GEOLOGY OF THE CENTRAL PART OF THE JAMES RIVER VALLEY, MASON COUNTY, TEXAS

By

George David Dannemiller

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

August, 1957

GEOLOGY OF THE CENTRAL PART OF THE JAMES RIVER VALLEY,

MASON COUNTY, TEXAS

A Thesis

by

George David Dannemiller

August, 1957

Approved as to style and content by:

Melvin C. Schroeder for H.K. Ericke
Chairman of Committee

Head of Department

A C K N O W L E D G M E N T S

The writer is grateful to Dr. H. R. Blank, Professor of Geology at the Agricultural and Mechanical College of Texas, for his aid in selecting the field problem and for his supervision of the writing of this thesis. Thanks are also due Dr. M. L. Schroeder and Mr. C. L. Seward of the Geology Department of the Agricultural and Mechanical College of Texas and Mr. J. D. Boon of the Department of Geology of Arlington State College, Arlington, Texas, whose suggestions and constructive criticism were of great assistance is gathering data and preparing this paper.

The writer is grateful to Mr. J. L. Goolsby for his help in measuring the described section. Thanks are also due Mr. K. L. Sliger who furnished considerable information on the geology of the northern portion of the James River valley.

Thanks are also due to the ranchers and local residents of Mason County, Texas for the hospitality and courtesy that were extended to the author.

Aerial photographs and equipment used by the writer were the property of the Department of Geology of the Agricultural and Mechanical College of Texas.

C O N T E N T S

ILLUSTRATIONS

PLATE PAGE

GEOLOGY OF THE CENTRAL PART OF THE JAMES RIVER VALLEY, MASON COUNTY, TEXAS

ABSTRACT

The Central Part of the James River Valley is located in south-central Mason County, southwest of the town of Mason. Rock units of Upper Cambrian, Lower Ordovician, and Quaternary age are found in the area.

The Upper Cambrian is divided into the Riley and Wilberns formations. The Riley formation is divided into three members. These are in ascending order: Hickory sandstone, Cap Mountain limestone, and Lion Mountain sandstone. The Hickory sandstone and the lower and middle beds of the Cap Mountain limestone are not exposed in the thesis area. The upper beds of the Cap Mountain that are exposed in the thesis area consist of a gray, granular, slightly glauconitic and fossiliferous limestone. The Cap Mountain member is overlain by the highly glauconitic Lion Mountain sandstone member.

The Wilberns formation is divided into the following members in ascending order: Welge sandstone, Morgan Creek limestone, Point Peak shale, and San Saba limestone. The yellowish-brown to brown, usually nonglauconitic sandstones of the Welge are in sharp contact with the underlying Lion Mountain sandstone. The Welge grades upward into the reddish to purple and very arenaceous lower Morgan Creek limestones. These purplish beds grade upward into greenish-gray, coarse-grained, highly glauconitic, very fossiliferous limestones.

A transitional contact separates the green calcareous shales, limestones, and conglomerates of the Point Peak member from the underlying Morgan Creek member. The upper Point Peak consists of a distinctive stromatolitic bioherm zone which grades into the calcareous sands and arenaceous, fossiliferous limestones of the San Saba member.

The Cambrian strata are overlain conformably by strata of Lower Ordovician age, represented by the Ellenburger group. The calcitic and dolomitic facies of the Ellenburger were differentiated in mapping, but no effort was made to differentiate the formations of this group. The Ellenburger rocks consist essentially of sublithographic, pearl-gray to wood ash gray, and old ivory, nonglauconitic limestones and microgranular to coarse-grained, gray dolomite.

The sediments of Quaternary age are limited to stream alluvium consisting of sand, gravel, and coarse conglomerates.

The outcrop pattern in the central part of the James River valley is greatly affected by faulting which occurred near the end of Paleozoic time. The faults are normal and trend northeast. The throws average about 200 feet, but range up to more than 600 feet. Three of the major faults are downthrown to the northwest and one is downthrown to the southeast. A large structural graben has been formed by two of the major faults, but the upthrown block has been eroded down to a topographic lowland. The strata, where unaffected by faulting, have an average regional strike of N 65° E and dip approximately 5° to the southeast.

Folding is limited to differential compaction over bioherm structures and to small sink hole depression features that are the result of solution of the limestone.

The most important natural resource is ground water. The Hickory sandstone is the most important aquifer, but several important wells produce from the Ellenburger. It is improbable that oil and gas production can be discovered by drilling. Bat guano is found in a large solution cave and is sold on the market as a commercial fertilizer.

GEOLOGY OF THE CENTRAL PART OF THE JAMES RIVER VALLEY, MASON COUNTY, TEXAS

INTRODUCTION

STATEMENT OF PROBLEM

The primary purpose of this paper is to determine the stratigraphy of the central part of the James River valley and to prepare a geologic map of the area based on data gathered in the field. Consideration was also given to: (1) the structural development of the area; (2) the geologic history of the area; (3) the economic geology.

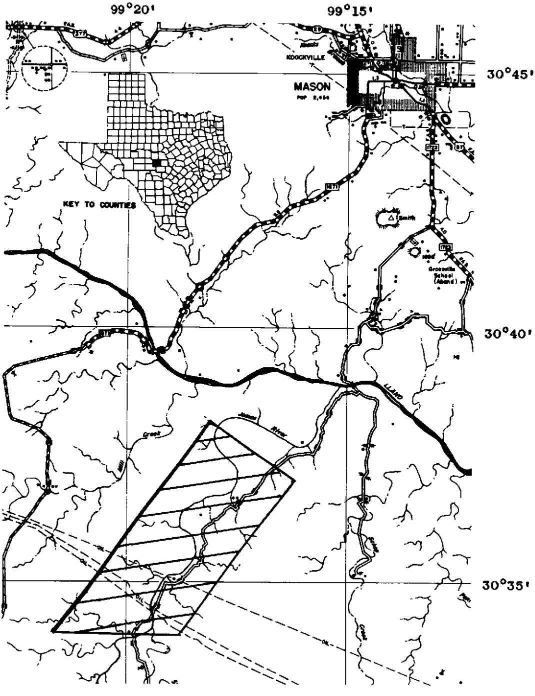
LOCATION

The thesis area is located in Mason County on the southwestern flank of the Llano uplift in Central Texas. The area is approximately fourteen square miles in extent and is approximately eleven air miles southwest of the town of Mason. The area lies within the drainage basin of the James River and its tributaries.

ACCESSIBILITY

The thesis area is fairly accessible. The principal road which furnishes access to the area is the unpaved but all-weather James River road which roughly bisects the area in a northeast-southwest direction. Several rough but passable ranch roads provide access to that portion of the area which is northwest of the James River road. Several ranch roads

Plate II



Reproduced from Highway Map of Mason County, Texas, Prepared by Texas Highway Department, 1954.

LOCATION OF THE CENTRAL PART OF THE JAMES RIVER VALLEY, MASON COUNTY, TEXAS furnish access to that portion of the area southeast of the James River road, but these are few in number and are mere rock-studded trails.

METHODS OF FIELD WORK

The field work was carried out between June 3, and August 5, 1956. Mapping was done on acetate-covered aerial photographs made by the United States Department of Agriculture. Photographs 158, 196, and 198 of series DFZ-5E and photograph 13 of series DFZ-6E, dated November 25, 1948 were used in preparing the map of the area. The scale of the photographs is 1:20,000.

Most of the formation contacts and faults were located and walked out in the field and then plotted on the acetate overlay with the aid of a pocket stereoscope. Other formation contacts and faults were determined at the drafting table from stereoscopic examination of the photographs and then checked in the field by a series of closely spaced traverses.

A Brunton compass was used in the field to obtain strikes and dips. These strikes and dips represent an average of several readings made in the immediate vicinity of each point. Some strikes and dips used in this thesis were obtained from Mr. K. L. Sliger who worked in the northern part of the James River valley and whose area overlapped the area of this thesis.

The measured and described section represents the best and most nearly continuous exposure that was found. The section was measured as nearly as possible in a direction perpendicular to the strike, and the dips were averaged along the section to improve the accuracy of the thickness calculations. The measurements were made with a Brunton compass set at the correct angle of inclination and the readings were made on a stadia rod.

PREVIOUS WORK

The first publication describing the geology of central Texas was by Dr. Ferdinand Roemer (1846). This publication gave an account of the area adjacent to the Central Mineral region on the south. Roemer (1849) also published the first report on the stratigraphy and paleontology of the Paleozoic rocks in the Central Mineral region of Texas. This report was accompanied by the first geologic map of Texas, which was crude and inaccurate. Roemer (1852) published a more detailed account of the Cretaceous of Texas.

In 1855 and 1856, an expedition of Army engineers was accompanied by Dr. G. G. Shumard (1886) who gave a brief description of the geology along the route through the San Saba River valley to Fort Mason and Fredericksburg.

The first description of the stratigraphy and paleontology of the Potsdam group of the Upper Cambrian system in Texas was made by B. F. Shumard (1861).

S. B. Buckley (1874), then State Geologist, gave a brief discussion of the mineral resources and general geology of the Llano region. He arbitrarily classified all granites in the Llano region as Azoic (p. 15). He also stated that the granites were younger than the metamorphic rocks with which they are associated.

The Late Cambrian age of the Potsdam group was established by Walcott (1884). He gave the name Llano group to the Lower Cambrian strata of the Central Mineral region and assigned a pre-Potsdamian age to the masses of granite in western Burnet County and Llano County.

R. T. Hill (1887) included a brief mention of the Llano region, with a notation as to the importance of Walcott's work, in a review of Texas geology. Hill (1889) disagreed with Walcott's belief that the granite in southwestern Burnet County was pre-Potsdamian in age. He assigned this granite to the late Carboniferous or post Carboniferous.

A Special Session of the Twentieth Legislature of 1888 created the Geological and Mineralogical Survey of Texas with the purpose of reporting on the mineral and other natural resources of the state. At this time the first systematic geological survey was made of the Central Mineral region. This was included by E. T. Dumble (1890) in a review of Texas geology as developed by the survey.

T. B. Comstock (1890) discussed the geology and the mineral resources of the Central Mineral region. He introduced the names Hickory series (Lower Cambrian), Riley series (Middle Cambrian), and San Saba series (Upper Cambrian). The Riley series as defined by Comstock in this report contained only a portion of the rocks which are now included in the Riley formation.

Ralph S. Tarr (1890) made observations on the origin of some of the topographic features of the Central Mineral region and studied their relationship to the later history of the superimposed drainage system. He stated that the evidence shows that this drainage began on Cretaceous strata in Tertiary time, and after the removal of the soft, relatively horizontal strata, it became superimposed on the harder, underlying Paleozoic rocks.

The Second Annual Report of the Texas Geological Survey (Dumble, 1891) is concerned chiefly with the mineral resources of the State. Special emphasis was given to the economic aspects of the Llano region and various mining areas and potential mining areas were discussed. Cross sections illustrating complicated structural conditions were also included in this report.

Sidney Paige (1911) named and described the Wilberns, Cap Mountain, and Ellenburger formations. He also discussed the mineral resources of the Llano-Burnet region and gave an excellent description of the Precambrian geology. Paige (1912) mapped the geology of the Llano and Burnet quadrangles in detail. In this latter report, he used the term Hickory sandstone rather than the Hickory series of Comstock.

The first comprehensive geologic map of Texas was published in 1916 by the Bureau of Economic Geology (Udden, et al, 1916). On this map, the Cambrian and Ordovician rocks are shown as one unit and the Precambrian rocks are undifferentiated.

In a report on the stratigraphy of Texas, Sellards (1933) presented a brief review of the Precambrian, Cambrian, and Ordovician systems of the Llano region. In a report on the structural and economic geology of Texas, Sellards (1934) discussed the Paleozoic deformation of the region. In this same report, Stenzel (1934) reviewed the Precambrian structural conditions.

A new State geological map (Darton, et al, 1937) was made from data gathered by Darton in 1933. This was the first map to show the outcrop area of Hickory sandstone, Wilberns and Cap Mountain limestones, and Ellenburger limestone.

Bridge (1937) named and described the Lion Mountain sandstone member of the Cap Mountain formation after examination of the rocks on the western side of the Llano uplift. He also redescribed many of Roemer's type localities.

Bridge and Girty (1937) redescribed the Paleozoic fossils of the Central Mineral region that were originally described by Roemer. Roemer's original type localities were re-established and the stratigraphic horizons were accurately determined.

Barnes and Parkinson (1940) presented the first description of the ventifacts that occur in the basal Hickory sandstone of central Texas. A map of the Hickory sandstone outcrop areas showing ventifact localities in Mason, Llano, and Blanco counties was also included in this report.

Plummer (1940) gave a brief account of the regional and local structure in the Llano area. He attributed the dip of the formations away from the central granite mass to original deposition, settling, and compaction.

Cheyney (1940) proposed that some changes be made in the nomenclature of time and rock units of the later Paleozoic in north-central Texas. He also proposed that the Smithwick and Big Saline formations be removed from the Bend group and be included in the Lampasas series.

Plummer (1943) wrote a short paper describing a white quartz sand near the middle part of the Wilberns formation in northeastern Mason County.

Barnes (1944) listed the previously-named units of the Upper Cambrian in the Llano uplift. The pre-Wilberns units were given formational status with the exception of the Lion Mountain sandstone which was designated as a member of the Cap Mountain limestone. The Wilberns formation was divided into four members. These are in ascending order: Welge sandstone, Morgan Creek limestone, Point Peak shale, and San

Saba limestone and its equivalent facies, the Pedernales dolomite. Barnes does not describe the units, but refers to an unpublished manuscript by Bridge and Barnes that was presented before the Geological Society of America in 1941.

Cloud, Barnes, and Bridge (1945) prepared a progress report on the stratigraphy of the Ellenburger group of central Texas. The Ellenburger limestone was elevated to group status and restricted to the Lower Ordovician. The formations of the group were named and defined for the first time in this report. The three formations named are in ascending order: Tanyard formation, Gorman formation, and Honeycut formation. The Riley series was also redefined and given formational status. The Hickory sandstone, the Cap Mountain limestone, and Lion Mountain sandstone were redesignated as members of the Riley formation.

In a report on the water resources of Texas, Plummer (1946) discussed the importance of the Hickory sandstone and the Ellenburger group as aquifers in the Llano region.

Bridge, Barnes, and Cloud (1947) completely revised the Upper Cambrian in the Llano uplift and provided a standard reference to the eight members and two formations. All the units were listed and redefined, and the stratigraphy of each was thoroughly described.

Cloud and Barnes (1948) reported on the Ellenburger group of central Texas and the pre-Ellenburger strata at various localities in the Llano region, with emphasis placed on the features having a possible significance in the search for petroleum. A summary of the structural geology of the Llano region was included.

Plummer (1950) briefly reviewed the pre-Carboniferous stratigraphy of central Texas in his report on the Carboniferous stratigraphy and paleontology in this region. This report included the most complete and detailed geologic map of the area compiled up to this time.

H. R. Blank (1951) described certain features of the weathering found on the Precambrian granite of the Llano region.

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

CLIMATE

The central part of the James River valley is located in a semi-arid region of Texas. The annual precipitation in Mason County averages approximately 22.5 inches during a normal year. The precipitation generally occurs in widely spaced, heavy rains which have a high percentage of runoff.

The mean annual temperature is approximately 64° F and the temperature over the year may range from a low of -5° F in the winter to a high of 110° F in the summer. The average daytime temperature during the summer months ranges from 90° F to 100° F.

VEGETATION

The vegetation in the central part of the James River valley is limited to those types which can exist in areas where there is poor soil development and moderate precipitation.

Many types of vegetation grow on the Paleozoic strata. The limestone outcrops generally support the growth of scrub oak, cedar, Spanish dagger, and several varieties of cactus. The sandstones usually support growths of mesquite, live oak, and needle grass. The shale outcrops are characterized by growths of mesquite and Mexican persimmon. The vegetation on the shale outcrops is generally less dense than on the adjoining formations.

DRAINAGE

The Llano region is drained to the south and east by the San Saba, Llano, and Colorado Rivers. The area considered in this paper lies several miles south of the Llano River. It is drained by the James River and its tributaries. The James River flows northeastward through the center of the area and empties into the Llano River.

GEOMORPHOLOGY

The central part of the James River valley is located on the southwest flank of the Llano uplift in central Texas. The region is structurally a dome, but is topographically a basin.

The thesis area is located on outcrops of Paleozoic rocks. The maximum relief of the thesis area is on the order of 300 feet and the maximum elevation is approximately 1,700 feet above sea level.

Strata of the upper part of the Cap Mountain member are the oldest rocks exposed in the central part of the James River valley. The Cap Mountain is a very resistant limestone that forms the bed of the James River in several places as well as steep bluffs along the river. The overlying Lion Mountain member is a highly glauconitic sandstone that generally erodes to form a bench with clumps of scattered vegetation. The brown, less glauconitic, fine-grained sandstones of the Welge member that overlie the Lion Mountain member form small cliffs that are very heavily vegetated, producing a very dark narrow line of vegetation that may readily be seen on aerial photographs. The limestones and bioherms of the Wilberns formation form steep hills and prominent ridges that trend in a northeast-southwest direction. The Lower Ordovician rocks of the Ellenburger group are the youngest rocks exposed in the thesis area, with the exception of some Recent alluvium, and form a rolling plateau. In general, the relief is slightly greater on the Ellenburger strata than it is on the Upper Cambrian strata but there are fewer deep valleys in the Ellenburger.

A system of parallel, northeast-southwest trending, normal faults has played an important part in the development of the physiographic features. Movement along these faults has brought the strata on the upthrown side under more active influence of wind and rain. In some cases, this results in the structurally high upthrown blocks being reduced to topographic lowlands. This is particularly noticeable in the central part of the valley where two major faults form a structural horst, but where erosion has formed two obsequent fault-line scarps, thus giving the feature the appearance of a graben.

The course of the James River, as well as the course of most of the major streams in the Llano region, became established on a nearly level plain of Cretaceous sediments. The region was uplifted and as the Cretaceous sediments were removed, the river became entrenched in the underlying Paleozoic rocks. The disregard of the course of the river for the geologic structure is evidence that the James River is a superimposed stream.

As uplift of the area continued, the river worked toward a stable base level and widened its valley on the easily eroded Lion Mountain outcrop. This is the most prominent valley in the thesis area and it is located between the two major faults that form the structural horst that was mentioned in a previous paragraph. More recent uplift caused the river to become entrenched in the Cap Mountain member, leaving its former valley floor as a bench.

The slight uplift of the area that resulted in the rejuvenation of the James River may be the result of an uplift in the immediate vicinity, or the result of a depression to the southeast. Unfortunately, the data available in the central part of the James River valley are insufficient to justify a definite conclusion.

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

GENERAL STATEMENT

Rocks of Paleozoic are crop out in the central part of the James River valley. Rocks older than the Cap Mountain limestone member of the Riley formation of Late Cambrian age are not exposed in this area. Some Recent alluvial deposits are found along the river bed, but other than this, rocks younger than the Ellenburger group of the Lower Ordovician are not exposed. The geologic column for this area is as follows:

- Cenozoic systems
  - Quaternary
    - Recent
- Paleozoic systems
  - Ordovician system
    - Lower Ordovician
      - Ellenburger group
  - Cambrian system
    - Upper Cambrian
      - Wilberns formation
        - San Saba limestone member-Pedernales dolomite member (equivalent facies)
        - Bioherm zone
        - 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 SYSTEMS

CAMBRIAN SYSTEM

The rocks of Late Cambrian age that are present in the central part of the James River valley belong to the Riley and Wilberns formations. These formations consist of sandstones, limestones, shales, and stromatolitic bioherms. The bioherms occur near the top of the Wilberns formation. A standard reference to the Upper Cambrian is provided by Bridge, Barnes, and Cloud (1947). This publication redefined and thoroughly described the two formations and eight members that compose the Upper Cambrian strata of the Llano uplift of central Texas.

Riley Formation

The Riley is the lowermost Paleozoic formation in the Llano uplift. According to Cloud, Barnes, and Bridge (1945, p. 154), the name Riley formation is used to include all of the Cambrian strata in central Texas beneath the Wilberns formation. The Riley formation includes, from base to top, the Hickory sandstone member, the Cap Mountain limestone member, and the Lion Mountain sandstone member.

The formation takes its name from the Riley Mountains in southeastern Llano County, where excellent exposures of the members can be found. Cloud measured the members that are exposed in the Moore Hollow area of the Riley Mountains and found the total thickness to be 780 feet. Bridge, Barnes, and Cloud (1947, p. 112) stated that the great variation in the thickness of the Riley formation throughout the Llano region was caused in part by the topographic irregularities of the Precambrian surface of deposition. The extremes in the thickness range from slightly under 200 feet in northwestern San Saba County, where the Cap Mountain limestone rests unconformably on the Precambrian, to almost 800 feet in southeastern Llano County. The average thickness given by Bridge, Barnes, and Cloud (1947, p. 110) is 680 feet. It was not possible to obtain the total thickness of the Riley formation in the central part of the James River valley, since the Hickory sandstone member and the base of the Cap Mountain limestone member were not exposed.

Hickory sandstone member

The Hickory sandstone is the oldest member of the Riley formation. Comstock (1890) first used the name Hickory to denote a series with its type locality at Hickory Creek in Llano County. Paige (1912, p. 42) revised the name to Hickory sandstone. Cloud, Barnes, and Bridge (1945, p. 154) redefined the Hickory and assigned it as a member in the Riley formation. They also lowered the upper boundary, thereby cutting out some of the beds which had been included in the Hickory sandstone by Paige.

Bridge, Barnes, and Cloud (1947, p. 112) stated that the Hickory sandstone member averages about 350 feet in thickness. They also stated that the thickness may range from a "feather edge" to about 415 feet. These variations were attributed to the topography of the area at the time the Hickory sea invaded it, to irregularities in deposition, and to lateral gradation of the Hickory sandstone into the limestones of the upper beds. It was not possible to obtain any measurements of the Hickory sandstone in the central part of the James River valley since the Hickory is not exposed.

Bridge, Barnes, and Cloud (1947, p. 113) stated that the sandstones of the Hickory are noncalcareous, non-glauconitic, and yellow, br wn, and red in color. The individual sand grains are angular to subrounded. The upper part of the Hickory in the western part of the Llano uplift is typically dull red or russet in color.

Cap Mountain limestone member

The Cap Mountain limestone member, as defined by Bridge, Barnes, and Cloud (1947, p. 113), is somewhat different from the original Cap Mountain formation of Paige (1911, p. 45). The recognition of the Lion Mountain sandstone member restricts the Cap Mountain at the top, but this loss is counterbalanced by the addition of beds at the bottom that were formerly included in the Hickory sandstone member. The type section is at Cap Mountain in Llano County.

According to Bridge, Barnes, and Cloud (1947, p. 113), the member ranges in thickness from about 135 feet to 455 feet and has an average thickness of 280 feet. The variation in thickness is due principally to lateral gradation into the sandstone of the underlying Hickory beds. It was not possible to measure the thickness of the Cap Mountain limestone member in the central part of the James River valley since the base was not exposed, but Sliger (1957, personal communication), measured a thickness of 315 feet for this member at a locality only a few miles to the north.

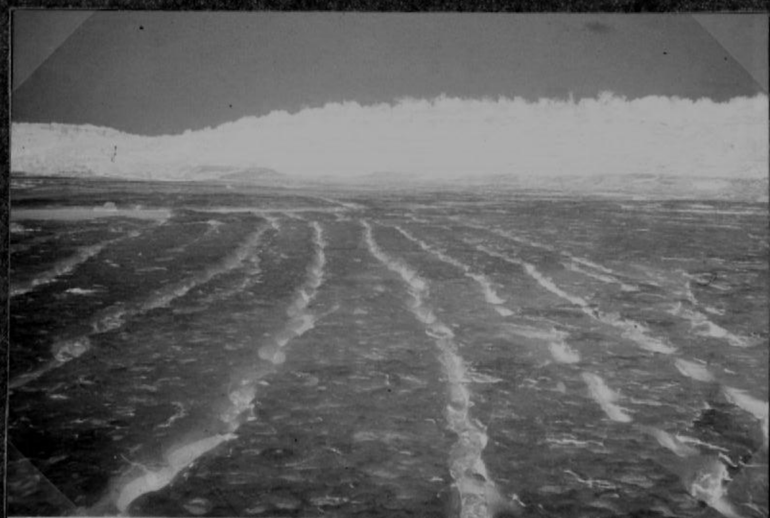
According to Bridge, Barnes, and Cloud (1947, p. 113), the contact with the Hickory sandstone member is gradational. The dark noncalcareous sandstones of the Hickory grade into and interfinger with the light brown sandy limestones of the Cap Mountain member. The boundary between the Hickory and the Cap Mountain is placed at a distinct topographic as well as vegetational change which shows well on aerial photographs. This boundary is at the top of a noncalcareous sandstone zone and beneath a zone of alternating impure, dark-brown limestones and calcareous sandstones which become more calcareous upward. The Cap Mountain is overlain by the Lion Mountain sandstone member.

The lower part of the Cap Mountain member is composed of dark reddish-brown, medium - to coarse-grained, calcareous sandstones that alternate with and grade laterally into light gray, fine-grained, arenaceous limestones. These beds grade upward into a series of dark brown, medium-grained, slightly fossiliferous limestones that alternate with tan, fine-grained, noncalcareous sandstones. The increased abundance of calcium carbonate higher in the section results in the formation of tan, thick-bedded to massive limestones. These massive ledges of limestone, which comprise the greater part of the Cap Mountain limestone member, often display a honey-combed weathered surface.

The lithology of the upper part of the Cap Mountain member, that is exposed in the thesis area, is not typical of the Cap Mountain limestone that is generally found elsewhere in the Llano region. For the most part, the lithology here resembles more closely that of the Morgan Creek member, or possibly the basal part of the San Saba member. Because of this situation, field relations had to be thoroughly studied in order to make a definite identification of these rocks. The unweathered rock, found in the bed of the James river, is composed of a white to gray, crystalline, fossiliferous, slightly glauconitic limestone that has the appearance of a marble. Higher up in the section, above the river bed, the upper part of the Cap Mountain is more weathered and is composed of glauconitic, fossiliferous, light gray to rusty brown, yellowish-green, and purplish limestones having a medium-grained to granular texture. In these rocks the glauconite is often weathered, leaving yellow streaks. It is the abundance of glauconite and the purplish color of many of the rocks that causes the marked resemblance to the Morgan Creek limestone member.

An interesting feature of the upper part of the Cap Mountain member in the central part of the James River valley is the distinctive erosional feature that is found in the bed of the river about two miles southwest of the Ziegler ranch house. This feature consists of potholes that have been connected by erosion to form a series of small trenches that are roughly parallel to one another, and which have been termed "wagon tracks". (Plate III) These "wagon tracks" occur on what appears to be the upthrown side of small faults. They tend to be more pronounced near the scarp and diminish in the downstream direction. They also trend in a direction that is parallel to the flow of the river. From these observations, Blank (1956) derived the hypothesis that the scarp caused a turbulent action that was instrumental in the formation of this feature. There are a number of joints in the river bed in the vicinity of these "wagon tracks", but the feature occurs in the more resistant, relatively unjointed rock rather than in the jointed rock where it would be expected that the limestone would be more susceptible to erosion.

PLATE III



"Wagon tracks" in the upper part of the Cap Mountain limestone member found in the bed of the James River about two miles southwest of the Ziegler ranch house.

Rejuvenation has caused the James River to cut down into the upper part of the Cap Mountain member and expose the relatively flat-lying strata of this member. This rejuvenation has also resulted in the formation of bluffs along the river.

The vegetation found in the upper part of the Cap Mountain member is rather dense and evenly distributed except where the member outcrops in the river bed. The vegetation consists of scrub oak, mesquite, prickly pear, Spanish dagger, and catsclaw.

Lion Mountain sandstone member

Bridge (1937) named the Lion Mountain sandstone as the top member of the Cap Mountain "formation", but in recent years Cap Mountain as a formation name has been dropped. Cloud, Barnes, and Bridge (1945, p. 154) redefined the Cap Mountain as a member of the Riley formation and recognized the Lion Mountain sandstone as the top member of the Riley formation.

Bridge, Barnes, and Cloud (1947, p. 114) stated that the thickness of the Lion Mountain varies from about 20 feet at the type locality at Lion Mountain in the northwestern part of the Burnet quadrangle to a maximum of 50 feet elsewhere in the Llano region. The measured thickness in the central part of the James River valley is 31.9 feet.

The Lion Mountain member forms a topographic bench of variable width. This bench shows on aerial photographs as a narrow, light band due to vegetational differences between the Cap Mountain member and the Lion Mountain member. Since the lower contact with the Cap Mountain member is a gradational one, the lower boundary was most conveniently located for mapping purposes at the lower edge of the sparsely vegetated bench. The vegetation on the bench consists chiefly of mesquite and needle grass with small amounts of scrub oak and various types of cacti.

The lower portion of the Lion Mountain member consists of thin-bedded, greenish-gray to green, glauconitic limestone containing numerous fragments of trilobites. This is commonly called "trilobite hash". The major part of the member is composed essentially of medium-to coarse-grained, highly glauconitic, greenish-gray to green, and gray, calcareous sandstones. The sandstones of the middle portion of the member are interbedded with thin beds of shale and clay.

A characteristic of the Lion Mountain member is the presence of numerous nodules of hematite which are found scattered all over its residual soil. (Plate IV) It is believed that the hematite (Fe_2O_3) is a product of the weathering of the glauconite ($KFeSi_2O_6 \cdot nH_2O$) that is so abundant in the member. In the thesis area and its vicinity it is possible to find nodules representing all stages of weathering, from practically unaltered glauconite to relatively pure hematite.

PLATE IV

Hematite float scattered on the Lion Mountain soil about 300 yards east of the Ziegler ranch house.

Wilberns Formation

The Wilberns formation was first named by Paige (1911, p. 46) after Wilberns Glen in Llano County. The lower boundary of the formation as originally defined by Paige has been retained, but the upper boundary was redefined by Cloud, Barnes, and Bridge (1945, p. 154) and placed at the top of the Cambrian system. Bridge, Barnes, and Cloud (1947, p. 114) redefined and described the five members of the formation.

According to Bridge, Barnes, and Cloud (1947, p. 114), the thickness of the formation ranges from 540 feet to 610 feet throughout most of the Llano region. In the southeastern corner of the region, truncation and a disconformity at the top of the formation have reduced the thickness to 360 feet. The average thickness is about 580 feet. Faulting made it impossible to obtain any accurate measurements of a complete section of the Wilberns formation in the central part of the James River valley, but Alexander (1952, p. 37) measured its thickness as 665 feet in the South Mason area about 6 miles to the northeast.

Welge sandstone member

According to Bridge, Barnes, and Cloud (1947, p. 114), the Welge sandstone member of the Wilberns formation was named by Barnes from the Welge land surveys between Threadgill and Squaw creeks in Gillespie County. At the type section the thickness of the member is 27 feet. The Welge member extends throughout the Llano uplift and ranges in thickness from 9 feet to 35 feet with an average thickness of 18 feet. The thicker sections of the Welge member are located along the northern and western sides of the uplift. A thickness of 12.4 feet was measured in the central part of the James River valley.

The lower contact of the Welge member is very abrupt. There is a very noticeable change from the highly glauconitic sands of the Lion Mountain member to the yellowish-brown, nonglauconitic sands of the Welge member (Plate V). There is an abrupt change in the topography from the Lion Mountain bench to the small cliffs of the Welge. There is also an abrupt change from the sparsely vegetated Lion Mountain to the more densely vegetated Welge. The live oak trees that grow at the contact of the Lion Mountain and Welge show on aerial photographs as a long, narrow, dark line. It was thus very convenient for mapping purposes to place the lower contact at this vegetation change.

The Welge member is composed of yellowish-brown to brown, nonglauconitic, noncalcareous, massive sandstone having a medium - to coarse-grained texture and subrounded quartz grains. Much of the Welge member contains quartz grains with recomposed faces which glitter in the sunlight.

Morgan Creek limestone member

According to Bridge, Barnes, and Cloud (1947, p. 114),

PLATE V

Contact between the Lion Mountain member and the Welge member. Located in a gully about two miles south of the Ziegler ranch house.

the Morgan Creek member was named by Bridge from exposures on both the north and south forks of Morgan Creek in Burnet County. The thickness of the type section, exposed on the point of land just north of the junction of the two forks, is about 110 feet. At other locations the thickness ranges from about 70 feet to about 160 feet. The average thickness is about 120 feet.

The continuity of the Morgan Creek was broken by faulting in the central part of the James River valley, thus making it impossible to obtain an accurate measurement of the thickness. Sliger (1957, personal communication) measured a thickness of about 130 feet in the nearby Lower James River area.

The lower contact is gradational and slightly sandy. The contact is placed at the base of the first reddish to purple, coarse-grained, arenaceous limestone bed. The Morgan Creek member grades upward into the shales and siltstones of the Point Peak member. The Morgan Creek member is generally exposed in gullies where the overlying Point Peak member has been eroded. In the northern part of the area, the Morgan Creek rises steeply from the Welge member and forms ridges and hills which range in relief from 25 feet to 50 feet.

The lower portion of the member is commonly reddish or purplish with the red tones becoming less pronounced and

PLATE VI

Ripple marks on the Morgan Creek limestone member found in gully three miles south of Ziegler ranch house and 100 yards east of the James River road.

and finally grading upward into gray or greenish-gray limestone, which is coarse-grained, highly glauconitic, fossiliferous and well-bedded in ledges of uniform thickness. The medium-bedded, sandy layers at the base erode easily leaving only indistinct ledges. The fossil, Eoorthis texana, begins to appear in the member about 60 feet above the base.

The upper portion of the member is composed of greenish-gray to yellowish-brown, glauconitic, medium- to coarse-grained, evenly bedded limestone. Small, isolated, thin, gray stromatolitic bioherms are occasionally found in the upper part of the Morgan Creek member. Their small size and limited extent distinguish these bioherms from those that occur in the bioherm zone between the Point Peak member and the San Saba member.

Zones of gray shaly or marly limestone are present throughout almost the entire member. These zones are generally thin in the lower portion of the member, but become thicker and shalier toward the top.

Point Peak shale member

According to Bridge, Barnes, and Cloud (1947, p. 115), the Point Peak member was named by Bridge from Point Peak, a conspicuous, isolated hill about 4 miles northwest of Lone Grove, Llano County. The thickness of the type section measured on the south slope of Point Peak is about 270 feet. The variations in the thickness have been attributed principally to facies changes. Irregularities in sedimentation contribute to the variation to a lesser extent. A rough measurement of the member in the central part of the James River valley showed the thickness to be about 120 feet.

In general, the lower contact is placed at the top of the uppermost bedded limestone of the Morgan Creek member. A characteristic topographic feature of the lower shale beds of the Point Peak member is a narrow bench which shows a recognizable topographic and vegetational change from the underlying Morgan Creek member. In mapping, the lower contact was generally placed at the lower edge of this topographic bench. Where protected by the overlying bioherms, the more resistant limestones and conglomerates that occur higher up the section form a steeper slope.

The Point Peak member consists of green to gray, calcareous, thin-bedded shales which are interbedded with thin-bedded, brownish-gray, calcareous siltstones and intraformational conglomerates. The intraformational conglomerates consist of layers of compact limestone, crowded with angular, flat siltstone pebbles of various sizes and colors. (Plate VII) Good exposures of the Point Peak member are seldom found in the central part of the James River valley since the member weathers readily to a dark soil that covers the Point Peak slopes. The soil is generally littered with caliche and rock debris that is chiefly the residue of the weathered conglomerate.

PLATE VII

Point Peak shale member showing the interbedded limestone, shale, and conglomerate. Located in a gully on the east side of the James River road about 2.1 miles south of the Ziegler ranch house.

Bioherm Zone

Bridge, Barnes, and Cloud (1947, p. 116) included the bioherms as the upper zone of the Point Peak member. Although this is a common procedure, the bioherms have been treated as a separate and distinct unit in this paper since there are distinct lithologic differences between the interbedded shales, limestones, and conglomerates of the lower Point Peak and the massive limestones of the bioherms. The distinctive nature of the bioherms as well as their widespread occurrence throughout the Llano region make them an easily recognizable and mappable unit. For these reasons, it is suggested that the bioherms be treated as a separate zone within the Wilberns formation.

The lower contact of the bioherm zone with the Point Peak shale member is characterized by a distinct lithologic and topographic change which is easily recognized in the field. The bioherm zone forms rough ridges with a slight to moderate relief and caps the Point Peak member throughout much of the thesis area.

The bioherms are composed of gray, microgranular to sublithographic, very hard, massive limestone. They not only occur as isolated masses, but often coalesce to form biostromes. The weathered surface of the bioherms is gray to black with a rough, circular pattern which is known as a "cabbage head" structure. The bioherms are interbedded with thin-bedded, yellowish-brown to gray, fine- to medium-grained, nonfossiliferous, nonglauconitic, hard limestone which weathers to thin slabs and fragments.

San Saba limestone member

Bridge, Barnes, and Cloud (1947, p. 117) stated that the type section of the San Saba limestone member is exposed along both sides of the Mason-Brady highway, beginning at the bridge across the San Saba River and extending northward for a distince of 0.7 miles. At this point, the San Saba is in collapse contact with the limestones of the Threadgill member of the Tanyard formation. The thickness of the San Saba member exposed at the type section is about 280 feet.

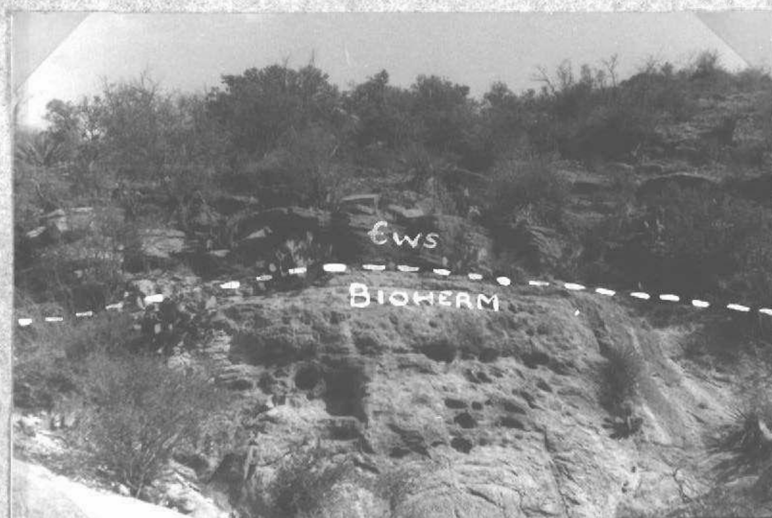
Comstock (1890, p. 301) originally used the name San Saba as a series term and applied it to a part of the beds found exposed in the type section along the Mason-Brady highway. Dake and Bridge (1932, p. 729) called these beds "Post Wilberns" and suggested that the name San Saba might well be used for a part of them. According to Bridge, Barnes, and Cloud (1947, p. 117), the San Saba was revised to a member status in the Wilberns by Bridge. The name is now applied to the entire sequence of more or less glauconitic limestone beds overlying the Point Peak member and underlying the Threadgill member of the Tanyard formation. The San Saba limestone grades eastward into the Pedernales dolomite which is the equivalent facies in the eastern part of the uplift.

The lower contact of the San Saba member is irregular and interwoven since the San Saba may be in contact with either the shale, siltstone, and conglomerate of the lower Point Peak member, or with the bioherms. Where the San Saba overlies the bioherms, the contact is sharp but irregular since the San Saba will be draped over the bioherms. (Plate VIII) This is the result of original deposition and differential compaction. In the places where the bioherms are absent or covered so as to be hidden from view, the contact is picked on the highest occurrence of shale.

The San Saba member is the most variable unit of the Wilberns sequence and shows marked facies changes from place to place. In the thesis area, the member consists mostly of thin- to thick-bedded, sublithographic to medium-grained, white to yellowish-brown to brown and gray, fossiliferous limestone. Glauconite appears intermittently throughout the member in varying amounts and decreases toward the top, but the sandy facies found by Grote (1952, p. 26) to be so common in the Bluff Creek region is not generally found in the central part of the James River valley.

Flaggy limestone ledges are common in the upper part of the San Saba member and intraformational conglomerates also appear towards the top of the member. These ledges are chiefly sublithographic, nonfossiliferous, and slightly glauconitic limestone. Many slopes are littered with thin slabs of this limestone.

PLATE VIII



Contact between the San Saba limestone member and a bioherm. Located 2.1 miles south of the Ziegler ranch house and 200 yards east of the James River road up a gully.

ORDOVICIAN SYSTEM

Ellenburger Group

The Ordovician rocks found in the central part of the James River valley are part of the Ellenburger group of Lower Ordovician age. No attempt was made to delineate the formations - the Tanyard, the Gorman, and the Honeycut - of the Ellenburger group. The calcitic and dolomitic facies were differentiated and mapped as separate units. Although the formations were not differentiated, a discussion of these units is here presented in order that a comparison may be made between the lithologies described in the literature and that found in the field.

The term Ellenburger was originally used by Paige (1911, p. 52) for the limestones making up the Ellenburger Hills in the northwestern corner of the Burnet Quadrangle, southeastern San Saba County. Cloud and Barnes (1948, p. 31) revised the term to a group status and restricted its use to rocks of Lower Orodovician age.

According to Cloud and Barnes (1948, p. 32), the maximum known thickness is 1820 feet in the vicinity of Johnson City, in the southeastern corner of the uplift. The group is 970 feet thick in the Bear Spring area of western Mason County. This area is located about 3 miles from the northwest corner of the central part of the James River valley.

As noted previously, the Ellenburger group is divided into three formations, which are, from bottom to top, the

Tanyard, Gorman, and Honeycut. The Tanyard is further subdivided into two members, the Threadgill and the Staendebach.

Cloud, Barnes and Bridge (1945, p. 142) proposed the name Tanyard for rocks similar to and partially correlative with the Lower Ordovician rocks exposed at the type section at "The Tanyard", on the east bank of Buchanan Lake opposite the mouth of Jim John Creek. The thickness ranges from 520 feet to 660 feet, with an average of 590 feet, and includes both limestone and dolomite.

Cloud, Barnes, and Bridge (1945, p. 143) revised the Threadgill member, which is the lower member of the Tanyard formation, to include equivalent dolomite as well as limestone. The type section is on Threadgill and Mormon creeks, south of Lange's Mill, in northwestern Gillespie County. The thickness of the member at the type section is about 280 feet and the thickness throughout the Llano region ranges from 91 feet to about 294 feet.

According to Cloud, Barnes, and Bridge (1945, p. 143), the Staendebach member, which is the upper member of the Tanyard formation, is exposed in Cherokee Creek in southeastern San Saba County and is named after the Staendebach survey. The thickness of the member at the type section is about 300 feet but ranges from 299 feet to 456 feet in the region.

Cloud and Barnes (1948, pp. 36-37) stated that the Tanyard formation is composed predominantly of fine- to coarse-grained, commonly vuggy to porous, light yellowish-gray to wood ash gray, and pearl gray, irregularly bedded dolomites, and sublithographic, pearl gray to wood ash gray, and old ivory, thinly to thickly bedded limestones which are essentially nonglauconitic. On weathering, the dolomites of the Threadgill member yield vuggy or spongy masses of highly dolomoldic or cellular chert interlaced with quartz druse. The Staendebach member is characterized by "an abundance of sparingly dolomoldic porcelanous to semi-porcelanous and chalcedonic to semi-chalcedonic chert". This chert weathers to solid, shiny, white or bluish-white masses, slabs or chips.

Cloud, Barnes, and Bridge (1945, p. 145) proposed that the name Gorman formation be used to designate rocks similar to and correlative with those in the composite type section along and near the gorge of the Colorado River in the vicinity of Gorman Falls, in the southeastern part of San Saba County. The thickness ranges from 430 feet to 500 feet with an average thickness of 470 feet.

Cloud and Barnes (1948, p. 39) stated that the dolomites of the Gorman formation are microgranular to very fine-grained. The colors range from tan to brown and old ivory. These dolomites weather to smooth, crudely sphenoidal blocks or hackly or blocky ledges. The calcitic facies of the Gorman formation consists principally of sublithographic, thickly to thinly bedded limestone with locally interbedded microgranular to fine-grained dolomite. The color of the limestone ranges from pearl gray to wood ash gray, old ivory and brownish-gray. It weathers to medium or light tones of bluish-gray. The Gorman also contains a porcelaneous, white to wood ash gray chert with scattered dolomolds and quartzose matter, irregularly interlayered with quartz druse, weathering russet and commonly containing fossils.

Cloud, Barnes, and Bridge (1945, p. 146) named the Honeycut formation and defined it to include all known Ellenburger strata above the Gorman formation at the surface in central Texas. The type section is at Honeycut Bend on the Pedernales River, about 5 miles east of Johnson City in Blanco County. The thickness ranges from 0 to 678 feet. This is the result of truncation which causes the Honeycut formation to thin to the west.

Cloud and Barnes (1948, p. 41) stated that the rock types of the Honeycut formation resemble those of the Gorman formation, differing principally in distribution, bedding, and color. The limestones of the Honeycut are generally more thinly bedded than those of the Gorman and more intimately interbedded with dolomite. The microgranular dolomites of the Honeycut formation also tend to have duller colors than those of the Gorman formation.

Lithology:

The contact between the Ellenburger group and the underlying San Saba member of the Riley formation was based on the highest occurrence of glauconite and the first appearance of the open gastropod, Lytospira gyrocera.

The rocks of the Ellenburger group in the central part of the James River valley consisted essentially of sublithographic, pearl gray to wood ash gray, and old ivory nonglauconitic limestone and microgranular to coarse-grained gray dolomite. On weathering, the dolomites yielded vuggy or spongy, cellular, reddish-brown and gray chert interlaced with quartz, Solid shiny, white to bluish-white chips of chalcedonic chert are also present in large amounts.

Topography and vegetation:

The Ellenburger is characterized by a rolling, hilly terrain with moderate relief. (Plate IX)

The Ellenburger strata seldom show the well-defined vegetation alignment that is common in the Cambrian strata. Instead, the vegetation shows an irregular pattern that is often easy to recognize on aerial photographs. Vegetation consists of cedar, scrub oak, prickly pear, bee brush, and Mexican persimmon.

CENOZOIC SYSTEMS

QUATERNARY SYSTEM

In the central part of the James River valley, the Quaternary sediments are limited to stream alluvium. This alluvium consists of sands, gravels, and coarse conglomerates which are derived from Paleozoic and Cretaceous rocks.

PLATE IX

Typical Ellenburger topography and vegetation. Located on the Will Loeffler ranch about 300 yards west of the James River and about 400 yards southeast of the hunting cabin.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Llano region is a structural uplift that is essentially elliptical in shape. It is approximately 80 miles long by 55 miles wide and trends in a northwest-southeast direction. Although the region is structurally an uplift, it is topographically a basin and in many places the metamorphosed and intensely deformed Precambrian basement rocks have been exposed.

The most prominent structural features of the region other than the dome itself are the large faults that have disturbed the Precambrian and Paleozoic strata. These faults are of a tensional type, and they are normal or nearly vertical, having a range of dip from 60 to 90 degrees. Most of the major faults of the Llano uplift trend in the northeast-southwest direction.

The Paleozoic strata may have originally dipped away from the center of the dome, but the faulting has disturbed them so that they now dip in various directions. The faulting also dropped blocks of Paleozoic strata to the level of the Precambrian rocks.

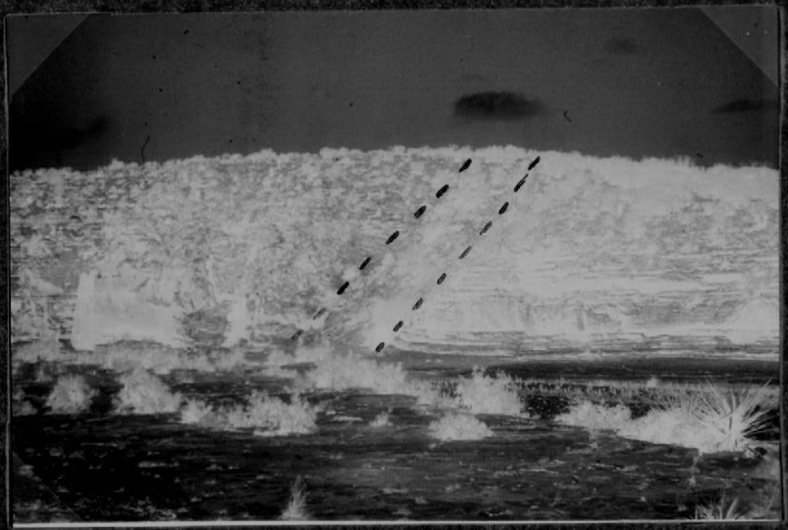
According to Plummer (1940, pp. 58-59), the local structures of the Llano region may be divided into seven classes. The seven structural classes are (1) spur ridges, (2) normal faults, (3) grabens, (4) buried ridges, (5) sharp flexures, (6) symmetrical anticlines, and (7) reef masses. All of these local structural movements occurred during or since the Carboniferous. Several of the above mentioned structural types are found in the central part of the James River valley and will be considered in more detail.

MAJOR FAULTS

There are four major faults present in the central part of the James River valley. These are the Simons, the Ziegler, the Martin, and the Loeffler faults. The Simons fault was named by Alexander (1952, p. 48). The Ziegler and Martin faults were named by Sliger (1957, personal communication). The Loeffler fault was named by the author. These faults are roughly parallel and strike in the northeast direction. They range in throw from about 150 feet to about 700 feet. The Simons, the Martin, and the Loeffler faults are downthrown to the northwest and the Ziegler fault is downthrown to the southeast.

The Simons fault passes through the central part of the valley and is crossed by the James River at several places (Plate X). According to Parke (1953, p. 49), the Simons fault has a throw of about 800 feet in the Southwest Mason-Llano River area. In the central part of the James River valley the throw ranges from about 200 feet in the northern part of the area where the upper Morgan Creek is in contact with the lower San Saba, to over 600 feet in the southern part of the area where the upper Lion Mountain is in contact with

PLATE X



Simons fault exposed on the north side of the James River showing sharp change in the vegetation between the Cap Mountain member and Lion Mountain member on the right and the San Saba member on the left. Located about two miles southwest of the Ziegler ranch house.

rocks of the Ellenburger group which probably belong to the Threadgill member of the Tanyard formation.

The Ziegler fault passes through the central part of the valley on the southeast side of the James River. This fault trends northeast-southwest throughout most of the area, but starts to curve toward the south in the southern part of the area at the James River road--James River crossing. For the most part, the trace of this fault was easily located on the aerial photographs and in the field, but it was very difficult to locate at the crossing due to the juxtaposition and similarity of the Cap Mountain and the Morgan Creek members. The throw ranges from about 100 feet to about 400 feet. In the northern part of the area, the lower Morgan Creek is in contact with the upper Morgan Creek, and in the southern part of the area the upper Cap Mountain is in contact with the Morgan Creek.

The Martin fault passes along the southeastern border of the area. This fault also trends in the northeast-southwest direction. This fault has a maximum throw of about 150 feet in the northeast part of the area. The amount of throw decreases southwestward until the fault can no longer be traced.

The Loeffler fault is located near the northwest boundary of the area. This fault trends northeast-southwest for the most part, but it starts to curve to the southeast near the southwestern portion of the area. The maximum throw of this fault is approximately 250 feet and the amount of throw decreased toward the northeast until the fault can no longer be traced. The fault is difficult to locate for the most part. This is particularly true where the Ellenburger is in contact with Ellenburger. At first, this fault was presumed to be a minor fault, but a cross section across the fault (Section along line B-b', Plate I) showed that it had an approximate throw of 240 feet. It must be pointed out that the amount of throw is a rough approximation since neither the thickness of the Ellenburger in this area, nor the exact location within the section is known.

The Simons and Ziegler faults form a large horst in the central part of the area. The upthrown block of this horst has been eroded so that it is now topographically low. The Ziegler and Martin faults form a smaller graben in the northeastern part of the area.

Where undisturbed by faulting, the Paleozoic strata have an average regional strike of N 65° E and dip approximately 5° to the southeast. This direction of dip is of importance since the central part of the James River valley is on the southwest flank of the Llano uplift where it might be expected that the dip would be away from the uplift or to the southwest. Although the relatively small dips are not generally indicative of uplift, the fact that the dip is to southeast instead of the southwest is evidence of a slight uplift in the vicinity of the thesis area, or depression to the southeast. That there is an uplift is further substantiated by the fact that the James River is a rejuvenated stream.

The strikes and dips of the beds against the major faults vary somewhat from that of strata in their normal position. This variation is not always present, so that faults are not everywhere detectable by this criterion. Slumping into limestone sinks and compaction around bioherms also results in strikes and dips that vary from the normal. Caution must be used in order that the strikes and dips that result from these features are not mistaken for evidence of faulting.

OTHER FAULTS

Numerous other faults of lesser throw occur in the northern part of the area in the upthrown block of the horst formed by the Simons and Ziegler faults. Several of these faults occur as fault slivers from the major faults. These faults have no definite trend. Some of them trend to the north and others to the northeast. There is no uniformity as to the direction of the throw, and the displacement is generally less than 100 feet.

The major faults, as a whole, have split somewhere along their length into divergent fault slivers. At these places it was often difficult to determine along which line the major displacement occurred.

There are several minor faults that cut across one or more major faults. These minor faults are not usually offset, but there is one important exception in the southern part of the area near the James River road--James River crossing where a minor fault crosses and is offset by the Ziegler fault and a fault sliver from the Ziegler fault.

Several minor faults occur in the Ellenburger, but no attempt was made to determine their throw since the formations were not differentiated. Many soil and vegetational differences appeared on the aerial photographs as possible faults, but upon closer examination many of these proved to be joints which had been enlarged by solution.

The recognition of these minor faults was, in some instances, very difficult. Generally the only indication of faulting was the abrupt termination of a key bed, or the presence of brecciated material. It is quite possible that there are more minor faults, particularly in the Ellenburger and San Saba, but there was no field evidence to indicate their presence.

AGE OF FAULTING

The time of faulting is not definitely known since the data available in the central part of the James River valley are inconclusive. However, it is known that the faulting occurred after the Ellenburger sediments of Lower Ordovician age were deposited since these sediments have been affected by the faulting.

Cloud and Barnes (1948, p. 121) stated that unfaulted beds of Canyon age overlap faulted rocks of Ellenburger age in the western part of the Llano uplift near Calf Creek. It is also known that the Smithwick formation of Bend age has been affected by the Mason fault in the vicinity of White's Crossing in Mason County. From this information, the conclusion can be derived that the late Paleozoic faulting is post-Bend and pre-Canyon in age.

CAUSE OF FAULTING

The normal faults of the thesis area indicate that tensional forces are chiefly responsible for the faulting. The graben in the northeastern part of the area that is formed by the Martin and Ziegler faults is also indicative of tensional forces. This graben block was downdropped into a potential void that was set up by the tensional forces which caused the faulting.

The horst formed by the Ziegler and Simons faults as well as the complex faulting found in the northern part of the area suggests that some additional forces might have complicated the fracturing in and around the central part of the James River valley. However, it is possible that this horst is the relatively high block between two grabens.

FOLDING

There is no direct evidence of folding in the central part of the James River valley. However, very gentle undulations or domal structures of local occurrence are common in the Point Peak member and San Saba member of the Wilberns formations. These features in the upper Point Peak and lower San Saba are due to differential compaction over large reef structures.

Some small solution sinks are present in the Ellenburger. These features often give the appearance of small local basins.

SUMMARY OF GEOLOGIC HISTORY

The Precambrian seas of central Texas deposited a thick series of sandstones, limestones, and shales. These sediments passed through the various stages of deep burial and metamorphism and were converted into quartzites, marbles, schists, and gneisses. These metamorphic rocks were then intruded by igneous rocks. The coarse texture of the granites indicate that intrusion occurred at considerable depth. Sellards (1932, p. 35) stated "that these granite intrusives were earlier than the overlying Paleozoic is indicated by the fact that at no place do they cut into the later rocks".

Following the intrusion of the igneous rocks, the region was subjected to extensive erosion. During this period of erosion the uppermost rocks were removed, the folds leveled off, and the granite exposed. The Upper Cambrian sediments were then deposited on these exposed granites and on the truncated folds of the metamorphic rocks. According to Sellards (1932, p. 36), this interval of erosion may have been largely or entirely within Cambrian time since the overlying sediments are of Upper Cambrian age.

Cloud and Barnes (1948, p. 111) stated that "the first Paleozoic sea to invade central Texas entered a region of considerable local relief". The sea reworked sands of eolian origin into the basal part of the Hickory sandstone member. According to Bridge, Barnes, and Cloud (1947, p. 113), the Hickory sandstone member rests on an irregular Precambrian surface having a relief as great as 800 feet in some places. Some of these buried hills are known to extend stratigraphically into the Cap Mountain limestone member.

By the middle of Riley time, according to Cloud and Barnes (1948, p. 112), the lands were largely exhausted of coarse detritus and reduced in elevation. As the sea transgressed, less sand was derived from the source area and calcium carbonate was deposited, causing the Hickory sandstone to grade into the sandy limestone of the lower Cap Mountain member. The presence of glauconite, trilobites, and brachiopods indicate that the Cap Mountain limestone formed in a shallow, neritic environment. In late Riley and early Wilberns time, changes in the relationship of land to sea occurred and the lands furnished abundant sand to supply the regressive-transgressive sand zone that comprises the Lion Mountain-Welge sequence. The highly glauconitic, granular limestones of the Morgan Creek member indicate that the source area was again lowered. This suggests a neritic environment similar to that which occurred in Cap Mountain time.

During middle Wilberns time quantities of argillaceous material were accumulated to form the Point Peak shale member. According to Paige (1912, p. 79), widespread flats which were alternately flooded by tides and dried by the sun existed at this time. This is indicated in the thesis area by the presence of thin alternating shale and calcareous siltstone beds, and shale-pebble conglomerates. The stromatolitic bioherms indicate a reduction in terrigenous sediments and an increase in algal activity. They also indicate a warming of the waters. These marine conditions probably persisted during the deposition of the San Saba limestone member, with sedimentation being continuous across the Cambrian-Ordovician boundary.

During early Ordovician time, according to Cloud and Barnes (1948, p. 112), the Llano region remained relatively stable, with minor fluctuations in depth and temperature of the water, condition of the bottom, and nearness of land. The marine waters of the region were generally warm, intermittently turbulent, and relatively well-oxygenated shoal waters, deepening to the northwest. Stromatolitic limestones, ripple marks, and intraformational conglomerates indicate a shallow water environment.

The absence of Middle Ordovician, Upper Ordovician, and Silurian rocks in the Llano region suggests that emergent conditions accompanied by erosion existed after Early Ordovician time. It has never been established whether sediments were deposited and subsequently removed, or whether a period of complete nondeposition is responsible for this lack of Middle Ordovician, Upper Ordovician, and Silurian rocks.

Cloud and Barnes (1948, p. 113) stated that "the greatest truncation of the Ellenburger rocks and thus probably the longest period of Paleozoic emergence of the Llano region occurred before Devonian time". The maximum truncation was in the western part of the uplift, whereas the oldest Devonian strata known are in the eastern part of the region and the youngest are in the western part of the region. A provisional inference that the region was tilted to the east and largely truncated before Devonian times, followed by an east to west Devonian marine invasion and continuing truncation of the emergent areas, may be made from the available data. The occurrence of rocks that are probably assignable to the Pillar Bluff limestone as pocket- and crack-fillings below the Stribling formation suggests that there were irregularities in the Devonian overlap and temporary withdrawals of the sea.

The Chappel formation of Mississippian age is present as a locally exposed deposit of a few feet in thickness. According to Sellards (1934, pp. 84-85), this mid-Mississippian formation was either of reduced thickness over the uplift or was subjected to erosion on account of the uplift. Either of these interpretations would suggest that the Llano uplift originated as a positive area as early as mid-Mississippian time. Sellards (1934, p. 22) stated that "the Barnett formation, consisting chiefly of clastic materials, may represent an outward or feather edge of the sediment resulting from an uplift in Mississippian time".

According to Sellards (1934, p. 23), the Marble Falls formation of Pennsylvanian age rests at some localities on Mississippian and elsewhere upon various units of the Ellenburger group. This indicates that erosion and shifting of sea level occurred in the Llano region between the deposition of the latest Mississippian and the earliest Pennsylvanian sediments now exposed in the uplift.

The doming that began during post-Devonian time continued during the early Pennsylvanian and produced dips that were away from the center of the dome. During post-Bend and pre-Canyon time, the region was intensely faulted and the faulting disturbed the strata so that they now dip in various directions. The faulting produced the large normal faults of the region and also caused blocks of Paleozoic strata to be dropped to the level of the Precambrian.

At the close of Paleozoic deposition the Llano region became emergent and remained so until the advent of the Cretaceous seas. During this long interval, erosion removed the Paleozoic sediments from parts of the uplift and exposed the Precambrian schists, gneisses, and granites. The Cretaceous sediments were then deposited on the truncated margins of all the formations from Precambrian to late Pennsylvanian.

Since Cretaceous time the Llano region has been uplifted and has remained dry land with very little deformation. There has been more than one post-Cretaceous uplift, but little or no tilting of the Cretaceous strata. The courses of most of the major streams of the Llano region, draining toward the Gulf of Mexico, were established on a nearly level plain of Cretaceous sediments. As the region was uplifted, the Cretaceous sediments were largely removed and the rivers were superimposed on the underlying Paleozoic and Precambrian rocks, in which the present topography is being carved.

E C O N O M I C   G E O L O G Y

The most important natural resource in the central part of the James River valley is ground water. The Hickory sandstone is the most important aquifer in the area, but several important wells produce from the Ellenburger. In normal years, when drought conditions have not dried it up, the James River offers a supply of water.

Since the central part of the James River valley is unsuited for the raising of crops, ground water is used chiefly for stock and domestic purposes.

It is very improbable that oil production will ever be attained. Cloud and Barnes (1948, p. 33) stated that the potential source beds have been so intensely faulted and exposed to the atmosphere that it is doubtful if petroleum will ever be discovered in the Llano region by drilling.

Building stones offer an important natural resource that could be exploited, but it is not economically feasible because of the long distances that this material would have to be transported to the railroads.

According to Cloud and Barnes (1948, pp. 127-129), rocks of the Ellenburger group could be crushed and used for railroad ballast, road metal, and concrete aggregate, but again the transportation difficulties prohibit this utilization of the Ellenburger rocks.

A minor industry in the area at the present time is concerned with bat guano for fertilizer. A large solution cave in the Ellenburger dolomite is inhabited by a large colony of bats whose guano litters the floor of the cave (Plate XI). The guano is removed at periodic intervals and sold on the open market as a commercial fertilizer.

PLATE XI

Solution cave in the Ellenburger dolomite from which guano is extracted. Located about 4.6 miles southwest of the Ziegler ranch house and about 400 yards west of the James River road.

REFERENCES

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

Barnes, V. E. (1940), Pre-Cambrian of the Llano region with emphasis on tectonics and intrusives, Excursions 53d annual meeting of the Geol. Soc. Am. and affiliated societies, Dec. 26-28, 1940, pp. 44-49.

__________ (1944) "Gypsum in the Edwards limestone of central Texas", Univ. Texas Pub. 4301, pp. 35-46.

__________ and Bell, W. C. (1954), "Cambrian rocks of central Texas", San Angelo Geol. Soc. Cambrian field trip, March 19-20, 1954, pp. 35-69.

__________ and Parkinson, G. A. (1939). "Dreikanters from the basal Hickory sandstone of central Texas", Univ. Texas Bull. 3945, pp. 665-670.

Blank. H. R. (1951), "Exfoliation and weathering on granite domes in central Texas", Texas Jour. Sci., Vol. 3, no. 3, pp. 376-390.

__________ (1956), "Wagon-track potholes in the bed of the James River, Mason County, Texas", Oral communication to meeting of Texas Acad. Sci., Brownwood, Texas, Dec. 1957.

Bridge, Josiah (1937), "The correlation of the Upper Cambrian sections of Missouri and Texas with the section in the upper Mississippi Valley", U.S.G.S. Prof. Paper 186-L, pp. 239-271.

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

__________ and Barnes, V. E. (1941), "Stratigraphy of the Upper Cambrian, Llano uplift, Texas", Geol. Soc. Am. Bull. Vol. 52, pp. 1996.

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

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

Cloud, P. E., Jr., Barnes, V. E., and Bridge, Josiah (1945), "Stratigraphy of the Ellenburger group of central Texas-a progress report", Univ. Texas Pub. 4301, pp. 133-161.

__________ and Barnes, V. E. (1948), "The Ellenburger group of central Texas," Univ. Texas Pub. 4621, 473 pp.

Comstock, T. B. (1890), "A preliminary report on the geology of the Central Mineral region of Texas", Texas Geol. Sur., 1st Annual Report 1889, pp. 235-391.

__________ (1891), "Report on the geology and mineral resources of the Central Mineral region of Texas", Texas Geol. Sur., 2nd Annual Report (1890), pp. 553-664.

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

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

Dumble, E. T. (1890), "Report of the State Geologist for 1889", Texas Geol. Sur., 1st Annual Report 1889, pp. xvii-lxxv, map.

__________ (1891), "Report of the State Geologist for 1890", Texas Geol. Sur., 2nd Annual Report 1890, p. xv.

Grote, F. R. (1954), Structural Geology of the Central Bluff Creek Area, Mason County, Texas, M.S. Thesis, Texas A. & M. College, 44 pp.

Hill, R. T. (1887), "The present condition of knowledge of the Geology of Texas", U.S.G.S. Bull., Vol. 45, 95 pp.

Jones, R. A. (1929), "The Paleozoic of the Pedernales Valley in Gillespie and Blanco counties, Texas," Univ. Texas Bull. 2901, pp. 95-130.

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

__________ (1912), "Description of the Llano and Burnet quadrangles", U.S.G.S. Geol. Atlas, Llano-Burnet Folio no. 183, 16 pp.

Parke, R. P. (1953), Geology of the Southwest Mason-Llano River Area, Texas, M. S. Thesis, Texas A. & M. College, 106 pp.

Plummer, F. G. (1940), "Paleozoic of the Llano region", Excursions 53d annual meeting of the Geol. Soc. Am. and affiliated societies, Dec. 26-28, 1940, pp. 56-65.

__________ (1943), "A new quartz sand horizon in the Cambrian of Mason County, Texas", Univ. Texas, Bur. Econ. Geol., Min. res., Cir. 22.

__________ (1950), "The Carboniferous rocks of the Llano region of central Texas", Univ. Texas Bull. 4329, 117 pp., 14 figs., 22 plates, 4 charts.

Roemer, Ferdinand (1846), "A sketch of the geology of Texas", Am. Jour. Sci. (2), Vol. 2, pp. 358-365.

__________ (1848), "Contributions to the geology of Texas", Am. Jour. Sci. (2), Vol. 6, pp. 21-28.

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

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

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

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

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

__________ (1934), "Pre-Cambrian structural conditions in the Llano region, Texas", Univ. Texas Bull. 3401, pp. 74-79.

__________ (1935), "Pre-Cambrian unconformities in the Llano region, Texas", Univ. Texas Bull. 3501, 115 pp., fig.

Tarr, R. S. (1890), "Superimposition of the drainage in central Texas", Am. Jour. Sci. (3), Vol. 40, no. 239, art, 45, pp. 359-362.

__________ (1890), "Origin of some topographic features of central Texas", Am. Jour. Sci. (3), Vol. 39, no. 232, art. 39, pp. 306-311.

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

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

A P P E N D I X

Section of the Cap Mountain limestone, Lion Mountain sandstone, and Welge sandstone occurring in a gully on the east side of the James River about two miles south of the Ziegler ranch house. Section begins in the upper Cap Mountain member at river level.

	Thickness of Interval Feet
Riley formation:	
Cap Mountain limestone member:	
1. Limestone, gray to greenish-gray, coarsely crystalline, glauconitic, slightly fossiliferous (chiefly coquina), unevenly bedded, hard, stained brown with iron oxide. Weathers to a dirty gray......	6.0
2. Limestone, grayish-white to grayish-purple, crystalline, fine-grained, hard, glauconitic, fossiliferous, well bedded, stained brown in slightly arenaceous portion with iron oxide. Weathered surface dirty gray and mottled brown....................	16.6
3. Limestone, reddish-brown, crystalline, glauconitic, slightly fossiliferous, stained brown in slightly arenaceous portion with iron oxide. Weathered surface mottled dirty gray..........................	2.3

Feet

4. Limestone, grey to greenish-grey and reddish-grey, crystalline, arenaceous, glauconitic, slightly fossiliferous, hard to friable, stained brown in arenaceous portion with iron oxide. Weathered surface dirty mottled grey.................................. 16.1

5. Sandstone, grey to greenish-grey, highly glauconitic, calcareous, stained brown with iron oxide. Weathered surface dirty greyish-green.................... 5.5

6. Limestone, purplish-grey and green, glauconitic, arenaceous, slightly fossiliferous. Weathered surface dirty grey.. 0.9

7. Sandstone, yellowish-green to reddish-brown, highly glauconitic, calcareous, friable, medium-bedded. Irregular iron oxide stain. Weathers to reddish-brown ledges................................. 5.9

8. Limestone, brown to green, highly glauconitic, medium-bedded, nonfossiliferous, arenaceous. Irregular iron oxide stains. Upper portion highly glauconitic and arenaceous. Forms a distinct bench.

Feet

Weathers to a rusty brown.............. 6.5

Total measured thickness of Cap Mountain limestone member............. 59.8

Lion Mountain sandstone member:

9. Limestone, arenaceous, brown to green, medium- to coarse-grained, thin- to medium-bedded, glauconitic. Interbedded with thin layers of iron oxide and green glauconitic sand. Surface is littered with hematite nodules. Lower portion forms a gentle, sparsely vegetated slope.................................. 20.8

10. Sandstone, medium- to coarse-grained, greenish-grey to green, slightly calcareous, slightly fossiliferous in places. Surface littered with hematite nodules and with float from the overlying Welge.................................. 11.1

Total measured thickness of Lion Mountain sandstone member............. 31.9

Wilberns formation:

Welge sandstone member:

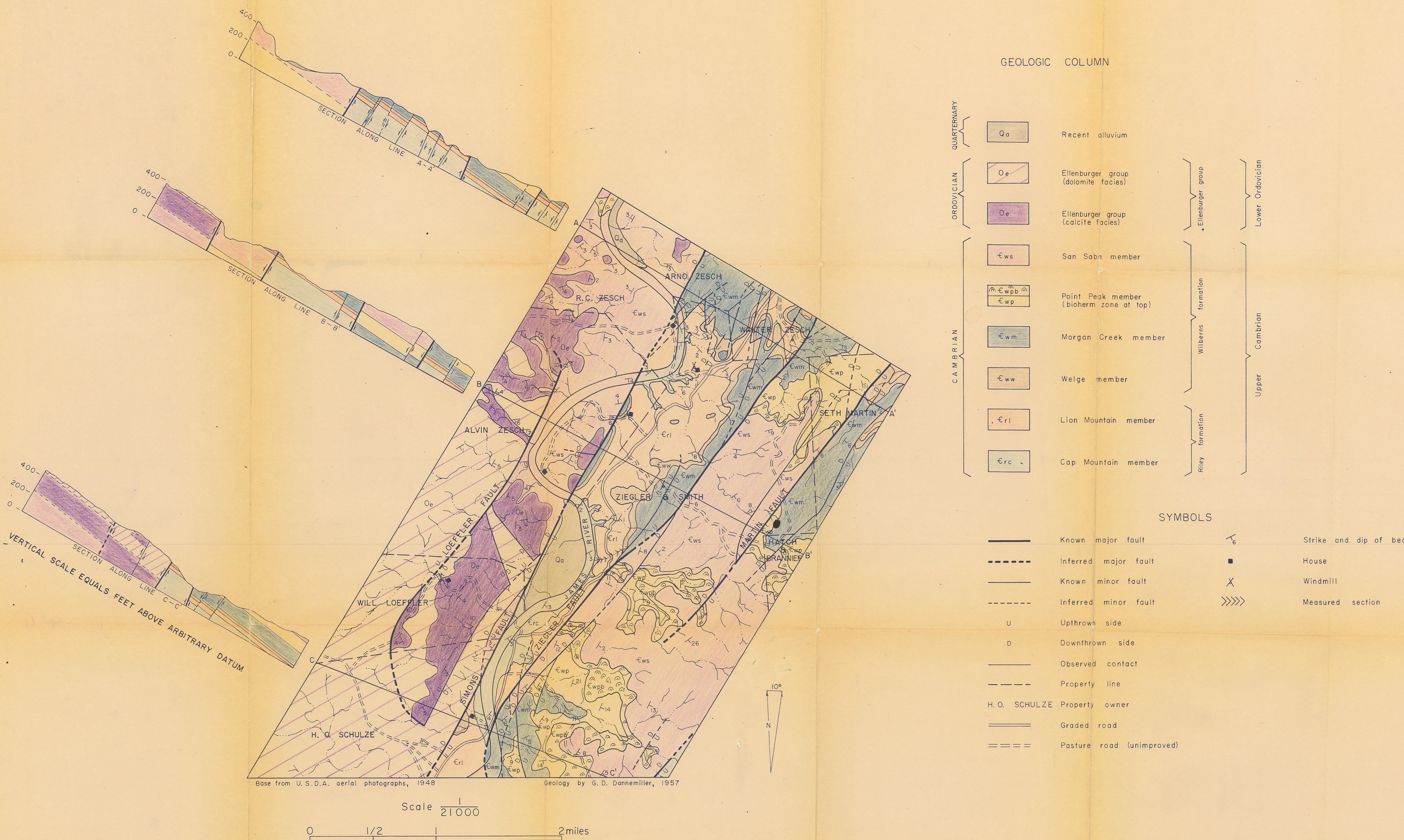
11. Sandstone, light brown to yellowish-brown medium-grained, indistinct bedding, noncalcareous except near upper boundary, nonglauconitic. Iron oxide present as

Feet

streaks and as a thin coating on surface. Recomposed quartz grains impart a sparkle to the soil and to the sandstone fragments. Upper part is fine- to coarse-grained and calcareous. As a unit the Welge weathers to small cliffs.................... 12.4

Total measured thickness of Welge sandstone member...................... 12.4

Total measured thickness of section....104.1



GEOLOGIC MAP AND CROSS SECTIONS OF THE CENTRAL PART OF THE JAMES RIVER VALLEY, MASON COUNTY, TEXAS