . . . . . . . . . . . . . . . . . . | 5.0 |
| 40. | Limestone, dark-grey, and tannish-grey mottled; mottled appearance due to weathering, massive beds; fine-grained, abundant Goniatites and coral . . . . . . . . . . . . . . . . . . . . | 1.0 |
| 39. | Covered . . . . . . . . . . . . . . . . . . . . . | 6.5 |
| 38. | Limestone, medium- to tannish-grey, fine-grained, medium-grained, weathering dark-bluish grey, sponge spicules abundant, chert rosettes up to one inch in diameter. . . . . . . . . . . | 1.0 |
| 37. | Covered . . . . . . . . . . . . . . . . . . . . . | 4.0 |
| 36. | Limestones, medium- to dark-grey, occasional tan and white grains, fine-grained. . . . . . . . | 1.0 |
| 35. | Covered . . . . . . . . . . . . . . . . . . . . . | 1.0 |
| 34. | Cotton rock, buff-colored . . . . . . . . . . . | 1.0 |
| 33. | Covered . . . . . . . . . . . . . . . . . . . . . | 1.0 |
| 32. | Limestone, dark-grey and brownish-grey, mottled, microgranular, weathers tannish-grey with olive cast. . . . . . . . . . . . . . . . . . . | 1.0 |
| 31. | Covered . . . . . . . . . . . . . . . . . . . . . | 4.0 |

| | | Thickness In Feet |
|---|---|---|
| 30. | Limestone, light-buff, fine-grained, poorly exposed . . . . . . . . . . . . . . . . . . . . . | 1.0 |
| 29. | Covered . . . . . . . . . . . . . . . . . . . . . | 7.0 |
| 28. | Limestone, light bluish-grey with tannish cast, massive beds, very fine-grained, "earthy", weathers light-buff, surface "spotted", contains rome to rust-colored fossil fragments . . | 1.0 |
| 27. | Covered, some chalk limestone in float; contains four feet of fine- to microgranular-limestone; contains abundant Producta . . . . . | 14.0 |
| 26. | Limestone, bluish-grey and brownish-grey mottled; very fine-grained, weathers medium grey with tan cast. . . . . . . . . . . . . . . | 1.0 |
| 25. | Calcarenite, partly covered, white to light grey, beds less than six inches thick, fine- to medium-grained, weathering medium-grey, abundant Fusulina; Producta weathered out on surface . . . . . . . . . . . . . . . . . . . . | 12.0 |
| 24. | Calcarenite, medium- to fine-grained, dark- to brownish-grey; mottled, bluish-grey; beds eight inches to one foot in thickness, weathering medium grey; contains Chaetetes . . . . . . | 2.0 |
| 23. | Covered . . . . . . . . . . . . . . . . . . . . . | 5.0 |
| 22. | Limestone, sublithographic, brownish-grey, massive bed, breaks with conchoidal fracture, surface somewhat fractured; weathering light-grey; contains scattered fossil material. . . . | 1.0 |
| 21. | Limestone, light bluish-grey; some thin, tan, cherty beds; beds three inches to six inches thick; very fine-grained, weathering medium grey. . . . . . . . . . . . . . . . . . . . . | 4.0 |
| 20. | Covered . . . . . . . . . . . . . . . . . . . . . | 4.0 |
| 19. | Limestone, some chert, medium-grey, fine-grained, weathering bluish-grey. . . . . . . . . . . . . | 2.0 |
| 18. | Calcarenite, grey with tan streaks, fine- to medium-grained, carinated surface weathers light-grey. . . . . . . . . . . . . . . . . . | 1.0 |

| | | Thickness In Feet |
|---|---|---|
| 17. | Covered . . . . . . . . . . . . . . . . . . . . . | 0.5 |
| 16. | Limestone, light grey, chert in upper part, medium-grey, very fine-grained homogeneous breaks with conchoidal fracture, weathering light bluish-grey . . . . . . . . . . . . . . . | 2.5 |
| 15. | Covered . . . . . . . . . . . . . . . . . . . . . | 2.0 |
| 14. | Limestone, medium-grey with tannish cast, contains abundant chert nodules and rosettes up to two inches thick, massive beds, fine-grained, weathering dark-grey; some sponge spicules. . . | 1.0 |
| 13. | Covered . . . . . . . . . . . . . . . . . . . . . | 2.0 |
| 12. | Limestone, dark- to medium-grey, medium-grained, weathers dark-tan, abundant sponge spicules and crinoidal hash . . . . . . . . . . | 1.0 |
| 11. | Covered . . . . . . . . . . . . . . . . . . . . . | 2.0 |
| 10. | Limestone, light-brownish grey, mottled medium-grey, beds two inches to six inches thick; microgranular, weathering grey with a buff cast . . . . . . . . . . . . . . . . . . . | 6.0 |
| 9. | Limestone and white chert in float; covered . . | 16.0 |
| 8. | Calcarenite, medium-grey, bedding massive, chert beds less than one inch thick, medium-grained, weathering bluish grey . . . . . . . . | 1.0 |
| 7. | Calcarenite, medium-grey, beds six inches to one foot in thickness, coarse-grained, abundant chert and sponge spicules weathers light, blue-grey, contains Producta. . . . . . . . . . | 1.5 |
| 6. | Limestone, blue-grey; tan, mottled, bedding, one inch to eight inches thick. . . . . . . . . | 10.0 |
| 5. | Covered with float. . . . . . . . . . . . . . . . | 2.5 |
| 4. | Limestone, chert present; indistinct bedding; chert beds up to eight inches thick, fine-grained, light-grey on fractured surface; weathers light blue-grey. . . . . . . . . . . . | 11.0 |
| 3. | Limestone, grey, mottled, massive, fine-grained, buff to tan-colored on weathered surface. . . . | 2.0 |

| | | Thickness In Feet |
|---|---|---|
| 2. | Shale and limestone, covered in line of section.. | 2.5 |
| 1. | Calcarenite; light grey, chert-bearing; medium- to fine-grained, chert nodules are up to one inch in diameter, very dark grey; weathering light-grey. . . . . . . . . . . . . . . . . . . . | 13.5 |
| | Total Thickness. . . . . . . . . . . . . . . | 162.5 |
| | Total Thickness, Pennsylvanian System . . . . . | 303.0 |

MEASURED SECTION OF THE SAN SABA
MEMBER OF THE WILBERNS FORMATION

The section of the San Saba member of the Wilberns formation was measured approximately one and one-half miles south of the Llano River along a drainage draw that enters Mill Creek from the south. The general line of this section is marked on the map in pocket, plate I. This section was measured in conjunction with Kenneth Sliger, whose Lower James River area overlaps the Bee Branch-Mill Creek area at this locality.

CAMBRIAN SYSTEM
Wilberns Formation

| San Saba limestone member | | Thickness In Feet |
|---|---|---|
| 26. | Limestone, medium-grey, lithographic, weathers medium-grey, contains some fossils. . . . . . . | 19.2 |
| 25. | Limestone conglomerate; light-grey pebbles composed of calcite with a pure, white fine- to medium-grained cement; contains a few grains of glauconite; weathers light grey. . . . . . . | 5.0 |
| 24. | Limestone, dark-grey, scattered pebbles of calcite, contains some glauconite, fine-grained, weathers buff-grey. . . . . . . . . . . . . . . | 0.8 |
| 23. | Limestone, light-grey, lithographic, weathers light-grey. . . . . . . . . . . . . . . . . . . . | 14.0 |
| 22. | Limestone, light-brown, weathers light-brown, one foot at base stationed dark brown, bedding massive, sublithographic, splotches of limonite, red specks of weathered glauconite. . . . . . . | 8.7 |

| | | Thickness In Feet |
|---|---|---|
| 21. | Covered . . . . . . . . . . . . . . . . . . . . | 19.7 |
| 20. | Calcarenite, consists of 25 percent glauconite, olive-grey limestone, layers of green glauconite, coarse-grained, weathers dark olive grey, fossil fragments. . . . . . . . . . | 4.8 |
| 19. | Glauconite (60 per cent), green, contains calcite crystals; large splotches of limonite, reddish-brown on fresh fracture, weathers greyish yellow. . . . . . . . . . . . . . . . . | 1.8 |
| 18. | Covered . . . . . . . . . . . . . . . . . . . . | 5.0 |
| 17. | Limestone and limonite, no glauconite, limestone pebbles up to one inch in diameter; beds of limonite one-half inch thick; weathers buff to medium grey. . . . . . . . . . . . . . . . | 2.2 |
| 16. | Limestone, medium-grey, stringers of calcite, lenses of limonite, contains a few rounded brown pebbles about 1/4-inch in diameter, fine-grained, weathers dove grey. . . . . . . . | 7.3 |
| 15. | Covered . . . . . . . . . . . . . . . . . . . . | 2.8 |
| 14. | Limestone conglomerate, composed of 20 per cent pebbles 1/4-inches to 1/2-inch in diameter, medium-grained cement, medium-grey; contains grains of glauconite; weathers yellow to buff . | 5.0 |
| 13. | Calcarenite, dark grey; contains a few brown, rounded pebbles, specks of glauconite; coarse-grained, weathers dark grey . . . . . . . . . . | 20.0 |
| 12. | Covered . . . . . . . . . . . . . . . . . . . . | 5.0 |
| 11. | Limestone, medium grey, massive, weathers medium grey . . . . . . . . . . . . . . . . . | 6.5 |
| 10. | Covered . . . . . . . . . . . . . . . . . . . . | 21.0 |
| 9. | Calcarenite, grey-brown; coarse-grained, rounded boulders, beds 3 inches to one foot thick, abundant glauconite, limonite stringers; weathers brown . . . . . . . . . . . . . . . . . . . | 37.9 |
| 8. | Calcarenite, buff colored, fine-grained; contains yellow bands of limonite up to one mm. thick, a few beds of red sandstone two inches to one foot thick; weathers to a smooth, light yellow-brown; grades into a white friable calcarenite . . . . . . . . . . . . . . . . . | 25.4 |

| | | Thickness In Feet |
|---|---|---|
| 7. | Calcarenite, medium-grey; beds one to 4 inches thick; fine-grained, contains some quartz grains, glauconite, shell fragments and limonite stringers; friable, weathers dark grey. . . . . | 4.4 |
| 6. | Limestone, brown, medium-grained, very friable, limonite cement, complete bed appears weathered. | 2.0 |
| 5. | Sandstone, light grey-brown; estimated percentage of mineral grains: quartz - 25%, calcite cement - 70%, glauconite - 1%; beds one-half to 2 inches thick; weathers into slabs; friable, weathers brown. . . . . . . . . | 1.7 |
| 4. | Calcarenite, light-grey, beds one inch to 2 inches thick, fine-grained; contains patches of limonite, lenses of limonite, trilobite fragments . . . . . . . . . . . . . . . . . . . . | 5.5 |
| 3. | Covered . . . . . . . . . . . . . . . . . . . . . | 35.3 |
| 2. | Limestone, medium-grey, white lenses; fine-grained, friable, contains limonite lenses and splotches of limonite, few thin beds of trilobite hash . . . . . . . . . . . . . . . . . . . . | 7.5 |
| 1. | Limestone, medium-grey, brown splotches and streaks of limonite; weathers buff with flat ledges; bed 6 inches to one foot thick. . . . . | 21.5 |
| | Total Thickness. . . . . . . . . . . . . . . | 290.0 |

MEASURED SECTION OF BIOHERM ZONE AND POINT PEAK SHALE

The thickness of the first 30 feet is subject to slight error because of the erratic dips due to the underlying bioherms.

Section of Point Peak shale and Bioherm zone measured approximately 1000 feet upstream from the mouth of Mill Creek. This section was measured about 1/4 mile southeast of the corner of the area mapped in Cliger's Lower James River Area (1956).

Bioherm Zone

| | | Thickness In Feet |
|---|---|---|
| 22. | Bioherms zone overlies the Point Peak shale and contains individual bioherms approximately | |

| | Thickness In Feet |
|---|---|
| 30 feet thick and up to 60 feet across. These bioherms are contained in the underlying Point Peak shale. A few of these bioherms are weathered out completely and rest on the Point Peak shale. | |
| Total Thickness. . . . . . . . . . . . . . . | 30.± |

Point Peak shale member

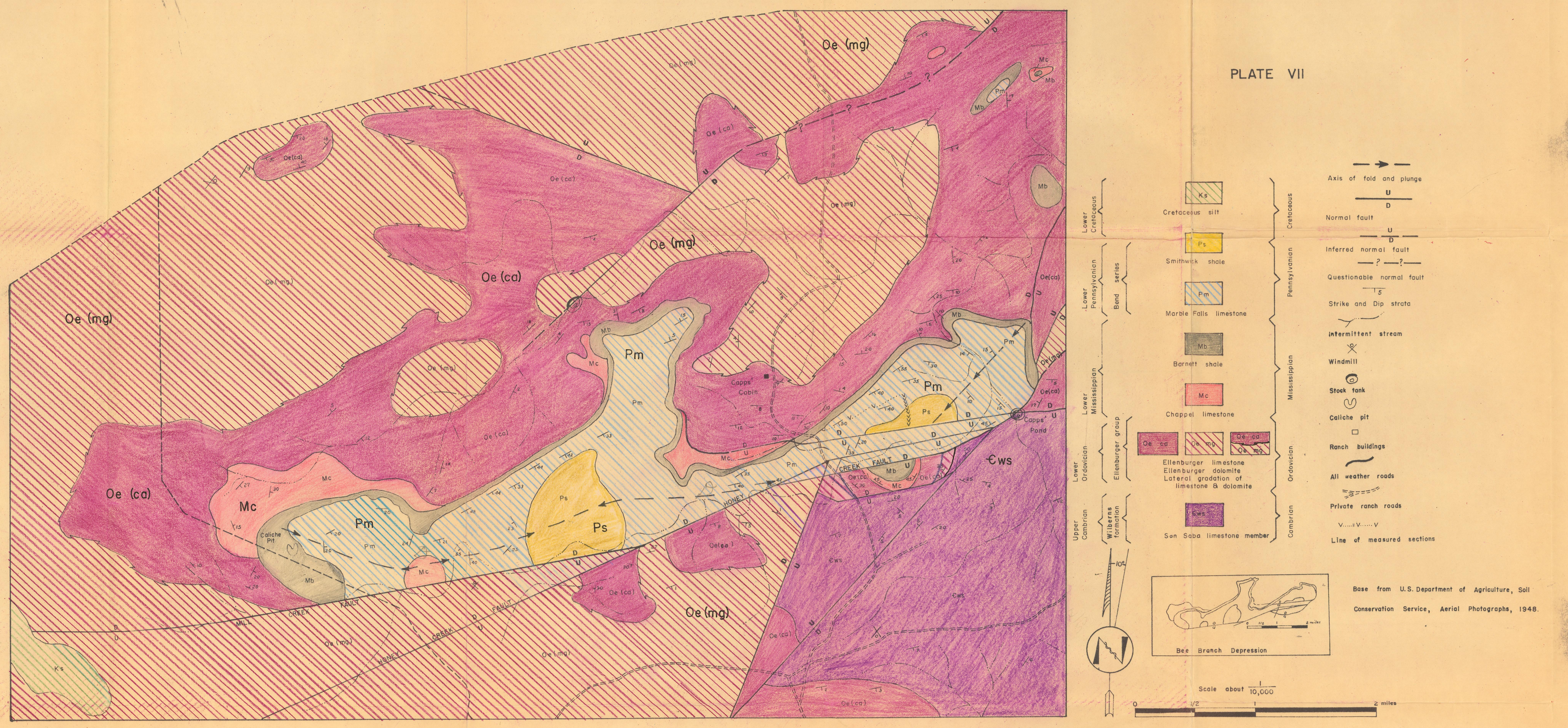
The uppermost beds of the Point Peak shale member of the Wilberns formation are distorted because of the overlying bioherms; consequently, the first few feet of the measured section are subject to error.

| | | Thickness In Feet |
|---|---|---|
| 21. | Limestone conglomerate, greenish-grey, red splotches; rounded pebbles up to 5 inches by 2 inches; fine-to-medium-grained matrix, contains pebbles of glauconite (1/4-inch by 1/4-inch), few fossil fragments . . . . . . . . | 11.5 |
| 20. | Covered, probably shale . . . . . . . . . . . . . | 4.6 |
| 19. | Fossiliferous limestone hash, greyish green, disseminated glauconite grains, fine-grained matrix, splotches of limonite; weathers to an olive grey, weathered out brachiopod shells and shell fragments, contains brachiopod shells and fragments. . . . . . . . . . . . | 1.4 |
| 18. | Limestone conglomerate, edgewise, light-grey, fine-grained matrix, rounded, splotches of limonite, dark-green pebbles up to 3/8-inch by 3 inches, disseminated grains of glauconite, weathers tannish grey . . . . . . . . . . . . . | 6.0 |
| 17. | Siltstone, brownish-grey; one inch to 5 inches laminae, the siltstone makes ledges; interbedded shales litter the slopes; also brownish-grey, disseminated glauconite . . . . . . . . . | 9.0 |
| 16. | Limestone conglomerate, rounded pebbles parallel to bedding (3/8-inch by 3 inches); both the pebbles and the fine-grained matrix are dark grey; contains limonite lenses, disseminated glauconite. . . . . . . . . . . . . . . . | 4.8 |
| 15. | Limestone conglomerate, edgewise, light-grey, fine-grained matrix, rounded, dark green | |

| | | Thickness In Feet |
|---|---|---|
| | pebbles up to 3/8-inch by 3 inches, splotches of glauconite, speckled with limonite; covered with a caliche crust; weathers tannish grey . . | 2.7 |
| 14. | Limestone, grey, medium-grained, contains a few brown pebbles of calcite (1/2-inch by 1-1/2 inches), disseminated grains of glauconite, speckled with limonite; covered with a caliche crust; weathers dark grey . . . . . . . . . . . | 1.5 |
| 13. | Limestone, white, medium-grained, lenses of limestone, light grey; spotted with limonite and glauconite; lenses of glauconite; weathered to buff . . . . . . . . . . . . . . . . . . . . | 3.8 |
| 12. | Limestone conglomerate, edgewise, light-grey, fine-grained matrix, rounded, dark green pebbles up to 3/8-inch by 3 inches, splotches of limonite, disseminated grains of glauconite, weathers tannish grey . . . . . . . . . . . . . | 17.3 |
| 11. | Limestone conglomerate, medium-grained matrix, pebbles up to 2 inches in diameter, not parallel to bedding. . . . . . . . . . . . . . . . . | 0.5 |
| 10. | Limestone conglomerate, edgewise, light grey, fine-grained matrix, rounded, dark green pebbles up to 3/8-inch by 3 inches, splotches of limonite, disseminated grains of glauconite, weathers tannish grey . . . . . . . . . . . . . | 7.4 |
| 9. | Limestone conglomerate, edgewise, olive-grey, fine-grained matrix, rounded, dark green pebbles up to 3/8-inch by 3 inches, splotches of limonite, disseminated grains of glauconite, weathers tannish grey . . . . . . . . . . . . . | 0.5 |
| 8. | Limestone conglomerate, edgewise, olive-grey, fine-grained matrix; rounded, dark green pebbles up to 3/8-inch by 3 inches, splotches of limonite, disseminated grains of glauconite, weathers tannish grey . . . . . . . . . . . . . | 14.8 |
| 7. | Shale 50 percent, siltstone 49 per cent, ledges formed by siltstone, slopes by shale; both are calcareous, dark olive grey disseminated limonite and glauconite specks, splotches of limonite; very few thin beds of olive-grey limestone. . . | 25.0 |

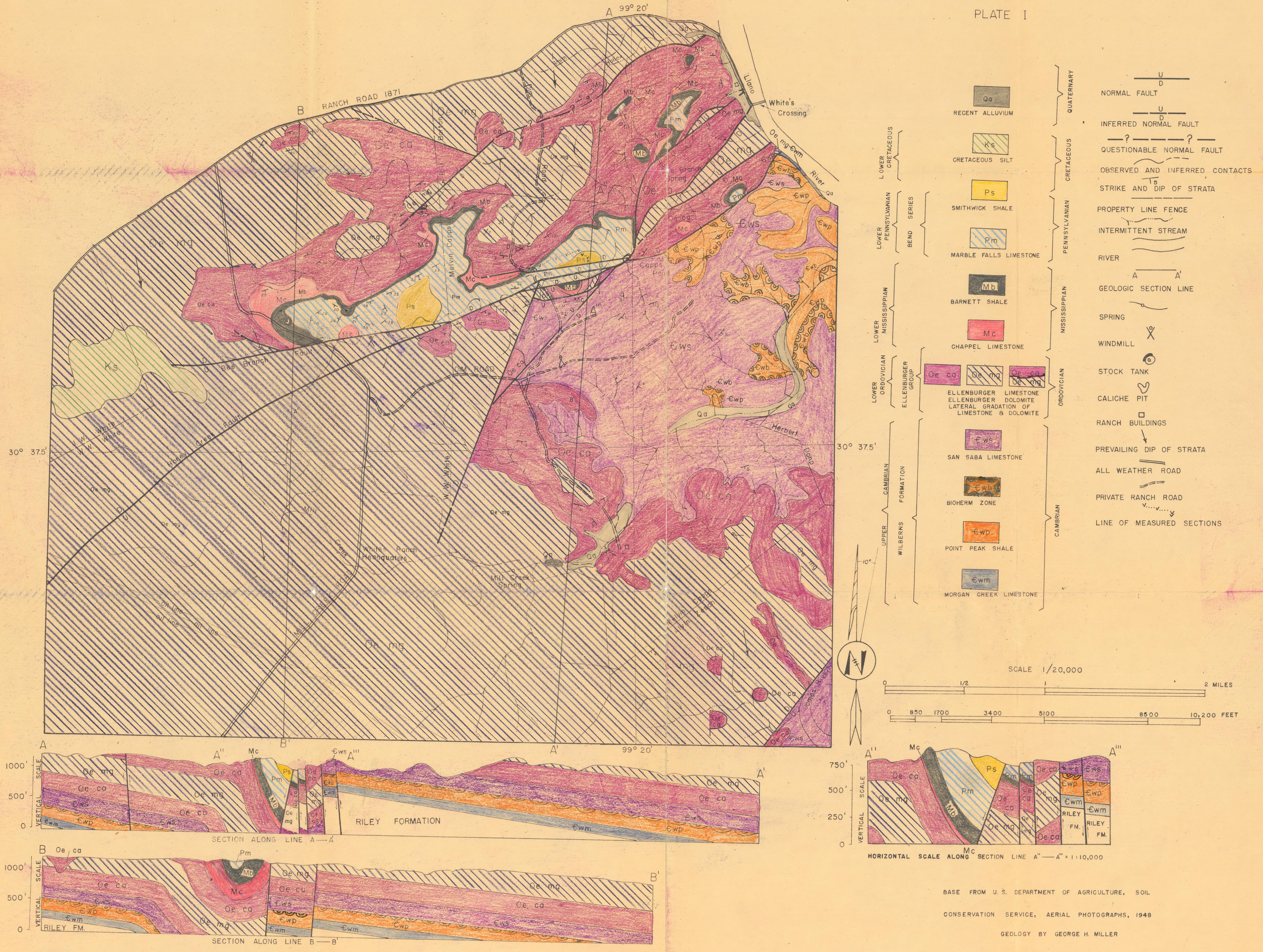
| | | Thickness in Feet |
|---|---|---|
| 6. | Bioherms (small), the bioherms are approximately 3 feet by 5 feet, occur in lenses; the bioherms coalesce to form lenses up to 30 feet in length; the overlying and underlying beds bow around the bioherms . . . . . . . . . . . . | 12.0 |
| 5. | Siltstone, calcareous, olive grey, contains disseminated glauconite and limonite specks, beds 1/4-inch to one inch thick, medium grey; weathers olive grey . . . . . . . . . . . . . . | 6.2 |
| 4. | Limestone, brownish grey, disseminated glauconite, splotches of limonite, medium-grained. | 1.0 |
| 3. | Bioherms, "baby", one to two feet in diameter, consist of light-grey sublithographic limestone.. | 1.4 |
| 2. | Siltstone, calcareous, medium grey; contains disseminated glauconite and limonite specks, bed 1/4-inch to one inch thick, weathered olive grey. . . . . . . . . . . . . . . . . . . | 1.5 |
| 1. | Bioherms (small), bioherms approximately 3 feet by 5 feet, occur in lenses; the bioherms coalesce to form lenses up to 30 feet in length; the overlying and underlying beds bow around the bioherms . . . . . . . . . . . . . . | 2.0 |
| | Total Thickness. . . . . . . . . . . . . . . | 124.4 |

PLATE VII




GEOLOGIC MAP OF A PORTION OF THE BEE BRANCH - MILL CREEK AREA

PLATE I




# GEOLOGIC MAP AND SECTIONS OF THE BEE BRANCH — MILL CREEK AREA, MASON COUNTY, TEXAS