GEOLOGY OF THE UPPER JAMES RIVER AREA

MASON COUNTY, TEXAS

A Thesis

By

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ABSTRACT

The Upper James River area is located in southwestern Mason County, Texas, on the southwest flank of the Llano uplift.

In this area, rocks of Paleozoic, Mesozoic, and Cenozoic age are found. The lithologic units that are exposed over most of the thesis area belong to the Riley and Wilberns formations of Late Cambrian age and the Ellenburger group of Early Ordovician age. The Riley formation is divided into three members. These are, in ascending order, the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone. The Hickory sandstone is not exposed in the thesis area. The Wilberns formation disconformably overlies the Riley formation and is divided into four members. These members are, in ascending order, the Welge sandstone, the Morgan Creek limestone, the Point Peak shale, and the San Saba limestone. The zone of large, stromatolitic bioherms, which is found at the top of the Point Peak shale, has been mapped as a separate unit because of the value of this zone as a stratigraphic marker.

The Ellenburger group of Ordovician age conformably overlies the San Saba limestone member of the Wilberns formation of Cambrian age. The Ellenburger group is divided, from bottom to top, into the Tanyard, Gorman, and Honeycut formations. In the thesis area, no attempt was made to differentiate between these formations; however, the dolomite and limestone faciès of the Ellenburger group were mapped separately.

Outcrops of Cretaceous silt, sand, and limestone sediments are found in the southern portion of the thesis area, and Cretaceous silt and sand deposits are found in the extreme western portion of the area.

Cenozoic deposits (alluvium and caliche conglomerate) are found at various localities along the banks of the James River.

The Paleozoic rocks of the Upper James River area strike approximately N 40° E and dip 4° SE. Three major, high angle, normal faults that strike northeast disrupt these strata in the thesis area. The throw of the major faults and the regional strike and dip of the strata exert a strong influence over the outcrop patterns of the rocks of the area.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Professors M. C. Schroeder and C. L. Seward for their aid in selecting the area of study, constructive criticism of this thesis, and invaluable assistance in the field. Additional thanks are due to Mr. T. D. White who assisted the author in taking the various photographs incorporated in this thesis. A special expression of thanks is extended to the ranchers in the Upper James River area for allowing the author access to their properties.

GEOLOGY OF THE UPPER JAMES RIVER AREA

MASON COUNTY, TEXAS

I N T R O D U C T I O N

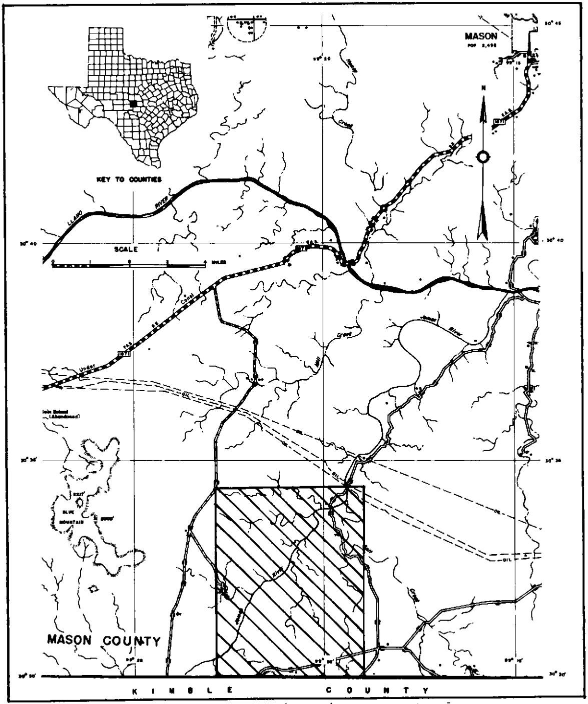
PURPOSE OF INVESTIGATION

The objectives of this research study are to determine the Early Paleozoic geologic history, stratigraphic relationships and structural features of the Upper James River area in Mason County, Texas. It is hoped that this work will explain the geology of the area, and will, in some small part, add to the knowledge of the geology of the Central Mineral Region of Texas.

LOCATION

The Upper James River area is located on the southwest flank of the Llano uplift in southwestern Mason County, Texas. The southern boundary of the area is formed by the southern boundary of Mason County, which is about 30°30' North latitude. The northern boundary is approximately 30°34'20" North latitude and consists of an east-west line which intersects the James River Road at the first (northern-most) low-water crossing of the road and the James River. The western boundary is formed by a north-south line which is approximately 99°22'45" West longitude. The eastern boundary is formed by a north-south line which is approximately 99°19' West longitude. The area extends for 5.2 miles in a north-south direction and 3.9 miles in an east-west direction.

Figure 1



Reproduced from Texas State Highway Department Map of Mason County, Texas, revised to January 1, 1958.

LOCATION MAP OF THE UPPER JAMES RIVER AREA

MASON COUNTY, TEXAS

ACCESSIBILITY

The Upper James River area may be reached by several unpaved, graded, county roads. In addition to the country roads in the area, there are several winding trails, which are passable for jeeps and pickup trucks. In general, the road network of the area is rather sparse, and most of the area can only be reached by foot or by horseback.

The James River Road furnishes access to the area from both the north and the south. The road fords the James River at two locations in the extreme northeastern portion of the thesis area and crosses the Llano River over a low-water crossing still farther to the north. These crossings make the James River Road impassable during the times that either of these rivers are in flood stage.

The south and southwestern portions of the area may be reached via the Hey Ranch road which intersects Farm Road 783 at Hilda Church.

Access to the west-central portion of the area may be gained by way of the Cedar Springs Ranch road, which intersects Farm Road 1871 approximately 3.8 miles southwest of White's Crossing on the Llano River. White's Crossing is a low-water crossing, and this road is closed when the Llano River is in flood stage.

METHODS OF FIELD WORK

The field work, from which the basic data of this thesis was derived, was done during January, February, and March of 1959. The mapping was accomplished by walking the outcrops and plotting the contacts of the various lithologic units on acetate covered, vertical, aerial photographs. This information was later transferred to a base map of the thesis area and was used to prepare Plate I, the geologic map of the area. The base map was made by tracing the physical and cultural features of the area from the various aerial photographs onto a large piece of acetate.

The aerial photographs used were United States Department of Agriculture aerial photographs, series DFZ - 2 P, numbers 69, 70, 71, 78, 79, 80, and 81, dated November 29, 1955. These photographs are the property of the Geology Department of the Agricultural and Mechanical College of Texas.

A Brunton compass was used to obtain strike and dip readings, and a Jacob's staff was used in conjunction with a Brunton compass to determine the thickness of the various measured sections.

PREVIOUS INVESTIGATIONS

In 1846 Dr. Ferdinand Roemer wrote the first description of the geology of the Central Mineral Region. His observations were made while travelling with an exploring party of German settlers who were seeking a site to colonize. Roemer also wrote the first report on the stratigraphy and paleontology of the Paleozoic rocks in Central Texas in 1849. This report by Roemer contained the first geologic map of Texas.

In 1855 and 1856 G. G. Shumard (1886) accompanied a party of the Army Engineer Corps on an exploratory expedition through parts of Texas and New Mexico. The route of this expedition led through parts of the San Saba River valley, through Fort Mason, and on to Fredericksburg. Shumard described the geology he observed along the route.

B. F. Shumard (1861) commented on Roemer's work and was the first to describe the stratigraphy and paleontology of the Potsdam group (Upper Cambrian) in Texas.

S. B. Buckley (1874) assigned the granites of the Central Mineral Region to an Azoic age. He reached the conclusion that these granites are younger than the metamorphic rocks associated with them.

In 1884 C. D. Walcott determined that the Potsdam group was of Late Cambrian age. He also studied the metamorphic rocks of the Central Mineral Region.

R. T. Hill (1887) reviewed previous geologic studies made in Texas and later (1889) named the rocks in the Marble Falls area and correctly assigned them a Carboniferous age.

In 1889 a geological survey of the Llano region was carried out under the direction of T. B. Comstock (1890) for the Geological and Mineralogical Survey of Texas. Comstock discussed the geology and mineral resources of the Llano region and introduced the terms Hickory series, Riley series, San Saba series, Packsaddle schist, and Valley Springs gneiss.

R. S. Tarr (1890) discussed the geomorphology of the Central Mineral Region. He determined that much of the present drainage pattern originated in Tertiary time and has been superimposed on the rocks which crop out at the present time.

Sidney Paige (1911) named and described the Wilberns formation, Cap Mountain limestone, and Ellenburger group. He redefined the Packsaddle schist and the Valley Springs gneiss and assigned them to the Algonkian system. He also described the Precambrian history and the mineral resources of the Llano Region. Paige (1912) was the author of a comprehensive geologic folio of the Llano and Burnet quadrangles which was published by the United States Geological Survey.

In 1916 the Texas Bureau of Economic Geology published a geologic map of Texas which was the most accurate geologic map of the state up to that time.

Sellards, Adkins, and Plummer (1932) reviewed and discussed the Precambrian, Paleozoic, and Mesozoic stratigraphy and the paleo-geography of the Llano area.

Sellards and Baker (1934) discussed Paleozoic deformation and structural relationships in the Llano region.

The Paleozoic fossils originally described by Roemer (1852) were redescribed by Bridge and Girty (1937). The stratigraphic zones in which these fossils occur were described in great detail in this paper.

Barnes and Parkinson (1939) wrote a paper which discussed the origin and distribution of the ventifacts which occur in the base of the Hickory sandstone. These authors concluded that an arid climate and aeolian erosion prevailed in many places during early Hickory time.

In 1940 Plummer briefly discussed the regional and local structure of the Central Mineral Region.

A report on the Ellenburger rocks was written in 1945, by Cloud, Barnes, and Bridge. These authors elevated the Ellenburger formation to group status, defined the boundaries of the group, and restricted it to rocks of Ordovician age. They also divided the group, from bottom to top, into the Tanyard, Gorman, and Honeycut formations.

Bridge, Barnes, and Cloud (1947) redefined and described the members of the Riley and Wilberns formations in the Central Mineral Region. The stratigraphic relationships and sedimentary environments of the different members were also discussed.

Cloud and Barnes (1948) discussed the regional correlation of the Ellenburger group, the genesis of the lithologic constituents, the paleontologic features, and described many measured sections.

The Pennsylvanian and Mississippian rocks in the Llano region were discussed in a detailed report by Plummer in 1950. Descriptions of measured sections and detailed geologic maps accompanied discussions of stratigraphy and paleontology in this report.

The San Angelo Geological Society's Guidebook (1954) for a Cambrian field trip in the Llano area contains a description by Barnes and Bell of the units comprising the Upper Cambrian strata. Several measured sections are included in this paper.

The northern portion of the Upper James River area overlaps part of an area mapped by Dannemiller (1957), and the western boundary of the Upper James River area slightly overlaps the eastern boundary of an area mapped by Harwood (1959). The writer is in general agreement with these authors regarding the structural features and the outcrop patterns of the overlapped areas.

P H Y S I O G R A P H Y

CLIMATE

Mason County is considered to have a sub-humid climate with a mean annual rainfall of about 22 inches. Most of the rainfall usually occurs in the winter and spring. The mean annual temperature is 64.5°F. The winters are rather mild, with below freezing temperatures occurring only for short periods of time. The summers are hot and dry with the temperature often exceeding 100°F.

VEGETATION

The vegetation of the Upper James River area is typical of western regions with poor soils. The trees consist of mesquite, scrub oak, post oak, cedar, and some willow along the water courses. Various grasses are common, and shrubs and cacti such as prickly pear, turkey pear (tasajillo), catsclaw, and yucca are abundant.

The topography and lithology of the surface rocks greatly affect the type and amount of vegetative cover. The affect the lithology of the various members exerts on the vegetative cover was a definite aid in the mapping of the area. The vegetation found on outcrops of the Cap Mountain limestone is commonly sparse, with catsclaw, prickly pear, and Spanish dagger predominating. A few mesquite and scrub oak trees occur locally.

The outcrops of the Lion Mountain sandstone support various grasses, scrub oaks and mesquite trees. Where the soil is well developed on the member, the grasses are abundant. In some localities, soils derived from the Lion Mountain member are cultivated.

The vegetation growing on the Welge sandstone is composed of turkey pear (tasajillo or jumping cactus), scrub oak, mesquite, Mexican persimmon, and various grasses. The outcrops of the Welge member can often be located by the abundance of turkey pear, which forms an impenetrable wall of spines over large portions of the outcrop.

The growth of vegetation on the Morgan Creek limestone is, in many places, distinctive due to a sparsely vegetated character rather than to the abundant growth of any particular plant. Scrub oak, prickly pear, Spanish dagger, mesquite, and some grass are found locally.

The area of outcrop of the Point Peak shale is covered mainly by mesquite trees, yucca, and Spanish dagger. Prickly pear and catsclaw are also present. Abundant growths of mesquite trees often indicate a soil derived from the weathering of the Point Peak shale.

The outcrops of the San Saba limestone normally show distinctive patterns on aerial photographs. The plants seem to be arranged in linear alignments which follow the contours of the surface. The vegetation consists of scrub oak, mesquite, Mexican persimmon, Spanish dagger, prickly pear, and various grasses.

The vegetation found on outcrops of the Ellenburger limestone also shows a distinctive pattern on aerial photographs. The vegetation appears to be evenly distributed but is without a discernable orientation and thus can be readily differentiated from the vegetation growing on the San Saba limestone. The vegetation consists primarily of scrub oak, mesquite and cedar.

Commonly, faults can be located in the area by noting linear patterns of vegetation on aerial photographs. These lineations of

Evidence of a pre-Cretaceous peneplanation of the region is found in the southern portion of the Upper James River area where the Point Peak shale crops out at approximately the same elevation as the Ellenburger limestone. In other portions of the area, rocks of varying resistances to weathering crop out on an erosional surface of low relief. The complete absence of fault line scarps in an area which has been highly faulted and has adjacent beds of rock having different resistances to erosion also suggests a period of peneplanation. As the cover of Cretaceout sediments have been removed for a short period of geologic time, the erosional and weathering processes have not had sufficient time to produce topographic features influenced by the structure and lithology of the Paleozoic rocks.

In the thesis area, the main drainage feature is the James River. The river flows toward the northeast and eventually empties into the Llano River. The area is a part of the Colorado River watershed, as is the entire Central Mineral Region.

Salt Creek, which flows most of the year, is the only major tributary of the James River in the thesis area. The creek is located in the northeastern portion of the area and flows toward the north. It joins the James River within the thesis area. Both the James River and Salt Creek were formed as consequent streams on the old post-Cretaceous surface. Uplift during Tertiary time rejuvenated the streams and caused their meander pattern to be superimposed on the Paleozoic surface with little regard for the structure or lithologic character of the outcrops.

STRATIGRAPHY

GENERAL STATEMENT

The rocks exposed in the Upper James River area of southern Mason County consist of limestones, dolomites, shales, siltstones, and sandstones that range in age from Cambrian to Recent. The Paleozoic era is represented by the Wilberns and Riley formations of Cambrian age, and the Ellenburger group of Ordovician age. The Cap Mountain limestone member of the Riley formation is the oldest rock unit exposed in the Upper James River area. The Paleozoic sediments are overlain by sediments of Cretaceous age.

The geologic column of the area is as follows:

CENOZOIC ERA

Quaternary

Recent alluvium

MESOZOIC ERA

Cretaceous System

Commanche Series

PALEOZOIC ERA

Ordovician System

Lower Ordovician

Ellenburger group

Cambrian System

Upper Cambrian

Wilberns formation

San Saba limestone member

Point Peak shale member

Morgan Creek limestone member

Welge sandstone member

Riley formation

Lion Mountain sandstone member

Cap Mountain limestone member

Hickory sandstone member (not exposed)

PALEOZOIC ERA

CAMBRIAN SYSTEM

A major portion of the Upper James River area is underlain by rocks of Late Cambrian age. Bridge, Barnes, and Cloud (1947) divided the Late Cambrian strata of the Llano uplift into the Wilberns and Riley formations with four and three members, respectively. Rocks of Early and Middle Cambrian age do not occur in the Central Mineral Region. The Upper Cambrian rocks rest unconformably on Precambrian metamorphic and intrusive rocks.

Riley Formation

The term, "Riley Series," was first used by Comstock (1890) to designate part of the strata that comprise the present Riley formation. Cloud, Barnes, and Bridge (1945) redefined the unit as a formation containing all the Cambrian strata in Central Texas below the Wilberns formation. It consists, from top to bottom, of the Lion Mountain sandstone member, Cap Mountain limestone member, and the Hickory sandstone member.

The Riley formation was named for exposures in the Riley Mountains of southeastern Llano County where it is 780 feet thick. Due to the irregularity of the Precambrian surface on which the Riley formation was deposited, the thickness of the formation varies from 200 to 780 feet thick. The average thickness of the formation is 680 feet, (Bridge, Barnes, and Cloud, 1947, p. 110).

The Hickory sandstone member and the lower portion of the Cap Mountain limestone member do not crop out in the thesis area. Therefore, the thickness of the Riley formation in the Upper James River area could not be determined.

Cap Mountain Limestone Member

Definition and Thickness: The term Cap Mountain limestone was first used by Paige (1912) as a formation name. Cloud, Barnes, and Bridge (1945, p. 154) redefined the Cap Mountain limestone as a member of the Riley formation.

According to Bridge, Barnes, and Cloud (1947, p. 113) the Cap Mountain limestone member ranges from 135 to 455 feet thick and is considered to have an average thickness of 280 feet. Only the upper part of the Cap Mountain member crops out in the thesis area. This part measured 77 feet in thickness.

Lithology: The portion of the Cap Mountain member which can be observed in the thesis area consists of a white to gray, fine-grained, fossiliferous, glauconitic, dense, limestone. A few of the beds contain small amounts of arenaceous material. Some rust to yellow-colored stains are present on weathered surfaces, probably due to the weathering of the glauconite. Beds of trilobite shell fragments, which are often referred to as "trilobite hash", are found in the member. The beds range from a few inches to a foot or more in thickness.

Distribution: The Cap Mountain limestone crops out in the bed of the James River in the northeastern portion of the thesis area.

Environment of Deposition: The Cap Mountain limestone appears to have been deposited in a warm shallow sea of normal salinity. The presence of the glauconite indicates that reducing conditions prevailed for much of the time and that the sea bottom was subjected to very little turbulent action. The presence of the "trilobite hash" beds, on the other hand, indicates that the sea was quite turbulent. It seems probable that the quiet periods in the sea were interrupted by short periods of extreme turbulence, which broke and transported the trilobite remains that are preserved in the "hash" beds. The glauconite indicates reducing conditions; therefore, the trilobite remains may have been brought into the area during the periods of extreme turbulence, or the reducing conditions may have occurred only beneath the water-sediment interface.

Stratigraphic Relationships: The Cap Mountain limestone member of the Riley formation overlies the Hickory sandstone member. The contact is not exposed in the thesis area, but elsewhere is reported to be gradational. In parts of the Llano region, the Cap Mountain member grades into the overlying Lion Mountain member of the Riley formation.

Special Features: A phenomenon called "wagon tracks" (Blank, 1958) is found where the Cap Mountain limestone crops out in the bed of the James River in the northeastern portion of the thesis area. The "wagon tracks" consist of a series of shallow grooves in the rocks forming the river bed. The grooves are sub-parallel and trend in the direction of stream flow. Their origin seems to be somewhat similar to that of the potholes, which are found in conjunction with them. Both the grooves and the potholes were formed by abrasion.

Lion Mountain Sandstone Member

Definition and Thickness:. The Lion Mountain sandstone member was first defined by Bridge (1937) who designated it as the top member of the Cap Mountain formation. The original definition has changed only in that the Lion Mountain sandstone is regarded as the uppermost member of the Riley formation, instead of the top member of the Cap Mountain formation.

> According to Bridge, Barnes, and Cloud (1947), "The name applies to a zone of highly glauconitic sandstone, containing in the lower part tangential lenses of limestone that are essentially composed of trilobites, as well as some rather continuous highly glauconitic limestone beds containing phosphatic brachiopods."

The Lion Mountain sandstone is named for exposures at Lion Mountain in Burnet County. At the type section, the member is 20 feet thick. The member attains a maximum thickness of 50 feet in some parts of the Llano region. In the Upper James River area, the Lion Mountain sandstone has a thickness of 31 feet.

Lithology: The Lion Mountain member of the Riley formation is essentially a highly glauconitic, fine- to medium-grained, cross-bedded, quartz sandstone. The member contains thin beds and lenses of arenaceous limestone and "trilobite hash". A few layers of sandy shale are found near the base of the member. The sandy shale, and the lenses of "trilobite hash" occur in minor amounts in the upper portion of the member.

In the thesis area, the maximum size of the "trilobite hash" lenses is 4 feet in length and 5 inches in thickness. Most of the lenses are approximately one foot long and 1 to 1 1/2 inches thick. They decrease in size and abundance toward the top of the member. These lenses of trilobite remains are commonly sub-parallel to the oblique layers of the cross-bedded glauconitic sands.

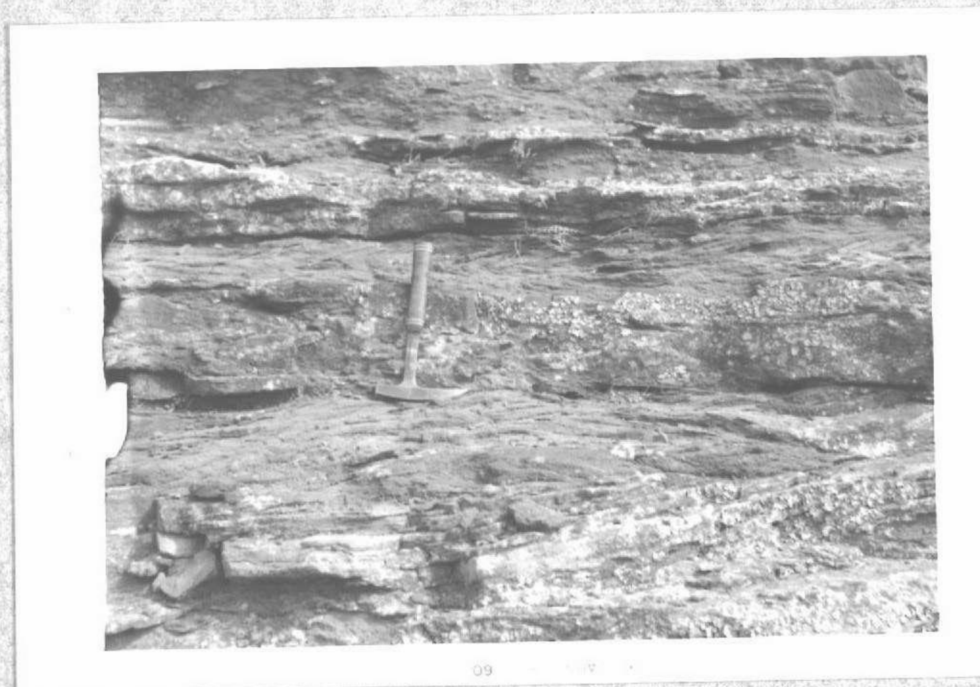
The weathered surfaces of the Lion Mountain outcrops have a distinct reddish color due to the weathering of the glauconite. Weathering of the glauconite also produces hematite nodules. The black, shiny hematite nodules are characteristic of the member and are commonly scattered on the weathered slopes of the Lion Mountain sandstone.

Fresh exposures of the member display a vivid green color that is due to the large quantities of glauconite contained in the sandstone. The extensive cross-bedding, which is characteristic of the Lion Mountain sandstone, is also very apparent on fresh exposures of the member (see Plate II).

A rather unique phenomena occurs at the base of the Lion Mountain outcrop across the river from Jefferies' Hunting Camp (see Plate I). In the shaley glauconitic sandstone, features that appear to be worm-like fossils are found in abundance (see Plate III). These features are from 2 to 10 inches long and from one-third to one-eighth of an inch in diameter. They are slightly browner in color than the enclosing rock. They taper to a point at either end and are apparently of the same composition as the enclosing rock. To the author, it seems possible that these features are some sort of mud-crack fillings, or perhaps lithified mud that adhered to some type of plant stems and rolled along the bottom.

Distribution and Topography: In the Upper James River area, the outcrops of the Lion Mountain sandstone are found adjacent to the James River. The member forms a long, gently sloping bench that is usually covered with a loose red soil. Across the river from Jefferies' Hunting

PLATE II



An exposure of the lower part of the Lion Mountain sandstone member showing the cross-bedded, glauconitic sandstones interbedded with limestone, found in the steep cliff forming the east bank of the James River across the river from Jefferies' Hunting Camp.

PLATE III

Possible mud-crack fillings in the lower Lion Mountain sandstone member of the Riley formation. Found at the base of the steep cliff forming the east bank of the James River near Jefferies' Hunting Camp.

first glauconitic sandstone occurring above the Cap Mountain limestone member. At this horizon there is a change in slope between the steep slope of the Cap Mountain limestone and the gently sloping Lion Mountain sandstone.

Wilberns Formation

The Wilberns formation was first named by Paige (1911), who designated the type locality as Wilberns Glen in Llano County, Texas. As redefined by Cloud, Barnes, and Bridge (1945), the Wilberns formation consists of all the Cambrian rocks stratigraphically above the Riley formation. It is composed, from top to bottom, of the San Saba limestone, Point Peak shale, Morgan Creek limestone, and Welge sandstone members.

Bridge, Barnes, and Cloud (1947) state the Wilberns formation averages 580 feet in thickness in the Central Mineral Region. In the Upper James River area, the formation is approximately 525 feet thick.

The author has mapped the zone of large stromatolitic bioherms, which is usually regarded as being the uppermost portion of the Point Peak shale, as a separate unit occurring between the Point Peak shale and the San Saba limestone. Discussion of the bioherm zone is included in discussion of the Point Peak shale member.

Welge Sandstone Member

Definition and Thickness: The Welge sandstone member was named by Barnes (Bridge, Barnes, and Cloud, 1947) from the Welge land surveys between Threadgill and Squaw creeks, Gillespie County, Texas. It is a brown, quartz sandstone that commonly does not contain glauconite. The

Welge sandstone is 27 feet thick at the type locality. It ranges from 9 to 35 feet in thickness and averages 18 feet in thickness throughout the Llano uplift. The member is 22 feet thick in the Upper James River area.

Lithology: In the Upper James River area, the Welge member is a yellow-brown to brown - in places leached to white, non-calcareous, non-glauconitic, medium- to coarse-grained, ferruginous, massive, sandstone. The quartz grains are sub-rounded, and many of them have recomposed crystal faces which glitter in the sunlight. The weathered surface of this member has a dark rusty-brown color that is much darker than the color of the unweathered surface.

In the thesis area, the quartz grains of the Welge sandstone are cemented together with a siliceous cement, and the member is rather resistant to erosion. Near the top of the member, in the zone where it grades into the overlying Morgan Creek limestone, the cement becomes calcareous.

Distribution and Topography: In the Upper James River area, the Welge sandstone member crops out on the hills on the east side of the James River. The outcrop forms a resistant ledge at the top of the gently sloping topographic bench formed by the Lion Mountain sandstone member.

Environment of Deposition: Textural and mineralogical studies of the Lion Mountain and Welge sandstones by Daugherty (1960, p. 60-65) suggest that the two members were derived from a similar source, but indicate that the Welge sediments are more mature than the Lion Mountain sediments. This situation suggests that the sands found in the Welge member were originally deposited as a part of the Lion Mountain member and were subsequently eroded and redeposited. Winnowing action by wind or water could have removed the silty fraction and the glauconite from the sand fraction. Exposure of the sediments to the processes of chemical erosion could have removed or destroyed the glauconite remaining in the reworked sediments.

The massively bedded nature of the Welge sandstone suggests that it was rapidly deposited. According to Cloud and Barnes (1946, p. 112), the Welge sandstone was deposited in a transgressive sea that entered the region after the exposure of the Lion Mountain sandstone to weathering. This assumption is compatible with the suggestion that the Welge sediments were derived from a weathered residium on the Lion Mountain member that was subjected to erosion and then to rapid redeposition as the seas again covered the region.

Stratigraphic Relationships: The Welge sandstone is the lowermost member of the Wilberns formation and disconformably overlies the Lion Mountain member of the Riley formation. In the thesis area, the lower boundary of the member was placed at the sharp lithologic change from a very glauconitic sandstone to a non-glauconitic sandstone. The live oak trees that flourish at the base of the Welge sandstone show on aerial photographs as a distinct, narrow, dark, line that is very close to the contact between the members. The Welge sandstone is overlain by the Morgan Creek limestone.

Morgan Creek Limestone Member

Definition and Thickness: The Morgan Creek limestone member was named by Bridge from exposures on Morgan Creek in northwestern Burnet

County (Bridge, Barnes, and Cloud, 1947, p. 115). The member is 110 feet thick at the type section and ranges from 70 to 160 feet thick throughout the Llano uplift. The average thickness is 120 feet. The member is 130 feet thick in the Upper James River area.

Lithology: In the thesis area, the Morgan Creek member is a thinly bedded, purple to pearl-gray, glauconitic, medium-grained, fossiliferous limestone. The beds are very sandy near the base of the member and have a distinctive, dark, purple color. Upwards from the base, the purple color of the limestone changes from pearl gray to gray, and the limestone becomes less sandy. However, small amounts of sand are found throughout much of the Morgan Creek limestone. Shale beds and shale partings between the limestone beds are common throughout most of the member. Shale is very abundant in a zone occurring from 20 to 50 feet above the base of the member, and it is also quite common near the top of the member where it grades upward into the Point Peak shale. The shale is green to greenish gray, glauconitic, and easily eroded. A few thin beds of detrital limestone, principally "trilobite hash", occur near the top of the member.

The brachiopod Eoorthis texana is considered to be a prominent marker for the Morgan Creek member and according to Barnes and Bell (1954, p. 59), occurs approximately 45 feet above the base of the member at the Camp San Saba locality. This zone was observed in the cliffs forming the bank of the James River south of Jefferies' Hunting Camp. The fossil first occurs at a level 43 feet above the base of the Morgan Creek limestone. This is almost the same stratigraphic position as that of the fossil at the Camp San Saba locality.

Small stromatolitic bioherms occur approximately 10 feet below the top of the Morgan Creek limestone. These bioherms are normally less than 1 1/2 feet thick and can thus be distinguished from the large bioherms occurring at the top of the Point Peak shale member. Their purplish-gray color also helps to distinguish them from the bioherms of the Point Peak shale member which have a light- to medium-gray color.

Distribution and Topography: The Morgan Creek limestone forms a range of rugged hills to the east of the James River in the north-central portion of the area. The member crops out on both sides of the James River in the central portion of the area where it also forms the bed of the river. Small, faulted exposures of the Morgan Creek limestone are found near the northern extremities of Salt Creek and Hey Creek.

Environment of Deposition: The Morgan Creek limestone was deposited in a shallow, warm, clear water, neritic environment. Oscillation ripple marks with a wave length of about 7 1/2 inches and an amplitude of 2 inches were found near the base of the member. The ripple marks indicate that the sea was probably very shallow during at least part of the interval in which the Cap Mountain limestone was deposited. The limestone beds composed of detrital limestone, which occur in the upper portions of the member, indicate that some periods of extreme turbidity occurred. The silt and shale partings between many of the limestone beds also indicate the existence of turbulent conditions. However, periods of extreme calm also occurred during which reducing conditions prevailed and the glauconite formed.

Stratigraphic Relationships: The Morgan Creek member overlies the Welge member conformably. The contact is gradational and is placed at the base of the first reddish-purple, arenaceous, limestone bed above the Welge sandstone. This horizon coincides with a change in slope and a vegetational change. The vegetational change is discernable on aerial photographs. The member is conformably overlain by the Point Peak shale member.

Point Peak Shale Member

Definition and Thickness: The Point Peak shale member was named by Bridge (Bridge, Barnes, and Cloud, 1947, p. 115) for the exposure at Point Peak near Lone Grove in Llano County. At the type section the member is 270 feet thick, but over the Llano region the member averages only 160 feet. In the Upper James River area, the Point Peak member, including the large stromatolitic bioherms at the top of the member, is 133 feet thick.

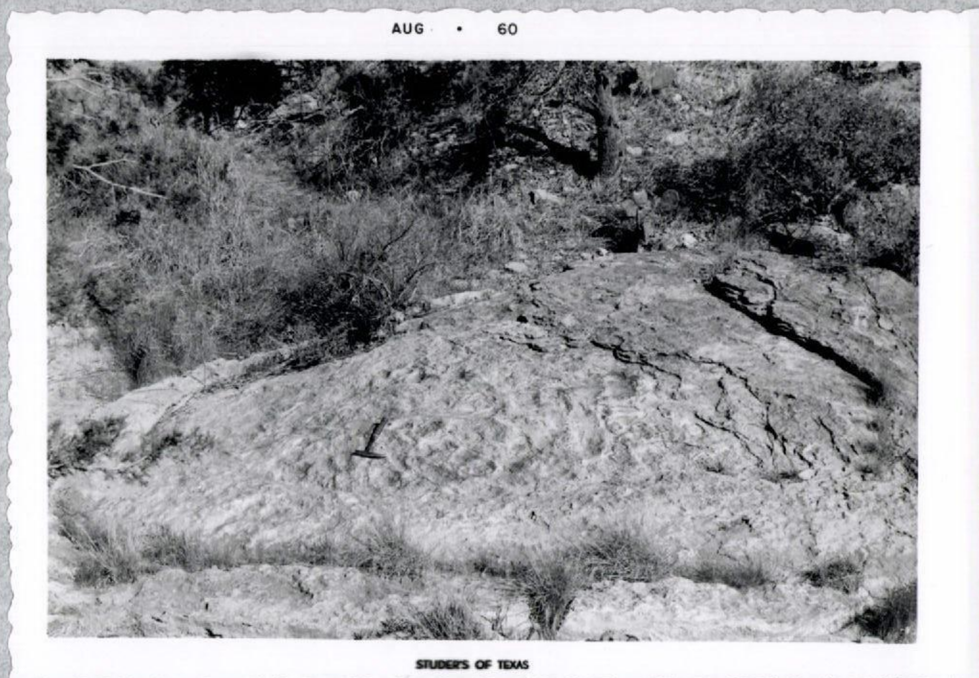
Lithology: The Point Peak shale member is composed of green to tan, calcareous, thin-bedded shale interbedded with gray siltstones, gray to brown, thin- to medium-bedded limestones, and thin beds of intraformational conglomerates. The intraformational conglomerates occur as thin beds that average about 4 to 6 inches in thickness. The conglomerates consist of grayish-brown, flat, limonite-stained fragments of calcareous siltstone and flat, white to gray pebbles of medium- to fine-grained, glauconitic limestone in a calcareous matrix.

Several zones of bioherms are found in the Point Peak member in the thesis area. The uppermost and largest bioherm zone occurs as a distinct zone at the very top of the Point Peak shale member. Although this bioherm zone has been mapped by the author as a separate lithologic unit, it is considered to be a part of the Point Peak shale. The bioherms of this zone are as much as 20 feet in diameter and are often more than 5 feet thick. These bioherms were formed by calcareous algae and usually exhibit "cabbage-head" structure on their uppermost surface (see Plate IV). These huge bioherms have compressed the shale that lies beneath them, causing the adjacent shale beds to bend around the bioherms. Differential compaction has caused the overlying strata to bend over the bioherms. The lateral space between the bioherms is occupied by beds of limestone separated by thin beds of shale. The shale is less abundant near the top of the zone than in the rest of the zone.

There is another zone of large bioherms which are similar in character to the bioherms in the upper zone. The bioherms of this zone are found 37 feet stratigraphically above the base of the Point Peak shale member in the eastern part of the area. Toward the western part of the area, this same zone of bioherms occurs lower in the section, and the bioherms decrease in size. A few small shale and limestone pebbles are found incorporated in some of the bioherms of this zone where the zone crops out on the bank of the James River three-fourths of a mile southwest of Jefferies' Hunting Camp. These pebbles are similar to those found in the intraformational conglomerates of the member, and suggest that the bioherms were formed in rather shallow water. The bioherms of this zone were observed to occur in close conjunction with some of the beds of intraformational conglomerate in the member (see Plate V) and in many instances overlie the conglomerate beds.

An additional zone of small bioherms was noted in the Upper James River area. This zone occurs in the lower part of the Point Peak

PLATE IV



Typical cabbage-head structure exhibited on the surface of one of the large, stromatolitic bioherms which occur in the bioherm zone.

PLATE V

Bioherm which occurs in the middle of the Point Peak shale member. The bioherm has fallen from the outcrop and lies in an overturned position. The intraformational conglomerate underlying the bioherm is also shown. The exposure is located on the east bank of the James River three-fourths of a mile upstream (southwest) from Jefferies' Hunting Camp.

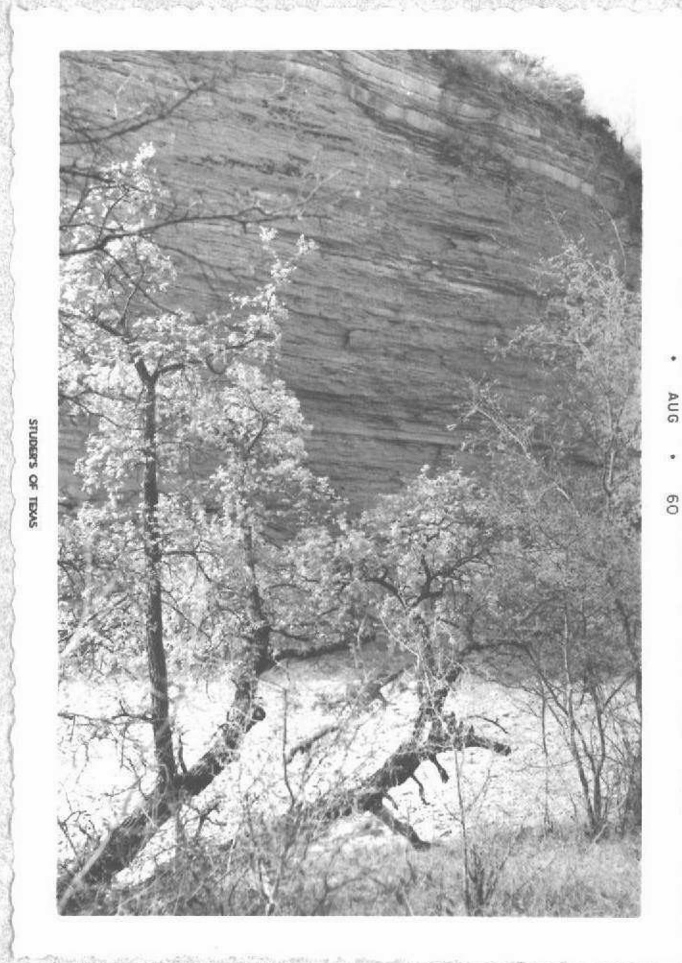
shale but is not present in all exposures of the lower portion of the member. The bioherms of this zone are readily differentiated from those of the other zones by their size, which seldom exceeds 1 1/2 feet in diameter.

Distribution and Topography: The Point Peak shale member underlies a rather extensive area in the southern and eastern portions of the Upper James River area. The shale is easily weathered, and the lower portion of the member usually forms gentle slopes. At the places where the outcrop is protected by the overlying, resistant bioherms, the member forms steep slopes and vertical cliffs (see Plate V).

Environment of Deposition: The occurrence of intraformational conglomerates and bioherms within the Point Peak shale indicate that the member was deposited in relatively shallow water. As the shale, siltstone, and shaley limestone pebbles comprising the intraformational conglomerates of the Point Peak member are flat, some geologists believe that the pebbles were formed by waves and currents from pieces of mud-crack scales. This would suggest that at various times during the deposition of the Point Peak shale member, the area of deposition was a tidal flat. Large ripple marks with a wave length as great as 3.2 feet and an amplitude of .5 feet are found 83 feet above the base of the member in the river bed three-fourths of a mile southwest of Jefferies' Hunting Camp (see Plate VII). The ripple marks strengthen the argument for a shallow water environment of deposition for the Point Peak shale member. The bioherm zones were probably formed in shallow, possibly clear, warm water.

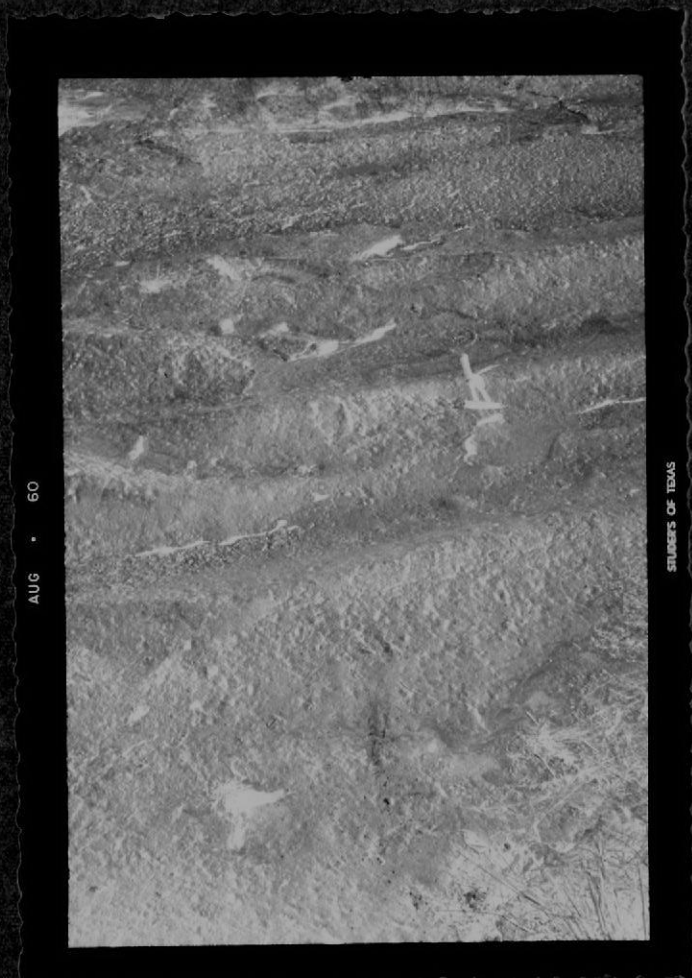
Stratigraphic Relationships: The Point Peak shale member conformably overlies and is transitional with the Morgan Creek limestone

PLATE VI



Point Peak shale cropping out in a steep cliff on the west bank of Hey Creek near the northern intersection of Hey Creek and the James River Road.

PLATE VII



Large ripple marks found in the upper portion of the Point Peak shale member in the bed of the James River three-fourths of a mile southwest of Jefferies' Hunting Camp.

member. In the thesis area, the contact was placed at the base of the first thick sequence of shale and siltstone found above the limestone beds of the Morgan Creek member. The member is overlain by the San Saba limestone.

San Saba Limestone Member

Definition and Thickness: The term San Saba was first used by Comstock (1890, p. 566), who applied it to a series of limestone exposed near Camp San Saba in McCulloch County, Texas. Bridge, Barnes, and Cloud (1947, p. 117) redefined the San Saba limestone as the uppermost member of the Wilberns formation. The San Saba limestone is 280 feet thick at the type locality, and the average thickness of the member is also 280 feet over the Llano uplift. As the San Saba limestone section in the thesis area is interrupted by faulting, the exact thickness of the member could not be determined. The author measured 228.3 feet of the San Saba member and believes that only a small part of the section is missing due to faulting.

Lithology: In the thesis area, the San Saba member is composed mainly of limestone but contains some beds of sandstone and shale. According to Barnes (1959, p. 33), the sandstone body that occurs in the San Saba limestone in western Mason County is not found in the eastern part of the county.

The limestone beds are gray to white or mottled tan in color. They commonly contain glauconite in varying quantities and are often separated by thin stringers of green to gray shale. The limestone is in well-bedded beds varying from one-half inch to two feet in thickness and is often arenaceous. The limestone varies from sub-lithographic to coarse grained and is fossiliferous. Girvanella, which are believed to be of algal origin and look like a chinaberry or a marble, are common in the limestone beds. Brachiopods, gastropods, and trilobites are also present. A small, tightly coiled unnamed gastropod is the most common form throughout the upper half of the member.

A few thin beds of intraformational conglomerate and some beds that are possibly detrital limestone are found approximately 50 feet from the top of the member. The conglomerate beds consist of angular limestone pebbles in a medium-grained, limestone matrix.

The sandstones are yellow to red in color and are fine to medium grained. They are, for the most part, quite friable, but a few of the beds are firmly cemented with a calcareous cement. The sandstone is non-glauconitic and occurs in beds 3 to 5 inches thick. Slight variations in the lithology of the sandstone occur in short lateral distances.

Distribution and Topography: The San Saba limestone member crops out in the eastern and southern portions of the Upper James River area. The member forms both steep hills and gentle slopes but usually forms rolling hills, as it is comparatively resistant to erosion.

Environment of Deposition: The presence of bioherms in the San Saba limestone has been reported by Bridge, Barnes, and Cloud (1947, p. 120). The presence of the bioherms and the existence of the many fossils indicate the San Saba limestone was deposited in relatively shallow water. The detrital nature of some of the limestone beds also suggests deposition took place in a shallow water environment similar to the present Bahama Banks.

The scattered occurrence of the glauconite in the limestone beds indicates that the glauconite was formed in place during the deposition of the limestone. As the limestone contains the fossils of bottom dwelling forms, and glauconite requires a reducing environment, it is suggested that the necessary reducing environment existed just beneath the depositional interface, and that the glauconite formed there.

The source of the arenaceous sediments forming the sandstone body in the San Saba limestone in the western portion of the region was located to the west of the Upper James River area. According to Barnes (1959, p. 33), a barrier reef was located to the east of the thesis area and prevented the transportation of arenaceous sediments to the eastern part of the Llano uplift.

Stratigraphic Relationships: The conformable contact between the San Saba limestone member and the underlying Point Peak shale member is gradational. In the thesis area, the contact was placed at the top of the large zone of stromatolitic bioherms overlying the Point Peak shale. In at least part of the thesis area, Barnes placed the same bioherm zone in the San Saba limestone because of the occurrence of distinct, though thin, limestone beds beneath the bioherms where they crop out in cliffs along the banks of the James River in the southwestern portion of the area. At this locality, Barnes has marked the point where he placed the contact with yellow paint. The present author believes that the bedded limestone beneath the bioherms at this locality grades laterally into siltstone and shale. The bioherms are considered to be the upper part of the Point Peak shale member although they are mapped as a separate unit.

ORDOVICIAN SYSTEM

Rocks of Early and Middle Ordovician age do not occur in the Upper James River area. In the thesis area, Lower Ordovician time is represented by the rocks of the Ellenburger group.

Ellenburger Group

Definition and Thickness: The term Ellenburger was first used by Paige (1911, p. 24) as a formation name for the limestone that crops out and forms the Ellenburger Hills in southeastern San Saba County, Texas. Cloud, Barnes and Bridge (1945, p. 133) elevated the Ellenburger to group status and divided it into the Tanyard, Gorman, and Honeycut formations (bottom to top).

The Ellenburger group has a maximum thickness of 1,820 feet in the southeast corner of the Llano uplift (Cloud and Barnes, 1946, p. 32). According to Barnes and Bell (1954, p. 35), the average thickness of the Ellenburger group in the Central Mineral Region is 1,694 feet.

It is believed that only the lower part of the Ellenburger group is exposed in the thesis area. The author estimates that the thickness of the Ellenburger limestone is approximately 1,200 feet in the Upper James River area.

Lithology: In the Upper James River area, the Ellenburger group consists of a limestone facies and a dolomite facies. The limestone facies is a white- to pearl-gray to dark, sub-lithographic to granular, fossiliferous, non-glauconitic, limestone. The beds vary from one-half inch to two feet in thickness. The limestone contains more fossils in the lower beds than in the upper beds. Intraformational breccias and conglomerates occur throughout the group. The outcrops of the limestone facies often weather to produce large, slab-like pieces of limestone.

The dolomite facies is a yellow-gray to rust-brown, medium- to fined-grained, non-fossiliferous, non-flauconitic dolomite. The dolomite usually weathers to a distinctive irregular surface which has many rounded boulders of dolomite extending above the surface. Pieces of white to black chert are often found associated with the dolomite.

In the thesis area, the dolomite facies seems to grade into limestone horizontally and vertically. The dolomite facies is less common than is the limestone facies.

Distribution and Topography: In the thesis area, the Ellenburger limestone outcrops generally form rough hilly terrain. Exposures of the group are found in the western and extreme southern portions of the area. In fact, most of the western third of the thesis area is covered by outcrops of the Ellenburger limestone. Mesquite, cedar, and scrub oak trees are evenly and sparsely distributed over the outcrops in a distinctive pattern which is recognizable on aerial photographs.

Environment of Deposition: The sediments that formed the Ellenburger group were deposited in a warm shallow sea. The presence of intraformational breccias indicates that the sea was shallow and very turbulent at times. Cloud and Barnes (1946, p. 100) reported the occurrence of many "stromatolites" (stromatolitic bioherms) in the Ellenburger section, and state that this situation, "suggests a maximum possible depth of 100 fathoms". The great thickness of carbonate sediments indicates that the climate of the times was tropical or semi-tropical. Cloud and Barnes (1946, p. 81) suggested that the depositional environments of the Ellenburger group and the sediments of the Bahama Banks were quite similar.

Stratigraphic Relationships: The Ellenburger limestone conformably overlies the San Saba limestone in the Upper James River area. Deposition across the Cambrian-Ordovician boundary appears to have been continuous. In the thesis area, the Ellenburger-San Saba contact was placed at the base of the first limestone bed containing the gastropod, *Lythospira gyrocera*. This gastropod, together with *Ophileta*, is very abundant in the lower part of the Ellenburger group in the Upper James River area (see Plate VIII).

The Ellenburger limestone is overlain by rocks of Cretaceous age. The contact is unconformable.

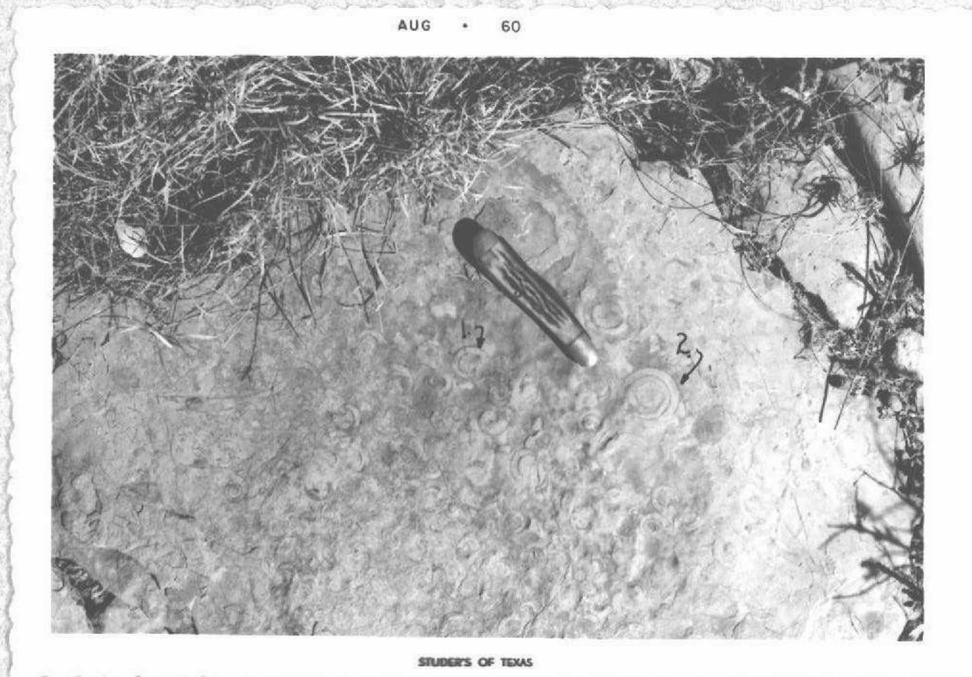
MESOZOIC ERA

CRETACEOUS SYSTEM

Definition and Thickness: In the Upper James River area, rocks of Cretaceous age unconformably overlie the Paleozoic rocks of the region. The Cretaceous rocks of southern Mason County belong to the basal Commanche Series and consist of the Travis Peak, Walnut, Commanche Peak, and Edwards formations (Cloud and Barnes, 1946, p. 189). In the thesis area, the Cretaceous sediments are approximately 230 feet thick.

Lithology: The Cretaceous sediments of the Upper James River area consist of three distinct lithologic types. These are, from the base upward, (1) sand and silt, (2) siltstone, and (3) limestone. No.

PLATE VIII



Fossils characteristic of the lower portion of the Ellenburger group:

(1) Lytospira gyrocera, (2) Ophileta.

attempt has been made by the author to differentiate the rocks of the Cretaceous section on any basis except a lithologic one.

The basal silt and sandstone is found at the base of the Cretaceous plateau and is a deep rust red in color. The silt is very fine, and the sand is calcareous and fine to medium grained. This unit grades upward into a buff-colored, calcareous siltstone. The thickness of the unit ranges from a feather edge to approximately 150 feet.

The siltstone unit is a gray- to light-buff, massively bedded, friable, calcareous siltstone. The unit is fossiliferous, containing unidentified gastropods and brachiopods. It has a rather high resistance to weathering and forms a very steep slope. This unit is approximately 50 feet thick in the Upper James River area.

The uppermost unit of the Cretaceous system in the thesis area is a light-gray to white, medium-bedded, fine-grained limestone. Much of the limestone contains dark-colored chert nodules. This unit is approximately 30 feet thick and is very resistant to erosion. It is probably the lower part of the Edwards limestone.

Distribution and Topography: Three small outliers of Cretaceous strata are found in the extreme south-central portion of the thesis area. These outliers form mesas and are capped by the hard, resistant, Cretaceous limestone unit. The tops of these mesas are roughly 230 feet above the surface of San Saba limestone upon which the base of the Cretaceous deposits rest.

There is a thin veneer of the basal Cretaceous sandstone extending over a considerable part of the southern and western portion of the thesis area. Much of this sheet of sand is not in place, but has been reworked by water flowing down from the Cretaceous highlands.

Environment of Deposition: The Cretaceous sediments of the Upper James River area were deposited in a gradually deepening transgressive sea. This is indicated by the nature of the sediments, which grade from sand to siltstone to limestone. The limited exposures of Cretaceous sediments in the area preclude other conclusions regarding the environment under which the Cretaceous sediments were deposited.

Stratigraphic Relationships: The Cretaceous sediments of the Upper James River area unconformably overlie the Paleozoic rocks of the area. The contacts between the three Cretaceous units appear to be gradational.

CENOZOIC ERA

The Cenozoic sediments of the Upper James River area are limited to small amounts of alluvium and caliche conglomerate. The alluvium is of Quaternary age and is composed of silts, sands, gravels, pebbles, and cobbles deposited by the James River and its tributaries. The alluvium may be as much as ten feet thick in places, but is normally quite thin.

The caliche conglomerate is composed of rounded to sub-rounded limestone pebbles in a caliche or calcareous tufa matrix. Harwood (1959, p. 44) suggested that these conglomerates are the dissected remains of old stream terraces which were formed in valleys of Tertiary or Quaternary age. The caliche conglomerate attains a maximum thickness of approximately 4 feet and is usually found in the valley of the James River.

S T R U C T U R A L   G E O L O G Y

REGIONAL STRUCTURE

The Llano region is a structural dome which, due to erosion, forms a topographic basin. The erosion of the Cretaceous rocks of the region has exposed the complex Paleozoic and Precambrian strata of the structural dome. The area of exposure of the Paleozoic and Precambrian strata is roughly elliptical in shape. The long axis of the ellipse trends in a west-northwest direction and is about 70 miles in length. The shorter axis is approximately 40 miles long.

Extensive deformation has taken place in the Llano region. Sellards (1934, p. 97) stated that the deformation of the Llano region occurred in the Pennsylvanian period and took place after Bend time and prior to Canyon time. This deformation developed the extensive system of faults which constitute the principal structural features of the Llano region. According to Cloud and Barnes (1946, p. 118), the faults are normal and have a range of dip from 60 to 90 degrees. The majority of the major faults of the region trend in a northeast-southwest direction, while a few of the larger faults trend north-south. Only rarely does a major fault follow an east-west directional trend.

The doming of the region was apparently well under way by Mississippian time as evidenced by the thinning of the Chappel and Barnett formations of Mississippian age as they approach the Llano uplift. It is possible that the doming of the region was accomplished entirely within the Mississippian Period.

The Paleozoic rocks of the Llano region have been only gently folded. Broad gentle folds occur at scattered localities, and small local folds have been formed by slumping, compaction around bioherms, and drag along faults.

LOCAL STRUCTURE

Structural features of the Upper James River area are limited to normal faults, grabens, horsts, and compaction folds. The more important normal faults trend in a northeast-southwest direction, while some of the minor faults which branch off from the major faults trend in a northwest-southeast direction. The grabens and horsts are formed by the normal faults of the area and have no discernible topographic expression. The compaction folds are found in the Point Peak shale member of the Wilberns formation and were formed by the compaction of shale around the large stromatolitic bioherms.

The rock units which crop out in the Upper James River area strike N 40° E and dip approximately 4° to the SE.

MAJOR FAULTS

Three major faults have affected the Paleozoic strata of the Upper James River area. These are the Simons faults, the Ziegler fault, and the Hey Creek fault. The Simons fault was named by Alexander (1952, p. 48), the Ziegler fault was named by Sliger (1957, p. 48), and the Hey Creek fault was named by the present author for Hey Creek.

The Simons fault passes entirely through the Upper James River area. The fault follows a northeast-southwest trend and is sub-parallel to the James River. The fault crosses the river at two localities about a quarter of a mile apart. Just north of the southern-most of these two places where the Simons fault crosses the James River, the Cap Mountain limestone strikes N 20° E and dips 25 degrees to the southeast. The high dip of the Cap Mountain limestone member at this locality is apparently due to the fault. Possibly the strata adjacent to the fault were tilted upward by compensatory movements along the fault plane. At this locality the Simons fault has placed the Ellenburger dolomite facies in contact with the Cap Mountain limestone, indicating a minimum vertical displacement of 540 feet. The throw of the Simons fault decreases to the southwest. At the southwestern border of the area, the fault is within the Ellenburger limestone facies.

The Ziegler fault is found in the northeastern corner of the thesis area approximately a quarter of a mile east of the Simons fault. The Ziegler fault appears to die out before it extends more than a mile into the thesis area. The fault follows a north-northeast to south-southwest trend in the area. Where the Ziegler fault crosses the James River it has brought the Cap Mountain limestone in contact with the Morgan Creek limestone. This contact indicates the Ziegler fault has a maximum throw of approximately 180 feet. The throw of the fault decreases to the north and to the south.

As the Simons fault is downthrown on the northwest and the Ziegler fault is downthrown to the southeast, the block between the two faults forms a small horst. This horst is located in the northeastern part of the thesis area and is approximately one-fourth of a mile wide and of undetermined length as it extends out of the thesis area. This small horst is contained within a larger horst formed by the Simons and Hey Creek faults.

The Hey Creek fault enters the Upper James River area about 1 1/2 miles south of the northeastern corner of the thesis area. The fault follows a northeast-southwest trend and disappears just short of the southwestern border of the area. The maximum throw of the Hey Creek fault is estimated to be 150 feet. The Hey Creek fault is parallel to, and southeast of, the Simons fault. As the Simons fault is downthrown to the northwest, and the Hey Creek fault is downthrown to the southeast, the block between the two faults is a horst, which has a width of approximately 1 1/2 miles.

The Hey Creek fault also forms one side of a small graben. This graben is bounded by the Hey Creek fault on its northwest side and by a small unnamed fault on its southeastern side. This small unnamed fault is the eastern-most fault cut by section B-B' (see Plate I). This graben is about three-fourths of a mile wide and, at the most, one mile in length.

MINOR FAULTS

There are many small, steeply dipping, normal faults in the Upper James River area. Most of these minor faults are aligned in a northeast-southwest direction as are the major faults of the area. However, a few of the minor faults that branch off from the Simons fault follow a northwest-southeast trend. The fact that all of the minor faults which depart from the usual directional trend are slivers of the Simons fault and have a small vertical displacement suggests to the author that these minor faults were formed due to local stresses caused by the major faults. It is possible that several small faults within the San Saba limestone or Ellenburger group are present in the area and were not found by the author.

AGE OF FAULTING

The exact time at which the faulting of the strata of the Upper James River area took place is not known. The youngest rocks affected by the faulting belong to the Ellenburger group. The overlying Cretaceous rocks were not displaced by the faults. Therefore, the deformation took place after the Lower Ordovician Ellenburger group was laid down, and before the Cretaceous Commanchean sediments were deposited. Both Cloud and Barnes (1946, p. 121) and Sellards (1943, p. 97) dated the regional faulting as being post-Bend (Early Pennsylvanian) and pre-Canyon (Late Pennsylvanian) in age.

CAUSE OF FAULTING

The faults of the Llano region are normal faults and should be due to tensional forces. The origin of these forces is uncertain, but several theories have been advanced to explain them.

Cloud and Barnes (1946, p. 118) believed that the faulting of the region was the result of tensional couples caused by the deformation of the sediments in the Llanoria geosyncline. Paige (1912, p. 10) considered compressional forces to be the cause of the faulting. Jennings (1960, p. 73) believed differential uplift to be the most likely manner by which the faulting was developed.

The author does not consider any of the previously mentioned theories wholly adequate to explain the origin of the faulting in the region. However, the northeast-southwest trend of the portion of the Ouachita trough (Barnes et. al., 1959, pp. 39-42) closest to the Llano region suggests that the forces which caused the faulting in the Llano region were related to the Ouachita trough.

FOLDING

The only folds occurring in the Upper James River area are small folds of local occurrence found in the San Saba and Point Peak beds immediately adjacent to the stromatolitic bioherms. These folds are due to differential compaction of the strata around the reef masses.

GEOLOGIC HISTORY

PRECAMBRIAN ERAS

The oldest lithologic unit which crops out in the Upper James River area is the Cap Mountain member of the Riley formation of Cambrian age. However, a considerable sequence of sediments were deposited in the Llano region during Precambrian time. These rocks were subsequently buried at great depth, folded, metamorphosed, and intruded by granitic magmas. The coarse-grained texture of some of the granites of the region indicates that they crystallized at considerable depth.

Following the intrusion of the granitic magmas, the region was uplifted and subjected to the processes of erosion. This period of erosion probably occurred during Late Precambrian and Early and Middle Cambrian time.

PALEOZOIC ERA

CAMBRIAN PERIOD

The first Paleozoic sea covering the area was during Late Cambrian time and reworked the existing eolian sands or a sandy residium to form the base of the Hickory sandstone member of the Riley formation (Cloud and Barnes, 1946, p. 113). These sediments were deposited on a surface which had as much as 800 feet of topographic relief according to Bridge, Barnes, and Cloud (1947, p. 113). Accumulations of dreikanters or ventifacts, together with the feldspar fragments in the basal portion of the Hickory sandstone member, suggest that an arid climate existed prior to the advance of the Cambrian seas. At some places aeolian erosion also occurred. The upper portion of the Hickory sandstone was deposited in a shallow sea. Cross-bedding, sub-rounded grains, and ripple marks are characteristic of this portion of the member. The Hickory sandstone does not crop out in the Upper James River area but probably does occur beneath the younger Paleozoic rocks in the area.

Following the deposition of the Hickory sandstone, the land continued to subside through early Cap Mountain time. The gradational contact between the Hickory sandstone and the Cap Mountain limestone is indicative of a gradual rise in sea level, or an increase in the distance to the shore line. The fact that a shale facies is not found between the Cap Mountain limestone and the Hickory sandstone suggests that either the change in sea level was relatively rapid, or that there was a deficiency of shale-size material from the source area, allowing the early deposition of carbonate sediments. The presence of glauconite and some coquina-like beds in the Cap Mountain limestone suggests the member was deposited in a fairly shallow water environment. The source area of the clastic sediments of the region was apparently eroded to a very low level by this time as very few clastics were being carried to the sea and incorporated into the carbonate sediments.

The cross-bedded sandstones, lenses of detrital limestone, and abundant glauconite of the Lion Mountain member indicate that the member was deposited during a time of unstable conditions on the land and in the sea. The cross-bedding and occurrence of the limestone lenses composed predominately of fragments of trilobite remains indicate that a turbulent environment was in effect part of the time. The great amount of glauconite in the section must have formed under quiet conditions which occurred between the shorter, periodic, turbulent periods.

According to Cloud and Barnes (1946, p. 112), the sediments of Lion Mountain-Welge time comprise a regressive-transgressive phase of the Cambrian sea. The Riley-Wilberns formational contact is placed in the middle of this regressive-transgressive sandstone sequence. The sharp lithologic change between the Lion Mountain and Welge members may be the expression of a short hiatus caused by a minor regional uplift which was directly or indirectly connected with the regressive-transgressive nature of the seas at that time.

The Welge sandstone is composed almost entirely of pure quartz sand, and its massive character implies that the sediments were deposited at a very rapid rate. This rapid rate of deposition of the Welge sandstone may have been the result of a sudden influx of large quantities of arenaceous sediments from the source area, or the rapid reworking and redeposition of a sand residium formed on the Lion Mountain member.

The close of Welge time and the beginning of Morgan Creek time was marked by a decrease in the quantity and size of clastic material delivered to the site of deposition and the gradual transgression of marine waters. This slow invasion by the sea is evidenced by the gradational Welge sandstone-Morgan Creek limestone contact, which is customarily placed at the base of the first arenaceous limestone bed above the Welge sandstone member. The abundance of glauconite and marine fossils in the middle and upper portions of the Morgan Creek member suggest that deposition took place in a shallow sea of normal salinity. The stromatolitic bioherms at the very top of the member suggest warm shoal waters and the gradual shallowing of the sea. The many lenses of intensively reworked trilobite remains, which increase in abundance in the upper portion of the unit, indicate fairly shallow water and the existence of periodic turbulent conditions.

During middle Wilberns deposition, argillaceous material was introduced into the sedimentary sequence in a rather quite sea. Evidence for this is the well-bedded shales and siltstones of the Point Peak member. The limestone beds and marine fossils within the member indicate that the waters were marine. Ripple marks and intraformational conglomerates suggest that the waters of the sea were shallow. Near the close of Point Peak time, there must have been considerable shoaling and warming of the waters as evidenced by the large zones of stromatolitic bioherms occurring in the upper part of the Point Peak shale.

During San Saba time, a gradual, moderate deepening of the waters resulted in the deposition of the glauconitic, fossiliferous, silty limestones of the uppermost member of the Wilberns formation. However, periods during which the sea was shallow enough for turbulent bottom conditions to occur undoubtedly existed, as evidenced by the beds of intraformational conglomerate which occur in the upper half of the member. Beds of arenaceous limestone, sandstone, and siltstone also occur in the upper half of the member in the thesis area. According to Bridge, Barnes and Cloud (1947, p. 121), the arenaceous phase of the San Saba limestone is common in western Mason County but is not found in the eastern portion of the county. This situation indicates the source of the arenaceous sediments was located to the west of the Llano region. According to Barnes (1959, p. 33), the arenaceous sediments were blocked off from the eastern part of the Llano uplift by a barrier reef. This barrier reef was located to the east of the thesis area and was aligned in a north-south direction.

ORDOVICIAN PERIOD

In the southwestern part of the Llano uplift, sedimentation was apparently continuous across the Cambrian-Ordovician boundary, and the warm shallow sea persisted throughout Ellenburger time. The presence of intraformational breccias indicates that the sea was shallow and, at times, quite turbulent. Cloud and Barnes (1946, p. 100) estimated that the Ellenburger sea had a maximum possible depth of 100 fathoms and was very likely much shallower. The limestones of the Ellenburger group probably originated as chemically precipitated carbonate muds in an environment somewhat similar to the present Bahama Banks region.

Rocks of Middle and Late Ordovician age do not occur in the Llano region. It is possible that sediments were deposited in the region during this interval and were subsequently removed by erosion, but no evidence of such has been found.

SILURIAN PERIOD

The withdrawal of the Lower Ordovician seas ushered in the longest period of Paleozoic emergence of the Llano region. No sediments of Middle or Late Ordovician age or of Silurian age have been found in the region. The deposition and subsequent erosion of sediments could have occurred during this interval, but evidence toward this end is nonexistent. The interval is considered to be a period of emergence.

During this period of emergence, a great truncation of the Ellenburger rocks occurred. Cloud and Barnes (1946, p. 113) state that there was a pronounced eastward tilting of the rocks prior to Devonian time. This regional tilting caused the truncation of the Ellenburger rocks to be more advanced in the western portions of the Central Mineral Region.

DEVONIAN PERIOD

According to Cloud and Barnes (1946, p. 113), sinkhole deposits of Devonian sediments are found at various localities on the eastern and western flanks of the Llano uplift. However, rocks of Devonian age are not present in the Upper James River area.

MISSISSIPPIAN PERIOD

The seas invaded the region several times during Mississippian time. The Chappel and Barnett formations were deposited during this period. Exposures of these rocks are found 5 1/2 miles north of the thesis area. There are no Mississippian sediments in the Upper James River area.

The thinning of these formations as they approach the Llano region shows that the uplift of the region had begun by thattime. The region emerged as a positive land mass prior to Pennsylvanian time.

PENNSYLVANIAN PERIOD

Sellards (1934, p. 23) states that the Marble Falls limestone of Pennsylvanian age was deposited on an eroded surface of truncated Mississippian and Ordovician strata. There is no evidence of Pennsylvanian deposition in the thesis area. However, it is quite possible that sediments of Pennsylvanian age were deposited in the thesis area and were later removed by erosion.

The Llano region was subjected to a period of deformation during Pennsylvanian time. Sellards (1934, p. 99) dated this deformation as being post-Bend and pre-Canyon in age. He attributed the northeast-southwest trending fault system of the region to this disturbance.

PERMIAN PERIOD

Sediments of Permian age have not been found in the Central Mineral Region. While deposition and subsequent removal by erosion could have taken place, it is most likely that the area was an emergent land mass undergoing erosion during this period.

MESOZOIC ERA

TRIASSIC AND JURASSIC PERIODS

No rocks of Triassic or Jurassic age are known to exist in the Llano uplift. The Triassic and Jurassic periods represent a continuation of the Permian erosive interval. During this period of erosion, the region was peneplaned prior to the advance of the Cretaceous seas.

CRETACEOUS PERIOD

The Cretaceous seas innundated the region and deposited a series of sandstones, siltstones, and limestones on the peneplaned surface which exposed rocks of Precambrian to Pennsylvanian ages. In the southern part of the thesis area the Cretaceous sediments unconformably overlie Cambrian and Ordovician strata.

CENOZOIC ERA

Since the uplift on the area and the consequent withdrawal of the Cretaceous seas, the area has remained above sea level. Erosion has removed the Cretaceous sediments from the center of the Llano uplift and exposed the Paleozoic and Precambrian rocks of the region. The incised meander patterns of the streams in the area suggest that the uplift of the region may still be going on.

Post Cretaceous deposition has been restricted to the collection of alluvium in the stream valleys.

ECONOMIC GEOLOGY

The economic activities carried on in the Upper James River area consist entirely of the raising of cattle, sheep, and goats. Water is the most important natural resource of the area and is present in sufficient quantities to supply the domestic and agricultural needs of the area.

In the thesis area, water is obtained from the James River and its tributaries, stock tanks, and from shallow wells. The Welge sandstone and the Ellenburger limestone are the main aquifers for the shallow wells in the area. The Hickory sandstone, the principal aquifer for the Llano region, underlies the Upper James River area but is not exploited as it is too deep for practical use except in the northeast portion of the area along the James River. In this locality the river furnishes all the necessary water.

No important mineral deposits are found within the thesis area, and according to Cloud and Barnes (1946, p. 33), the nature of the outcrop patterns and the deformation of the potential source beds of the region render the possibility of petroleum production improbable.

REFERENCES

Alexander, W. L., 1952, Geology of the South Mason Area, Mason County, Texas: Unpublished M.S. Thesis, A. & M. College of Texas, 103 pp.

Barnes, V. E., 1940, Pre-Cambrian of the Llano Region with Emphasis on Tectonics and Intrusives: Excursions 53rd Annual Meet of the Geol. Soc. American and Affiliated Societies, Dec. 26-28, 1940, p. 44-49.

__________, 1956, Lead Deposits in the Upper Cambrian of Central Texas: Univ. of Texas, Rept. Inv. 26, p. 8-15.

__________ and Bell, W. C., 1954, Cambrian Rocks of Central Texas: San Angelo Geological Soc., Cambrian Field Trip, Mar. 19, 1954, p. 35-69.

__________ and Parkinson, G. A., 1939, Dreikanters from the Basal Hickory Sandstone of Central Texas: Univ. of Texas, Bur. Econ. Geol., Bull. 3945, p. 665-670.

Barnes, V. E., et al, 1959, Stratigraphy of the Pre-Simpson Paleozoic Subsurface Rocks of Texas and Southeast New Mexico, Univ. of Texas, Bur. Econ. Geol., Bull. 5924, p. 25-43.

Blank, H. R., 1958, Pothole Grooves in the Bed of the James River, Mason County, Texas: Texas Jour. Sci., v. 10, no. 3, p. 293-301.

Bridge, Josiah, 1937, The Correlation of the Upper Cambrian Section of Missouri and Texas with the section in the Upper Mississippi Valley: U.S. Geol. Survey, Prof. Paper 186-L, p. 233-271.

__________, Barnes, V. E., and Cloud, P. E., Jr., 1947, Stratigraphy of the Upper Cambrian, Llano Uplift, Texas: Geol. Soc. America Bull., v. 58, p. 109-134.

__________ and Girty, G. H., 1937, A Redescription of Ferdinand Roemer's Paleozoic Types from Texas: U.S. Geo. Survey, Prof. Paper 186-M, p. 239-271.

Buckley, S. B., 1874, First Annual Report of the Geological and Agricultural Survey of Texas, Houston, Texas Geological Survey.

Cloud, P. E., Jr., Barnes, V. E., and Bridge, Josiah, 1945, Stratigraphy of the Ellenburger Group of Central Texas, A Progress Report: Univ. of Texas, Bur. Econ. Geol. Bull. 4301, p. 1333-1361.

__________ and Barnes, V. E., 1946, The Ellenburger Group of Central Texas: Univ. of Texas, Bur. Econ. Geol. Bull. 4621, 473 pp.

Comstock, T. B., 1890, A Preliminary Report on the Geology of the Central Mineral Region of Texas: Texas Geol. Survey, 1st Annual Report, p. 235-301.

Dannemiller, G. D., 1957, Geology of the Central Part of the James River Valley, Mason County, Texas: Unpub. M.S. Thesis, A. & M. College of Texas, 70 pp.

Daugherty, T. D., 1960, A Petrologic and Mechanical Analysis of the Lion Mountain and Welge Sandstones of Southern Mason County, Texas: Unpublished M.S. Thesis, A. & M. College of Texas, 88 pp.

Harwood, W. E., 1959, Geology of the Salt Creek Area, Mason County, Texas: Unpublished M.S. Thesis, A. & M. College of Texas, 69 pp.

Hill, R. T., 1887, The Present Condition of Knowledge of the Geology of Texas, U.S. Geol. Survey, Bull. 45, 95 pp.

__________, 1889, A Portion of the Geologic Story of the Colorado River of Texas: Amer. Geol., v. 3, p. 287-299.

Jennings, A. R., 1960, Geology of the Pontotoc Northwest Area, San Saba and Mason Counties, Texas: Unpublished M.S. Thesis, A. & M. College of Texas, 93 pp.

Paige, Sydney, 1911, Mineral Resources of the Llano-Burnet Region, Texas with an Account of the Pre-Cambrian Geology: U.S. Geol. Survey Bull., v. 450, 103 pp.

__________, 1912, Description of the Llano-Burnet Quadrangles; U.S. Geol. Survey, Geological Atlas, Folio 183.

Plummer, F. B., 1940, Paleozoic Geology of the Llano Region: Excursions 53rd Annual Meeting of the Geol. Soc. America and Affiliated Societies, Dec. 26-28, 1940, p. 56-60.

__________, 1943, A New Quartz Sand Horizon in the Cambrian of Mason County, Texas: Univ. of Texas, Bur. Econ. Geol., Mineral Resources Circular 22, 3 pp.

__________, 1950, The Carboniferous Rocks of the Llano Region of Central Texas: Univ. of Texas, Bur. Econ. Geol., Bull. 4329, 117 pp.

Roemer, Ferdinand, 1846, A Sketch of the Geology of Texas: Amer. Jour. Sci., ser. 2, v. 2, p. 358-368.

Sellards, E. H., 1934, Major Structural Features of Texas East of the Pecos River: Univ. of Texas, Bur. Econ. Geol., Bull. 3401, p. 11-136.

__________, Adkins, W. S., and Plummer, F. B., 1932, The Geology of Texas: Univ. of Texas, Bur. Econ. Geol., Bull. 3232, p. 15-238.

__________ and Hendricks, Leo, 1946, Structural Map of Texas: Revised, 3rd Edition, Univ. of Texas, Bur. Econ. Geol.

Shumard, B. F., 1861, The Primordial Zone of Texas, with Descriptions of New Fossils: Amer. Jour. Sci., ser. 2, v. 32, no. 95, p. 213-221.

Shumard, G. G., 1886, A Partial Report on the Geology of Western Texas: State Printing Office, Austin, Texas, 145 pp.

Sliger, K. L., 1957, Geology of the Lower James River Area, Mason County, Texas: Unpublished M.S. Thesis, A. & M. College of Texas, 94 pp.

Stenzel, H. B., 1934, Pre-Cambrian Structural Conditions of the Llano Region, Texas: Univ. of Texas, Bur. Econ. Geol., Bull. 3401, p. 74-79.

Tarr, R. S., 1890, Superimposition of the Drainage in Central Texas: Amer. Jour. Sci., ser. 3, v. 40, p. 359-362.

Trewartha, G. T., 1941, Climate and Settlement of the Subhumid Lands: Climate and Man, U.S. Dept. of Agriculture Yearbook, 1941, U.S. Government Printing Office, Washington, D.C., pp. 167-176.

Walcott, C. D., 1884, Notes of Paleozoic Rocks of Central Texas: Amer. Jour. Sci., ser. 3, v. 28, p. 431-433.

A P P E N D I X

MEASURED SECTION OF THE POINT PEAK SHALE, MORGAN CREEK LIMESTONE, WELGE SANDSTONE, LION MOUNTAIN SANDSTONE, AND CAP MOUNTAIN LIMESTONE IN THE NORTHEAST PART OF THE UPPER JAMES RIVER AREA

The section was measured from a place on the south bank of the James River 300 yards west of the southernmost ford of the James River in the thesis area. The section was measured upwards stratigraphically, and the measured traverse was started in the Cap Mountain limestone.

	Thickness of Interval Feet
Wilberns formation:	
Point Peak shale member:	
49. Bioherms, gray, sub-lithographic, very resistant, up to 20 feet in diameter and up to 5 feet thick. Cabbage-head structure is very apparent on the surface of the bioherms. Weathered surface is light to dark gray.	17.0
48. Shale and limestone, interbedded. The shale is poorly exposed but appears to make up 75% of the section. The shale weathers to a light yellowish tan. The limestone is pearl gray, medium to fine grained, glauconitic, and fossiliferous (*Girvanella*); in beds 2 to 4 inches thick; weathers to a dull gray.	21.5
47. Shale, poorly exposed, yellow to green; beds one half to 2 inches thick. Weathers to a light yellowish tan	7.8

Feet

46. Soil-covered slope. Shale particles and limestone flags are on the surface. The shale comprises about 80 percent of the interval. 32.0

45. Bioherms, gray, poorly exposed, as large as 4 feet in diameter, and up to 2 feet thick. Surface is weathered but some traces of cabbage-head structure remain. The weathered surface is dark gray. 3.5

44. Shale and some limestone. The shale is poorly exposed, arenaceous, and weathers to a yellow gray. The few beds of limestone are dark gray, fine grained, and occur in beds 3/4 to 1 1/2 inches thick 18.5

43. Shale and limestone. The limestone is light gray, well exposed, medium grained, glauconitic, in beds up to 8 inches thick, and gray to brown on the weathered surface. The shale is poorly exposed, green to gray, and well bedded in beds up to 5 inches thick. 4.0

42. Bioherms, gray, small, poorly exposed, up to 2 feet in diameter, weathering into rounded lumps the size of a grapefruit. Weathered surface is a dull gray color 1.3

41. Shale and limestone beds. Shale is masked by soil cover, and appears to comprise 75 percent of

	Feet
the interval. The limestone is light gray, medium grained, resistant, and occurs in beds 2 to 2 1/2 inches thick.	11.0
40. Bioherms, gray, small, having an average diameter of one foot and a maximum diameter of three feet. The bioherms are poorly exposed due to soil cover, but seem to weather into a donut pattern. The weathered surface is dark gray.	1.8
39. Shale and limestone. Shale is yellow tan to green, and well bedded in beds 1 1/2 to 3 inches thick. The limestone is white to gray, medium grained, glauconitic, fossiliferous (<u>Girvanella</u>), resistant, in beds 1 1/2 to 2 inches thick interspersed between the shale. The weathered surface of this section consists of light-gray, flaky, shale particles and gray, limestone flags.	27.0
38. Soil-covered slope. Believed to be underlain by siltstone	<u>8.0</u>
Total measured thickness of Point Peak shale member. . .	<u>153.4</u>
Morgan Creek limestone member:	
37. Limestone, light gray, fine grained, slightly arenaceous (sand grains are scattered and are of coarse to medium size), in beds 2 to 4 inches thick. Weathered surface is irregular and gray in color.	1.5

		Feet
36.	Limestone, light gray, fine grained, arenaceous, glauconitic, in beds 3 to 5 inches thick. Weathers to a chocolate-tan color.	4.8
35.	Limestone, gray, medium grained, slightly glauconitic, well bedded in beds about 4 inches thick. Weathered surface is smooth and grayish yellow in color	5.5
34.	Limestone, grayish white, medium grained, slightly glauconitic, beds 2 to 6 inches thick, separated by very thin shale partings.	6.0
33.	Bioherms, gray to purple, poorly exposed, up to 1.5 feet in diameter. Weathered surface is a dark gray..	1.5
32.	Limestone, pearl gray, medium grained, contains a few scattered grains of glauconite, beds 2 to 6 inches thick. Weathers to a mottled gray	8.0
31.	Soil-covered slope. Probably underlain by white, medium-grained, limestone	3.2
30.	Limestone, white, medium grained, fossiliferous, in beds 3 to 4 inches thick. The beds are separated by thin arenaceous, glauconitic, gray, shale partings. Weathers to a medium gray.	2.0
29.	Soil-covered slope. Probably underlain by gray to white, medium- to fine-grained, bedded, limestone .	3.4
28.	Bioherms, dark gray, small, average two feet in diameter, apparently more resistant around the	

Feet

circumference than in the center as weathering produces a donut affect. Individual bioherms are 3 to 6 inches thick. The bioherms are composed of a light gray, somewhat lithographic limestone 1.3

27. Soil-covered slope. Probably underlain by gray to white, medium- to fine-grained limestone. 3.7

26. Limestone, gray to white, fine grained, slightly glauconitic, very slightly arenaceous, in beds 2 to 6 inches thick. Weathered surface is smooth and yellow gray in color. 14.0

25. Limestone, pearl-gray, fine-grained, glauconitic, in beds 2 to 6 inches thick. Weathers to a mottled gray. 2.0

24. Soil-covered slope. Probably underlain by white to gray, medium- to fine-grained limestone 27.0

23. Limestone, white to pearl gray, fine to medium grained, faintly glauconitic, in beds 2 to 6 inches thick. Beds separated by very thin partings of gray shale. Weathers to a dark tan. 16.0

22. Limestone, white to light purple, coarse grained, arenaceous (sand grains are medium coarse), fossiliferous (possibly cystoids), in beds 4 to 8 inches thick; weathers to a dirty white. 3.2

21. Limestone, white to pearl gray, medium-fine-grained, glauconitic, fossiliferous (no identification possible)

Feet

in beds 1 1/2 to 6 inches thick. Rather resistant, weathers to a smooth, light-gray surface. 1.5

20. Soil-covered slope, probably underlain by granular, slightly arenaceous, glauconitic, white to purple, limestone 3.4

19. Limestone, purple to white, medium grained, slightly arenaceous, glauconitic (glauconite occurring in small scattered grains), in beds 2 to 4 inches thick, rather resistant to weathering. Weathered surface is smooth and is light chocolate in color 2.3

18. Limestone, white to dark purple, medium grained, arenaceous, contains scattered, large grains of glauconite, well bedded with beds 2 to 3 1/2 inches thick. Weathered surface is rouned and has a distinct spongy feeling when struck with a hammer. Weathers to a purplish tan. 9.5

17. Soil-covered bench, gently sloping, lightly vegetated, believed to be lower portion of transition zone between Morgan Creek limestone and Welge sandstone . . . . <u>10.2</u>

Total measured thickness of Morgan Creek limestone member . . . . <u>130.0</u>

Welge sandstone member:

16. Sandstone, light yellow to brown, medium to fine grained, limonitic, non-glauconitic, non-fossiliferous,

Feet

massively bedded, rather resistant. Recomposed sand grains have a distinctive glitter in the sunlight. Weathered surface is a dark reddish brown . 20.7

Total measured thickness of Welge sandstone member . . . 20.7

Riley formation:

Lion Mountain sandstone member:

15. Sandy soil, yellow to brown, contains numerous hematite nodules. A few flags of "trilobite hash" are found at the base of this slope. A fresh exposure would apparently consist of highly glauconitic, medium-grained sandstone containing a very few lenses of limestone composed of fragments of trilobite remains. 14.0

14. Limestone, composed of "trilobite hash" coquina, and separated by thin partings of highly glauconitic sand, in beds 2 to 4 inches thick. Slope partially covered by sandy soil and hematite nodules 8.0

13. Sandy soil containing hematite nodules and limestone flags of "trilobite hash". Probably underlain by highly glauconitic sand interbedded with lenses of "trilobite hash" 2 to 3 inches thick 9.0

Total measured thickness of Lion Mountain sandstone member 31.0

Cap Mountain limestone member:	Feet
12. Limestone, light gray, fine grained, arenaceous, only slightly glauconitic, in well-defined beds 1/2 to 2 inches thick. Weathered surface is irregular and pitted, and is yellow to gray in color	8.5
11. Limestone, pearl gray, fine grained, well bedded in beds 2 to 3 inches thick. It is very hard and resistant, and weathers to a smooth surface that is dirty tan in color.	1.5
10. Limestone, white, composed almost entirely of trilobite remains and glauconite. The glauconite shows very little weathering. The limestone is very hard and resistant and is in beds 2 to 4 inches thick. The weathered surface is brown to dark gray	2.3
9. Limestone, light gray to tan, fine grained, slightly glauconitic, very hard and resistant; in beds 2 to 4 inches thick. Weathered surface is smooth and dark gray in color.	1.5
8. Limestone, white to purple, medium to fine grained, glauconitic, contains numerous, well-rounded, small grains. Thin bedded with a weathered surface of dark mottled gray	2.2
7. Soil-covered bench, probably underlain by white to gray, glauconitic limestone	5.0

	Feet
6. Limestone, white to yellow, fine grained, glauconitic, arenaceous, fossiliferous ("trilobite hash"), thinly bedded. The weathered surface is a mottled dirty gray.	25.0
5. Soil- and vegetation-covered bench, apparently underlain by arenaceous limestone	5.0
4. Limestone, white, fine to medium grained, glauconitic (glauconite is scattered but is somewhat concentrated in poorly defined bands), fossiliferous (thin "trilobite hash" beds), in beds 6 to 18 inches thick. Weathered surface is dark brown to gray.	4.5
3. Limestone, gray to yellow, slightly arenaceous, slightly glauconitic. Weathered surface is light gray to tan	0.8
2. Limestone, white, fine grained, glauconitic (glauconite concentrated in poorly defined horizontal bands), in beds 6 to 18 inches thick. Weathered color is a dirty gray	9.8
1. Limestone, white to pearly gray, crystalline, fine grained, contains many small grains of glauconite and numerous small yellow patches due to the weathering of glauconite, in thin well-defined beds. The weathered surface is fairly smooth, but with numerous, small, rounded humps, and is a dirty-gray color.	10.2

	Feet
Total measured thickness of Cap Mountain limestone member, base not exposed	77.3
Total measured thickness of section.	412.4

MEASURED SECTION OF THE LION MOUNTAIN SANDSTONE

The base of the section is located at the river's edge on the east side of the James River across from Jefferies' Hunting Camp approximately one foot above the base of the Lion Mountain sandstone. The section proceeds upstream (southwest) along the bluff which forms the west bank of the river at this locality. This section was measured because the fresh exposures at this locality allow a very good description of the lithology of the member.

	Thickness of Interval Feet
Riley formation:	
Lion Mountain sandstone member	
5. Sand, shale, and limestone. Sand comprises most of the unit, and is medium to fine grained, white to green, highly glauconitic, shaley, cross bedded, in beds 1 1/2 to 8 inches thick, and weathers to a brownish green. The shale is grayish green to tan, arenaceous, glauconitic, in beds 2 to 4 inches thick, and becomes much less abundant in the upper part of the unit. The limestone consists of lenses of "trilobite hash" which have a maximum length of 48 inches, and a maximum thickness of 6 inches. Most of the lenses are about 12 inches long, and 1 1/2 inches thick. The limestone lenses become smaller and less abundant in the upper part of the unit.	29.0

	Feet
4. Sandstone, brownish green, fine grained, shaley, glauconitic, in beds 1/2 to 2 inches thick. This unit contains a phenomenon which appears to be a worm-like fossil. The feature ranges from 2 to 10 inches in length and is usually one-eighth to one-fourth of an inch in diameter. It is a little browner in color than the enclosing rock. The unit weathers to a dull gray brown	1.2
3. Sandstone, in alternating layers of fine-grained, shaley, sandstone, and laminated, very highly glauconitic sandstones. The beds of each are about 3 inches thick. The shaley layers are the more resistant of the two types, and form a stair-step effect on the outcrop. The shaley sandstone is green to gray, and weathers to a dull, gray black. The glauconitic sandstone is bright green, weathering to a dull gray green	4.6
2. Sandstone, brown to green, medium to fine grained, highly glauconitic. Splotches of purple are present which apparently are a result of the concentration of hematite which represents one stage in the formation of the hematite nodules.	0.8
1. Limestone, coquina of trilobite remains, glauconitic, very hard and resistant	1.5

	Feet
Total measured thickness of Lion Mountain sandstone member	37.1
Total measured thickness of section.	37.1

MEASURED SECTION OF THE MORGAN CREEK LIMESTONE, WELGE SANDSTONE, LION MOUNTAIN SANDSTONE, AND CAP MOUNTAIN SANDSTONE ABOUT ONE MILE NORTHEAST OF JEFFERIES' HUNTING CAMP

The base of the section is in the upper Cap Mountain limestone at the river's edge 0.8 miles downstream (northeast) from Jefferies' Hunting Camp. The section was measured southeastward to the Morgan Creek-Welge contact. This section contains few fresh exposures and is partially masked by soil cover, but contains unfaulted thicknesses of the Welge and Lion Mountain members in the Upper James River area.

	Thickness of Interval Feet
Wilberns formation:	
Morgan Creek limestone member:	
5. Limestone, dark purple, medium grained, slightly glauconitic, very arenaceous, fairly well bedded in beds 1 1/2 to 3 inches thick. Weathers to a rounded surface which is purple in color.	3.0
Total measured thickness of Morgan Creek limestone member	3.0
Welge sandstone Member:	
4. Sandstone, light yellow to dark brown, medium to fine grained, limonitic, non-fossiliferous, non-glauconitic, rather resistant, covered with an abundant growth of turkey pear, prickly pear, mesquite, and buck brush. Recomposed sand grains that glitter distinctively in the sunlight are common. The	

Feet

weathered surface is irregular and rounded.

Weathers to a yellow brown to dark purplish brown . 22.0

Total measured thickness of Welge sandstone member . . . 22.0

Riley formation:

Lion Mountain sandstone member:

3. Sandstone and limestone. The slope is partially covered by soil. The sandstone is green to brown, medium to fine grained, highly glauconitic, well bedded and cross bedded. The limestone occurs as lenses of highly indurated fragments of trilobite remains 28.0

2. Alluvium in river bed. Believed to be underlain by glauconitic sandstone 10.0

Total measured thickness of Lion Mountain sandstone member 38.0

Cap Mountain limestone member:

1. Limestone, gray to white, medium to fine grained, glauconitic (the glauconite occurring in very fine grains), slightly arenaceous, in beds 1 1/2 to 2 inches thick, very hard and resistant to weathering. Weathers to a light gray. 2.0

Total measured thickness of Cap Mountain limestone member 2.0

Total measured thickness of section. 65.0

MEASURED SECTION OF THE SAN SABA LIMESTONE, POINT PEAK SHALE, AND MORGAN CREEK LIMESTONE IN THE SOUTHWESTERN PART OF THE UPPER JAMES RIVER AREA

The base of the section is located at the river's edge on the west side of the James River 0.6 miles upstream (southwest) from Jefferies' Hunting Camp. The section was measured to the southwest.

	Thickness of Interval Feet
Wilberns formation:	
San Saba limestone member:	
42. Limestone, gray to yellow brown, fine grained to sub-lithographic, slightly arenaceous, slightly glauconitic, in beds 1/2 to 4 inches thick. Weathers to a light gray with many yellow stains. .	56.0
41. Limestone, white to brownish gray, medium to coarse grained, in beds about 3 inches thick. Weathered surface is gray to white with a slight pinkish tint.	10.0
40. Sandstone and limestone, interbedded. The sandstone is yellow to red, fine grained, and medium bedded. The sandstone gets progressively redder in the upper part of the unit. The limestone is gray to white, fine grained, arenaceous, and fossiliferous	34.0
39. Soil-covered slope. Believed to be underlain by limestone..	4.0

	Feet
38. Limestone, yellowish brown to gray, fine grained, slightly glauconitic, beds variable in thickness and ranging from 1/2 to 5 inches in thickness. A few thin shale partings are found between the thinner limestone beds. Weathers to a yellowish brown	5.5
Fault with the San Saba member. The direction and amount of throw could not be determined.	
37. Limestone, yellowish brown, medium grained, slightly glauconitic, in beds up to 1.2 feet thick. Weathers to a smooth, tan surface	4.8
36. Limestone, gray to yellowish brown, medium grained, glauconitic, thin to medium bedded. The beds grade from thin to medium thicknesses laterally. Weathers to a light gray	12.0
35. Limestone and shale with the limestone beds separated by the shale beds. Limestone is white to gray, fine grained, in beds 1/2 to 3 inches thick. The shale is light gray, calcareous, and occurs in beds 1/2 to 1 inch thick. The limestone and shale weather to a wood ash gray	9.0
34. Limestone, gray to purple, medium grained, highly glauconitic, fossiliferous (*Girvanella*), bedded in beds 1/2 to 4 inches thick. Weathers to a yellow gray.	7.0

	Feet
33. Limestone, grayish brown to yellow, medium grained, rather resistant. Thick bedded with beds up to 3.5 feet thick. Weathers to a smooth yellow surface. .	11.0
32. Limestone and shale. The limestone makes up more than 50% of the interval and is gray, fine grained, in beds 1/2 to 3 inches thick. The limestone beds are separated by thin shale partings. The shale beds are gray, calcareous, well bedded in beds 1/2 to 1 1/2 inches thick, and are easily eroded. The limestone weathers to a yellow brown, while the shale weathers to a dull gray	75.0
Total measured thickness of San Saba limestone member. .	228.3
Point Peak shale member:	
31. Bioherms, pearl gray, sub-lithographic, as large as 15 feet in diameter and 5 feet in thickness. Distinct, cabbage-head structure is exhibited on the upper surface of the bioherms. The bioherms are very resistant to weathering and weather to a light gray to tan	15.0
30. Shale and limestone. The shale comprises about 90% of the unit and is greenish yellow, calcareous, thinly bedded and weathers to a dull gray green. The limestone is more abundant in the lower part of the unit and is light gray, fine grained, thinly bedded, and weathers to a dull gray	35.0

Feet

29. Shale and intraformational conglomerate. The shale is greenish yellow, calcareous, in thin beds 1 to 3 inches thick. The conglomerate is composed of flat pebbles of shale and siltstone and occurs in beds 3 to 5 inches thick. The shale and conglomerate make up about equal portions of the unit. Some huge ripple marks occur at this level. They have a wave length of 3.2 feet and an amplitude of .5 feet. The ripple marks trend in an east-west direction 40.0

28. Bioherms, pearl gray, sub-lithographic, large, up to 7 feet in diameter. Cabbage-head structure is apparent, and some of the reefs have a surface structure that resembles brain whorls. Numerous small shale and siltstone pebbles that resemble the pebbles found in Point Peak intraformational conglomerates are incorporated in some of the bioherms of this zone. 6.0

27. Shale, yellowish green to green, calcareous, thin bedded with beds 1/2 to 2 inches thick. 15.0

26. Bioherms, pearl gray, medium sized with some as large as 48 inches in diameter. They weather out into large, round, gray boulders. A few of the bioherms exhibit a donut erosional effect 3.0

25. Shale and limestone. The shale makes up most of the unit and is tan to green in color. It is in

Feet

beds 1 1/2 to 3 inches thick. The limestone is white to gray, fine grained, glauconitic, and well bedded in beds 1 to 2 inches thick. 19.0

Total measured thickness of Point Peak shale member. . . 133.0

Morgan Creek limestone member:

24. Limestone and siltstone. Limestone is gray to brown, medium grained and in beds 8 to 12 inches thick. The siltstone beds make up less of the section than the limestone beds. The siltstone is gray, calcareous and bedded in beds about 4 inches thick. Both the limestone and siltstone weather to a dull gray. 3.7

23. Soil-covered slope. Believed to be underlain by limestone 5.5

22. Bioherms, sub-lithographic, pearl gray, large, up to 8 feet in diameter and 3 feet in thickness. Cabbage-head structure is dim, but apparent. They often weather out into a donut pattern. The weathered surface is light to dark purplish gray. . 8.0

21. Limestone, pearl gray, medium-fine-grained, fairly well bedded in beds 2 to 6 inches thick. Weathered surface is gray to wood ash gray. 19.0

20. Bioherms, sub-lithographic, pearl gray, small, up to 24 inches in diameter and 8 inches in thickness. They weather out into round boulders with a dull purplish-gray surface 1.5

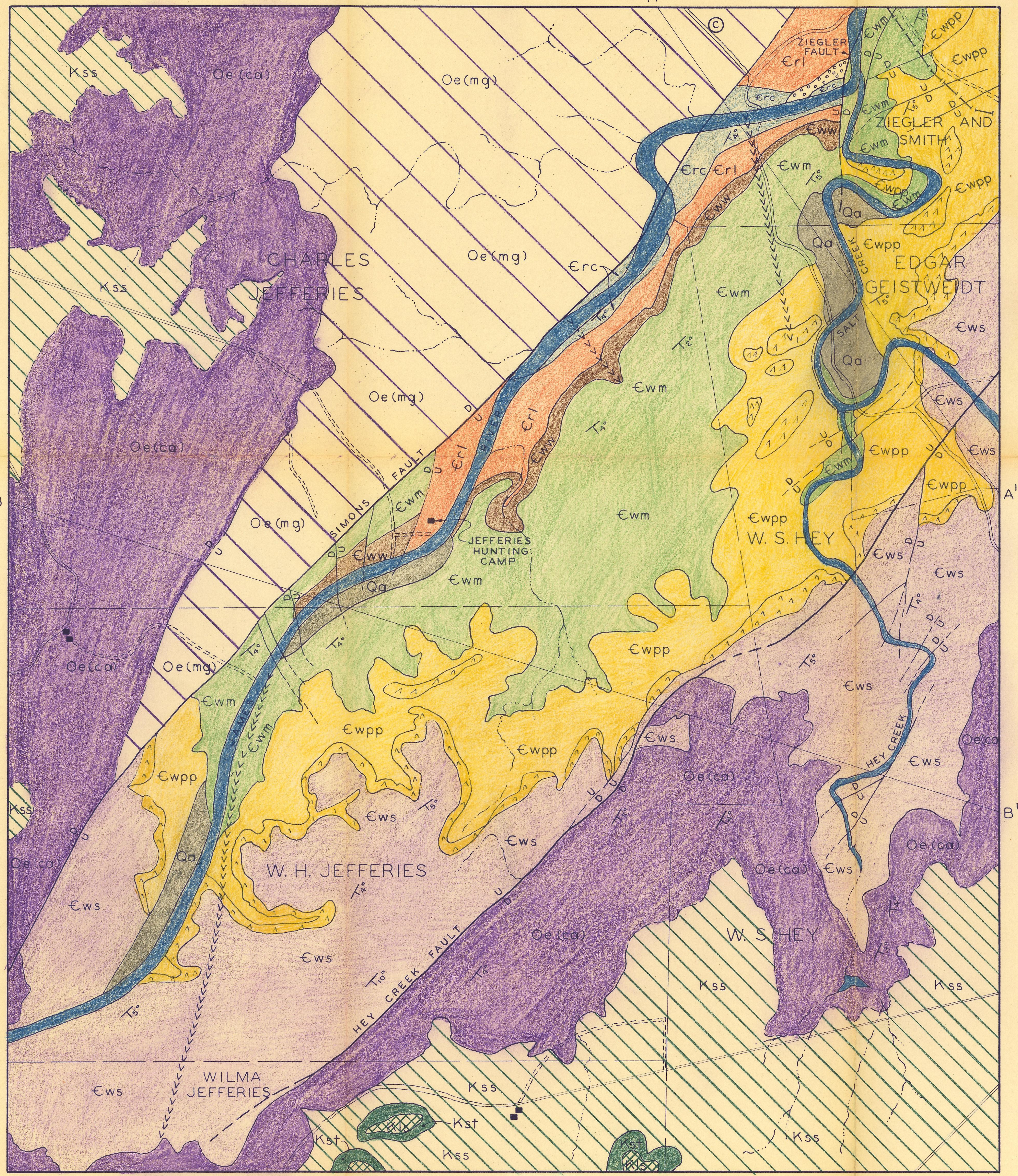
		Feet
19.	Soil-covered slope. Believed to be underlain by gray, fine-grained limestone.	10.8
18.	Shale and limestone is alternating layers. Shale is yellowish green, calcareous, glauconitic, poorly bedded in beds 1 to 3 inches thick and in layers up to 18 inches thick. Weathered color is a dull grayish green. The limestone is light gray, fine grained, shaley, slightly glauconitic, well bedded in beds 4 to 8 inches thick and in layers up to 36 inches thick.	45.0
17.	Limestone, yellowish green, shaley, arenaceous, massively bedded, easily eroded. Weathers to a wood ash gray	3.7
16.	Limestone, pearl gray, sub-lithographic, well bedded in beds 1/4 to 2 inches thick. The beds are separated by very thin stringers of shale. Weathered surface is a grayish tan.	0.5
15.	Limestone, pearl gray, medium to fine grained, very hard and fossiliferous. The fossil appears to be the brachiopod <u>Eoorthis texanna</u>. Weathered surface is smooth and light gray in color.	1.4
14.	Shale, yellowish green, calcareous, poorly bedded. Weathers to a wood ash gray	1.4
13.	Limestone, mostly coquina composed of trilobite remains, very resistant, green to gray on weathered surface	0.4

		Feet
12.	Limestone, gray, fine grained, glauconitic, arenaceous, silty, bedded in beds about 2 inches thick. Weathers to a gray green.	0.5
11.	Limestone, pearl gray, medium grained, slightly glauconitic, well bedded in beds 4 to 7 inches thick. Weathers to a grayish tan	3.7
10.	Limestone, greenish tan, fine grained, arenaceous, silty, slightly glauconitic. Weathers to a dull gray.	1.6
9.	Limestone, pearl gray, medium to fine grained, glauconitic, slightly arenaceous with the sand grains of medium size and well rounded, poorly bedded in beds 2 to 3 inches thick. Weathers to a wood ash gray .	2.0
8.	Limestone and shale in alternating layers. The limestone is light gray, medium to fine grained, faintly glauconitic, and rather resistant, found in layers 12 to 18 inches thick. The shale is yellowish green, calcareous, in layers 6 to 12 inches thick, and is easily eroded. Weathered surface of sand and shale is a dirty gray	8.5
7.	Limestone, white to light gray, medium to fine grained, glauconitic, bedded in beds 6 to 8 inches thick. Weathered surface is smooth and dirty gray in color.	4.9

	Feet
6. Shale, greenish yellow, calcareous, contains some fine-grained sand. Easily eroded, in beds 2 to 4 inches thick. Weathers to a light wood ash gray. .	1.5
5. Limestone, greenish gray, fine grained, glauconitic, arenaceous, silty, in beds 2 to 3 inches thick. Weathers to a dirty gray.	2.6
4. Limestone, fine grained, gray to light purple, glauconitic, slightly arenaceous, well bedded. Weathers to a light gray.	3.0
3. Limestone, gray to purple, medium to fine grained, arenaceous, silty, in beds 6 to 12 inches thick. Weathered surface is irregular and grayish brown in color	6.5
2. Limestone, gray to light purple, medium grained, arenaceous, glauconitic, in beds 8 inches thick. Weathered surface is smooth and light gray in color	2.2
Fault. Completely within the Morgan Creek. The throw could not be determined.	
1. Limestone, purple, medium grained, glauconitic, very arenaceous, well bedded in beds 6 to 12 inches thick. Weathers to a tannish purple. Ripple marks are found at the top of this unit. They have a wave length of 7.5 inches, and an amplitude of 2.0 inches.	4.5

	Feet
Total measured thickness of Morgan Creek limestone member	142.4
Total measured thickness of section.	503.7

PLATE I



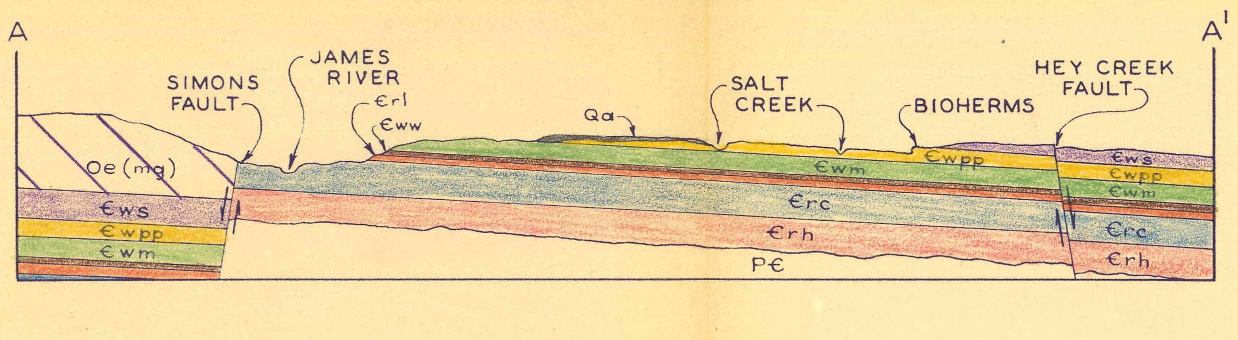
Base from U. S. Department of Agriculture Aerial Photographs, 1955

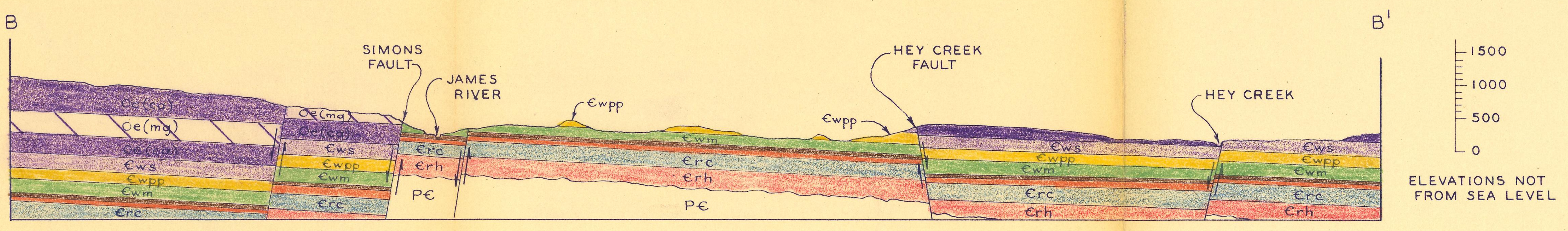
Geology by Dixon N. White 1959

SCALE: 1/20,000

1 0.5 0 1 mile

1,700 850 0 8500 feet





EXPLANATION

CENOZOIC — TERTIARY-QUATERNARY
- Qa — Recent alluvium
- (T?)cc — Caliche conglomerate (Tertiary ?)

UNCONFORMITY

LOWER CRETACEOUS — UNDIFFERENTIATED — CRETACEOUS
- Limestone
- Kst — Siltstone
- Kss — Silt and Sand

UNCONFORMITY

LOWER ORDOVICIAN — ELLENBURGER GROUP — ORDOVICIAN
- Oe(mg) — Ellenburger dolomite
- Oe(ca) — Ellenburger limestone

UPPER CAMBRIAN — CAMBRIAN

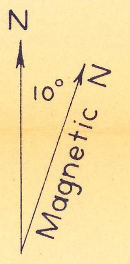
WILBERNS FORMATION
- €ws — San Saba limestone member
- €wppb — Bioherm Zone
- €wpp — Point Peak shale member
- €wm — Morgan Creek limestone member
- €ww — Welge sandstone member

RILEY FORMATION
- €rl — Lion Mountain sandstone member
- €rc — Cap Mountain limestone member
- €rh — Hickory Sandstone member (Not exposed)

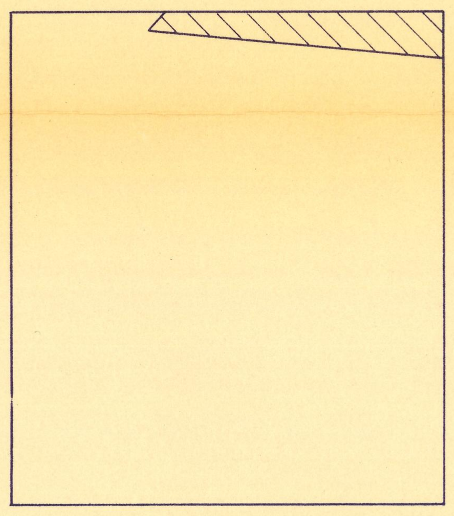
UNCONFORMITY

PRECAMBRIAN
- P€ — Undifferentiated (Not exposed)

Symbols:
- Major fault (U/D)
- Inferred major fault
- Minor fault
- Inferred minor fault
- Observed contact
- Inferred contact
- Strike and dip of beds
- Stream
- Intermittent stream
- County road
- Ranch road
- Property line
- <<<<<<<<<< Location of measured section
- Pipeline
- House
- Stock tank
- Stock pens
- Ⓒ Cave



Approximate mean declination



Crosshatched area mapped by Dannemiller (1957). Modified by White.

GEOLOGIC MAP AND CROSS SECTIONS OF THE UPPER JAMES RIVER AREA
MASON COUNTY, TEXAS