LIBRARY
A & M COLLEGE OF TEXAS

GEOLOGY OF THE LOWER JAMES RIVER AREA
MASON COUNTY, TEXAS

A Thesis

By

Kenneth Leon Sliger

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

May 1957

Major Subject <u>Geology</u>

GEOLOGY OF THE LOWER JAMES RIVER AREA

MASON COUNTY, TEXAS

A Thesis

By

Kenneth Leon Sliger

Approved as to style and content by:

Chairman of Committee

Head of the Department of Geology

May 1957

1957
Thesis
S633

CONTENTS

Page

A B S T R A C T 1

I. I N T R O D U C T I O N 4

STATEMENT OF PROBLEM 4

ACKNOWLEDGMENTS 4

LOCATION 5

ACCESSIBILITY 5

METHODS OF FIELD WORK 7

REVIEW OF THE LITERATURE 8

II. G E O G R A P H Y 14

CLIMATE 14

VEGETATION 14

INDUSTRY 15

III. P H Y S I O G R A P H Y 16

PHYSICAL FEATURES 16

DRAINAGE 17

IV. S T R A T I G R A P H Y 19

GENERAL STATEMENT 19

PALEOZOIC ERA 20

CAMBRIAN SYSTEM 20

Riley Formation 20

Hickory sandstone member 21

Cap Mountain limestone member 23

Lion Mountain sandstone member 25

Bd Special Graduate fund
OCT 10 1957
331098

Page

Wilberns Formation 28

Welge sandstone member 28

Morgan Creek limestone member 29

Point Peak shale member 32

Bioherm Zone 34

San Saba limestone member 37

ORDOVICIAN SYSTEM 39

Ellenburger Group 39

MISSISSIPPIAN SYSTEM 43

Chappel Limestone 43

Barnett Formation 44

PENNSYLVANIAN SYSTEM 45

Marble Falls Limestone 45

CENOZOIC ERA 46

QUATERNARY 46

Recent 46

V. STRUCTURAL GEOLOGY 47

GENERAL STATEMENT 47

REGIONAL STRUCTURE 47

STRUCTURE OF THE LOWER JAMES RIVER AREA 48

Major Faults 48

Minor Faults 52

Detection Of Faulting 53

Age Of Faulting 53

Page

Cause Of Faulting 54

Folding 57

VI. G E O L O G I C H I S T O R Y 59

GENERAL STATEMENT 59

SUMMARY 59

VII. B I B L I O G R A P H Y 64

VIII. A P P E N D I X 67

SECTION 1 - 1 : Measured section of Cap Mountain limestone member of the Riley Formation 68

SECTION 2 - 2 : Measured section of the Riley and Wilberns formations 72

SECTION 3 - 3 : Measured section of the Point Peak member of the Wilberns Formation 83

SECTION 4 - 4 : Measured section of the San Saba member of the Wilberns Formation 88

ILLUSTRATIONS

			Page
Figure	1.	LOCATION MAP OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS	6
Plate	I.	GEOLOGIC MAP AND SECTION OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS . . .	folded for a pocket
	II.	Fig. 1: Lensing sandstone bed in middle Hickory Fig. 2: Ripple marks in middle Hickory in bed of Schep Creek	22
	III.	Fig. 1: Cap Mountain ledges along west bank of James River Fig. 2: Cap Mountain topography	24
	IV.	Fig. 1: Lion Mountain - Welge contact Fig. 2: Black hematite nodules on weathered Lion Mountain slope	27
	V.	Morgan Creek ledges in south bank of Llano River 100 feet east of Honey Creek fault	31
	VI.	Fig. 1: Point Peak bluff along south bank of Mill Creek Fig. 2: Small bioherms near base of Point Peak	33
	VII.	Fig. 1: Bioherms at Point Peak - San Saba contact in bluff along south bank of Llano River Fig. 2: Slumped bioherms in water along south bank of Llano River	35
	VIII.	Fig. 1: "Cabbage head" surface of large bioherm Fig. 2: San Saba beds arching over bioherms along James River	36
	IX.	Fig. 1: Ellenburger limestone Fig. 2: Dolomite boulders on weathered Ellenburger slope	42
	X.	Simons fault cutting bluff along James River . .	51

GEOLOGY OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS

ABSTRACT

The Lower James River area is located on the southwest flank of the Llano uplift in Mason County, Texas. Strata exposed in the area are Upper Cambrian, Lower Ordovician, Mississippian, and Pennsylvanian in age.

The Upper Cambrian rocks are represented by the Riley and Wilberns formations. The Riley formation consists of the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone members.

Only the upper half of the Hickory sandstone is exposed in the thesis area. It is composed of light-brown to red, coarse-grained sandstone which grades upward into the calcareous, medium-grained, maroon sandstones of the basal Cap Mountain. The upper Cap Mountain consists of buff to gray, glauconitic, fossiliferous limestones. The Lion Mountain conformably overlies the Cap Mountain and is composed of very glauconitic, calcareous sandstone and layers of glauconitic, sandy limestone containing lenses composed essentially of trilobite shell fragments.

The Wilberns formation contains four members: the Welge sandstone, the Morgan Creek limestone, the Point Peak shale, and the San Saba limestone. A bioherm zone at the top of the Point Peak was mapped as a separate unit.

The Welge consists of medium-grained, essentially noncalcareous, buff to brown sandstone. The Lion Mountain-Welge contact is sharp. The Welge is overlain conformably by the Morgan Creek which is composed

of purplish to rust colored arenaceous limestones grading upward into gray to greenish-gray, glauconitic limestones with lenses of shell fragments. The Morgan Creek is conformably overlain by the greenish - gray calcareous shales and siltstones and interbedded tan to gray limestones of the Point Peak. The upper part of the Point Peak contains a flat-pebble conglomerate. The bioherms are micro-granular to sub-lithographic, buff to gray limestone in roughly spherical masses. The San Saba conformably overlies the Point Peak and consists of white to brown, fossiliferous glauconitic limestones and a few beds of calcareous, fine-grained sandstones.

The San Saba - Ellenburger contact, which has been generally considered to be the Cambrian - Ordovician boundary, is gradational and is drawn at the first appearance of Lytospira gyrocera. Barnes and Bell (1954, p. 25) suggested that the Cambrian - Ordovician boundary should be drawn within the San Saba member.

The Lower Ordovician is represented by the Ellenburger group, whose various formations were not differentiated in the thesis area. The group was mapped only as limestone or dolomite. The limestone is sub-lithographic, gray to brown, and fossiliferous. The dolomite is gray to brown, fine to medium-grained and cherty, and weathers to rounded boulders.

The Mississippian Chappel limestone and Barnett shale, and the Pennsylvanian Marble Falls limestone occur in an outlier resting unconformably on the Ellenburger in the northwest corner of the area. The Chappel consists of tan to rose, crinoidal limestone. The Barnett consists essentially of dark petroliferous limestones and interbedded dark brown shales. The Marble Falls is a dark, fine-grained limestone containing chert which is dark gray with a bluish cast.

Six major faults strike northeast through the area with throws varying from 150 to 1200 feet. In addition there is a system of minor faults with throws less than 100 feet. The strikes of the minor faults vary from northeast to northwest. Both the major and minor faults are high angle normal faults.

The regional northeast trend of the major faults and the lack of intensive folding in the Llano region are difficult to combine in a satisfactory explanation of the origin of the faults. Although it is postulated that the origin of the faults is associated with the Ouachita orogeny, no explanation of the actual mechanics of the faulting is given in this paper.

Folding in the thesis area is negligible. Very small local folds occur in strata above and below the bioherms at the top of the Point Peak. These folds result from differential compaction.

One isolated, anticlinal fold of limited extent occurs near the center of the area. The fold is older than the faulting and may be due to differential compaction over a Precambrian granite knob.

GEOLOGY OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS

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

STATEMENT OF PROBLEM

The principal objectives of this thesis are: (1) to map and describe the stratigraphic units which crop out in the Lower James River area; (2) to determine the structure of the area; and (3) to present a reconstruction of the geologic history of the area which is compatible with the stratigraphic and structural data assembled during field investigations. The first problem includes the determination of exposed or inferred formation boundaries and the megascopic study of the lithologies of those formations. The second problem involves the distribution and magnitude of the faults within the area. An analysis of the relations of stratigraphy, structure and physiography within the area is essential to the third problem.

ACKNOWLEDGMENTS

The writer wishes to express sincere thanks to Mr. C. L. Seward; to Dr. T. J. Parker; to Dr. M. C. Schroeder; to Dr. H. R. Blank; of the Geology Department of the Agricultural and Mechanical College of Texas, and to Mr. S. A. Lynch, Head of the Department; and to Dr. R. G. Bader of the Oceanography Department of the same institution. These professors supplied assistance in the field as well as constructive criticism and suggestions during the preparation of the manuscript for this thesis.

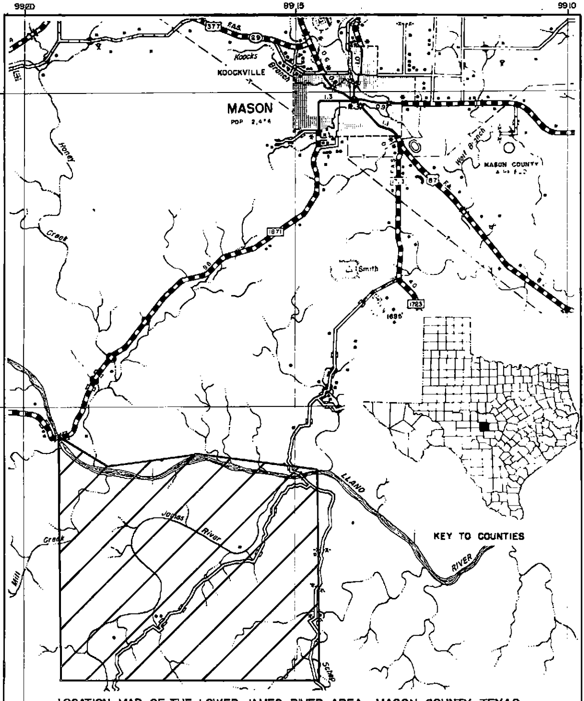
LOCATION

The Lower James River area, approximately 20 square miles in extent, is located in Mason County, Texas. The northwest corner of the area is at Whites Crossing on the Llano River, 9.0 miles southwest of Mason along Texas Farm Road No. 1871 (Figure 1). The north boundary meanders eastward with the Llano River from Whites Crossing to a point some 0.5 of a mile east of the confluence of the Llano and James Rivers. The west and east boundaries extend four miles due south from the northwest and northeast corners respectively. Geologically the area is situated on the southwest flank of the Llano uplift in central Texas.

ACCESSIBILITY

Public roads in comparatively good repair provide access by automobile to major parts of the Lower James River area. From its Llano River crossing, near the northeast corner of the area (Figure 1), the gravelled James River road passes diagonally through the area in a southwesterly direction. A secondary road leaves the James River road at the Llano River crossing and runs southward along the east boundary of the area. Private ranch roads branch off these county roads and meander through various parts of the area. As a rule the ranch roads are rather rough. The southern part of the area is the most difficult to reach, but no part of the area lies more than an hour walk from a passable road.

Figure I



LOCATION MAP OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS

Reproduced from Highway Map of Mason County, Texas, Prepared by Texas State Highway Department, 1949

0 1 2 3 4 5 Miles
Scale

METHODS OF FIELD WORK

The field work was accomplished between June 6, 1956, and August 6, 1956. Mapping was done on acetate covered aerial photographs made by the United States Department of Agriculture. Photographs of the series DFZ- 5E - 194 through 196 and 155 through 158 were used in preparing the base map of the area. These series are dated November 25, 1948. The scale of the photographs is approximately one inch equals 1667 feet.

Faults and stratigraphic contacts were walked out or determined by traverses made roughly perpendicular to the strike of such features. All geologic data were recorded on the photographs in the field with the aid of a pocket stereoscope. Later the photographs were studied with a larger office stereoscope in an effort to more accurately locate the contacts. Bands of vegetation appearing as dark lineations on the photographs were valuable in predicting the strike of most of the faults in the area.

Strikes and dips shown on the map (Plate I) represent an average of more than 300 determinations made in the thesis area with a Brunton compass. The compass dial was set on 10 degrees east to compensate for the local magnetic declination.

The sections described in the appendix of this report were measured at sites chosen for good exposures. Measurements were made by sighting on a Philadelphia self-reading rod with a Brunton compass, which was set on the average dip of the strata. The sections were measured as nearly as possible at right angles to the strike of the beds.

No vertical control was available for the thesis area. The relief shown in the geologic cross section (Plate I) was estimated by a stereoscopic study of the photographs. An Academy Height Finder and an Abrams Photogrammetric Computer were used in conjunction with the stereoscope. Horizontal distances were scaled on the aerial photographs.

REVIEW OF THE LITERATURE

Prior to this thesis the published results of detailed geologic surveys conducted in southern Mason County have described only a small tract in the extreme northwest corner of the Lower James River area.

The first geologic reference to the Llano region was published by Ferdinand Roemer in 1846. His report (Roemer, 1846) was based on observations made on a reconnaissance trip northwest from New Braunfels to Fort San Saba. Roemer suggested that in this central Texas area the stratified rocks of the eastern side of the continent contacted the crystalline rocks of the Rocky Mountains. Following later studies Roemer (1848, 1852) published descriptions of fossils collected at various localities and established the Paleozoic age of the strata superjacent to the central Texas granites.

Shumard (1861) reviewed Roemer's fossil descriptions and included additional descriptions. In this paper Shumard named and discussed the Potsdam sandstone and the overlying Calciferous sand group. He considered the Potsdam faunal assemblage analagous to that of the Potsdam sandstone in Iowa, Wisconsin, and Minnesota.

Using the evidence of fossil content Walcott (1884) concluded that the Potsdam was Upper Cambrian in age. He mentioned an unconformity noted at the base of all Potsdam sections studied in central Texas and applied the name Llano series to pre-Potsdam strata.

Hill (1888) mentioned the importance of Walcott's work on the Paleozoic rocks of central Texas. In his summation of previous geologic work in Texas, Hill referred to two periods of tectonic activity in central Texas. He placed the disturbances at the end of deposition of the Llano series and at the close of the Paleozoic era.

In 1889 the Texas State Geological Survey was established with E. T. Dumble as State Geologist. Recognition of the potential importance of the Llano region as a mineral province induced the state to finance a comprehensive survey of the area. T. B. Comstock was engaged to direct this special survey. Comstock (1890) published a preliminary report in which he proposed the terms Hickory series, Riley series, and San Saba series. The Hickory and Riley series represented the lower and middle parts of the Potsdam sandstone as defined by Walcott. Comstock retained the Potsdam designation and applied it to the upper part of Walcott's Potsdam. Comstock considered the Hickory, Riley and Potsdam to be Lower, Middle, and Upper Cambrian in age, respectively.

General aspects of the drainage system in central Texas were discussed by Tarr (1890). He concluded that the present drainage system originated upon Cretaceous strata in Tertiary time. Erosion removed those Cretaceous rocks resulting in superposition of the streams upon the harder, underlying, Paleozoic strata.

Paige (1911) named and briefly described the Wilberns, the Cap Mountain, and the Ellenburger formations in a discussion of the mineral resources of the Llano region. In addition Paige named the Smithwick shale and applied the name Hickory sandstone to the strata which had been designated the Hickory series by Comstock. In his "Geologic Folio of the Llano and Burnet Quadrangles" Paige (1912) published detailed descriptions, including measured sections, of the Hickory sandstone, the Cap Mountain formation, the Wilberns formation, the Ellenburger limestone, the Marble Falls limestone, and the Smithwick shale.

A geologic map of the state of Texas was published by the Bureau of Economic Geology in 1916 (Udden et al, 1916). On this map the various stratigraphic units were largely undifferentiated and were presented as Pennsylvanian, Paleozoic, or Cambrian - Ordovician.

Sellards et al (1932) reviewed the Precambrian, Cambrian, Ordovician, Mississippian, and Pennsylvanian systems of the Llano region and included a brief discussion of the paleogeography of those periods. The time of the initial Paleozoic uplift in the Llano region was dated as Mississippian by Sellards (1934). In his description of the structural features of the Llano region, Sellards mentioned the general northeast - southwest trends of major faults but no details concerning individual faults were included.

Precambrian structural conditions were reconstructed by Stenzel (1934). He indicated that the Precambrian rocks of the Llano region could be divided into three series dependent upon the attitude of the rocks relative to existing structures.

Bridge (1937) published a short discussion of the faunal assemblages of the Upper Cambrian rocks in the Llano region, in the upper Mississippi valley, and in Missouri. On the basis of similarity or mutual occurrence of identical fauna, Bridge proposed a correlation of Upper Cambrian strata in the three areas. In the same paper Bridge described a thick unit of glauconitic sandstone, included by Paige in the Cap Mountain formation, and named this unit the Lion Mountain member of the Cap Mountain formation.

In 1933 Darton made field studies in the Llano region and compiled unpublished data on the area. Later he integrated these data on a state geologic map (Darton et al, 1937) on a scale of 1 to 500,000. General areas in which the larger stratigraphic units crop out were indicated and major structures were shown on this map.

Bridge and Girty (1937) redescribed the Paleozoic fossils first described by Roemer. Efforts were made to accurately establish the locations of the sections and the stratigraphic horizons from which Roemer collected the fossils.

The dreikanters which occur in the basal Hickory sandstone were first reported by Barnes and Parkinson (1939). Barnes suggested the possibility that the four-faceted shape of the ventifacts might be the result of four prevailing wind directions during the reworking of the basal Hickory sediments.

Keppel (1940) described in detail the texture and composition of large circular massifs of granite exposed in the Llano region. He proposed an origin of forcible, simultaneous injection to explain the three textural varieties of granite which occur in concentric arrangement in the massifs.

A paper concerned primarily with the occurrence of gypsum in the Cretaceous Edwards limestone in central Texas was published by Barnes in 1943. In the same paper Barnes referred to an unpublished manuscript by Bridge and Barnes in which the Wilberns formation was divided into four formations as follows, in ascending order: (1) the Welge sandstone; (2) the Morgan Creek limestone; (3) the Point Peak shale; and (4) the San Saba limestone.

Cloud, Barnes and Bridge (1946) revised the usage of the term Ellenburger limestone as defined by Paige. They defined the Ellenburger group and restricted application of the term to strata of Lower Ordovician age. Under this classification the Ellenburger was divided into three formations which are, in ascending order: (1) the Tanyard formation, containing the Threadgill and Staendebach members; (2) the Gorman formation; and (3) the Honeycut formation. These authors also proposed the name Riley formation for all pre-Wilberns rocks of Cambrian age. So defined, the Riley formation included the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone as members. Characteristic topographic expressions and vegetation peculiar to the formations were described in the same paper.

All Upper Cambrian units in the Llano region were described or redefined by Bridge, Barnes, and Cloud (1947). This detailed publication, which includes nineteen measured sections and three geologic profile sections, provides a standard reference for the Upper Cambrian stratigraphic units in central Texas.

Cloud and Barnes (1948) presented a detailed report on the Ellenburger group, which was based on field studies made from 1943 to 1947. A large part of this material had been published by Cloud, Barnes, and Bridge in 1946. This publication contains brief discussions of pre-Ellenburger and post-Ellenburger strata in central Texas and is supplemented by detailed geologic maps of various areas in the Llano region. An area which includes the northwest corner of the Lower James River area was mapped and named the Bear Springs area.

The Carboniferous rocks of the Llano region were discussed in a detailed publication by Plummer (1950). This paper includes measured sections from various localities and a brief review of pre-Carboniferous stratigraphy. The report is supplemented by a geologic map which does not differentiate the pre-Carboniferous formations.

Hendricks (1952) emphasized the importance of insoluble residues in the Ellenburger group in his discussion of the correlation of subsurface Ellenburger sections in north Texas and west Texas with exposed sections in central Texas. The correlations were based almost entirely on residue logs.

Parke (1953) published a detailed geologic map of approximately 18 square miles north of the Lower James River area.

G E O G R A P H Y

CLIMATE

The Lower James River area is located in the semi-arid belt of central Texas. Normally the average annual rainfall totals some twenty inches and occurs as heavy, sporadic rains during the spring and winter months. During the past six years, however, drouth conditions have existed with rainfall considerably below normal. Consequently, the region is suffering from loss of vegetation with an attendant increase in the effects of erosion.

Temperatures range from 110°F. in the summer to possibly - 5°F. in the winter. The average annaul temperature is about 70°F.

VEGETATION

The thesis area supports the restricted vegetation characteristic of regions with thin rocky topsoil and a semi-arid climate. Mesquite, scrub oak and ceder are commonly found on the uplands. Larger oaks, sycamores, and pecan trees grow along the major streams. Common shrubs include the Mexican persimmon, catclaw, turkey pear, and agerita. Prickly pear is locally quite abundant and attains a large size. Several unidentified species of smaller cactii were noted in the area.

The distribution of the various types of vegetation is influenced to a certain extent by the character of the rock units which crop out in the area. On the limestone soils scrub oak, cedar, and yucca predominate. Growths of mesquite and Mexican persimmon occur on the shale slopes. Most of the sandstone outcrops support growths of post oak, mesquite, and stunted elm. In local areas this selective growth may be so pronounced as to indicate formation boundaries on the aerial photographs.

INDUSTRY

The economy of Mason County is based on ranching. Cattle, sheep, and goats are raised in that order of importance. Various grain crops, cotton, peanuts and watermelons are raised on a small scale. The successful production of such crops commonly depends on private irrigation projects.

In the Lower James River area the rough topography and poor soil practically eliminate farming. In this area angora goats seem to provide one of the chief sources of income.

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

PHYSICAL FEATURES

The Lower James River area is located on the southwest flank of the Llano uplift. The uplift consists of a broad topographic basin formed by erosion on the crest of a structural dome. Precambrian rocks are exposed in the basin, which is surrounded by Paleozoic and Cretaceous strata. To the south and east the basin rim consists largely of the Edwards limestone of Cretaceous age. Paleozoic rocks predominate to the north and the western rim is a poorly defined, dissected plateau. According to Plummer (1950, p. 8) the maximum elevation of the Llano region is more than 2200 feet and the maximum relief is approximately 1600 feet.

Precambrian rocks do not crop out in the Lower James River area. With the exception of a small outlier of Mississippian and Pennsylvanian rocks in the northwest corner of the area, the exposed strata are of Upper Cambrian and Lower Ordovician age. The maximum relief is estimated at about 350 feet.

Topographically that part of the thesis area northwest of the Simons fault (Plate I) consists of rounded hills formed essentially by stream erosion. The southeast-dipping strata are mostly unfaulted and show normal stratigraphic relations. The oldest rock unit cropping out in this part of the area is the Morgan Creek limestone. This member is exposed in the bed of Mill Creek at the Schmidt fault and in the base of the cliff along the south bank of the Llano River 0.3 of a mile below Whites Crossing. The highest hills are capped by the

Ellenburger limestones and dolomites.

Southeast of the Simons fault the topography and outcrop pattern are controlled by a system of normal faults. In some places more or less elongated hills parallel the northeast strikes of the faults. However, erosion has dissected the hills and formed slopes which make it difficult to recognize fault scarps or fault line scarps. The outcrop trend is offset in many places by either minor or major faults. The strata dip generally southeast, although dips are locally erratic due to the numerous faults.

DRAINAGE

The Lower James River area is drained by the Llano River system. The James River, which is the largest local tributary, flows through the central part of the area and empties into the Llano River near the northeast corner of the area. Mill Creek and Schep Creek, in the northwest and southeast parts of the area respectively, are the remaining tributaries of major importance to the drainage of the thesis area. The three tributaries flow generally northeast.

Tarr (1890, p. 359-362) studied the drainage pattern of the major streams in the Llano region and concluded that these streams established their courses on an originally eastward-dipping plain and have since cut downward into the older strata of Paleozoic and Precambrian age. The major stream pattern in the thesis area seems to agree with this theory. The Llano River, The James River, and Mill Creek cross major faults and lithologic boundaries several times within the area with no apparent deviation from their courses.

Ellenburger limestones and dolomites.

Southeast of the Simons fault the topography and outcrop pattern are controlled by a system of normal faults. In some places more or less elongated hills parallel the northeast strikes of the faults. However, erosion has dissected the hills and formed slopes which make it difficult to recognize fault scarps or fault line scarps. The outcrop trend is offset in many places by either minor or major faults. The strata dip generally southeast, although dips are locally erratic due to the numerous faults.

DRAINAGE

The Lower James River area is drained by the Llano River system. The James River, which is the largest local tributary, flows through the central part of the area and empties into the Llano River near the northeast corner of the area. Mill Creek and Schep Creek, in the northwest and southeast parts of the area respectively, are the remaining tributaries of major importance to the drainage of the thesis area. The three tributaries flow generally northeast.

Tarr (1890, p. 359-362) studied the drainage pattern of the major streams in the Llano region and concluded that these streams established their courses on an originally eastward-dipping plain and have since cut downward into the older strata of Paleozoic and Precambrian age. The major stream pattern in the thesis area seems to agree with this theory. The Llano River, The James River, and Mill Creek cross major faults and lithologic boundaries several times within the area with no apparent deviation from their courses.

Relatively short obsequent streams enter the major streams from the south.

STRATIGRAPHY

GENERAL STATEMENT

Rocks cropping out in the Lower James River area range in age from Cambrian to Recent. The strata of Paleozoic age are almost entirely referable to the Cambrian and Ordovician systems. A small outlier in the northwest corner of the area is composed of Mississippian and Pennsylvanian formations. The stratigraphic column for the area consists of the following units:

CENOZOIC ERA
- Quaternary
  - Recent

PALEOZOIC ERA
- Pennsylvanian System
  - Lower Pennsylvanian
    - Marble Falls limestone
- Mississippian System
  - Barnett formation
  - Chappel limestone
- Ordovician System
  - Lower Ordovician
    - Ellenburger group
- Cambrian System
  - Upper Cambrian
    - Wiberns 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

PALEOZOIC ERA

CAMBRIAN SYSTEM

Upper Cambrian rocks crop out extensively over the Lower James River area. There is a complete absence of Middle and Lower Cambrian strata in the Llano region. The seven members of the Riley and Wilberns formations represent the rocks of Upper Cambrian age in the thesis area.

Riley Formation

The Riley series was named for the Riley Mountains in Llano County by T.B. Comstock (1890, p. 286-289). Comstock also proposed the name Hickory series for strata beneath the Riley. Sidney Paige (1912, p. 42) redesignated the Hickory series as the Hickory sandstone and named the overlying limestone beds the Cap Mountain formation. Bridge (1937, p. 235) described the Lion Mountain sandstone as a member of the Cap Mountain. Finally, Cloud, Barnes, and Bridge (1946, p. 154) reduced the original Riley series to formation status. As a formation the Riley includes three members, which are:

Lion Mountain sandstone
Cap Mountain limestone
Hickory sandstone.

The total thickness of the Riley formation in the thesis area is estimated at 440 feet.

Hickory sandstone member

The original Hickory series was named by Comstock (1890, p. 285) for Hickory Creek in Llano County. Paige (1912, p. 42) redefined this series as a formation and named it the Hickory sandstone. Cloud, Barnes, and Bridge (1946, p. 154) published the present designation of the Hickory as a member of the Riley formation.

According to Bridge, Barnes, and Cloud (1947, p. 112) the thickness of the Hickory in the Llano region ranges from a feather edge to 415 feet with an average thickness of 360 feet. This inconsistency in thickness may be attributed largely to the varying relief of the Precambrian surface upon which the member was deposited.

A complete section of the Hickory is not exposed in the Lower James River area. The lowest exposure forms low bluffs and ledges along Schep Creek in the southeast corner of the area. This exposure consists of tan to light brown sandstone which weathers to a grayish-brown color. The sandstone occurs in layers a few inches to 2 feet thick and is composed of fine to coarse, well rounded, clear quartz grains. The sandstone is friable. Some cross bedding occurs as well as lateral pinching and swelling of some of the thicker layers. Some large oscillation ripple marks were noted in the bed of Schep Creek. The sandstone contains zones of light green to buff, shaly siltstone in layers up to 2 inches thick. The shaly zones weather more rapidly leaving protruding sand ledges. Muscovite is disseminated on the bedding planes of the siltstone.

LIBRARY
A & M COLLEGE OF TEXAS
22

Plate II

Figure 1
Lensing sandstone bed in middle Hickory

Figure 2
Ripple marks in middle Hickory in bed of Schep Creek

North of Schep Creek the Hickory is poorly exposed on a hillside. Fragments and chunks of reddish-brown sandstone litter the slope. Near the top of the hill, where the Hickory is faulted against the Cap Mountain, a few ledges of maroon, non-calcareous, medium-grained sandstone are exposed.

Brown, sandy soil derived from the Hickory covers the gentle slopes south of Schep Creek. The normal transitional contact with the overlying Cap Mountain limestone occurs near the foot of a low hill in the southeast corner of the area.

Cap Mountain limestone member

The Cap Mountain formation was named by Paige (1911, p. 23) for Cap Mountain in Llano County. Cloud, Barnes, and Bridge (1946, p. 154) redefined the Cap Mountain as a member of the Riley formation.

According to Bridge, Barnes, and Cloud (1947, p. 112) the member varies from 135 to 455 feet thick in the Llano region. In the Lower James River area the Cap Mountain reaches a measured thickness of 315 feet. Exposures occur along the James River and in the southeast part of the area as gentle slopes and low hills.

The Hickory - Cap Mountain contact is transitional. In the southeast corner of the thesis area this boundary was drawn at a change in slope which corresponds roughly with the first appearance of a calcareous sand.

The lower part of the Cap Mountain section is composed of calcareous, maroon to brown, fine to medium-grained, quartz sandstone. The

Plate III

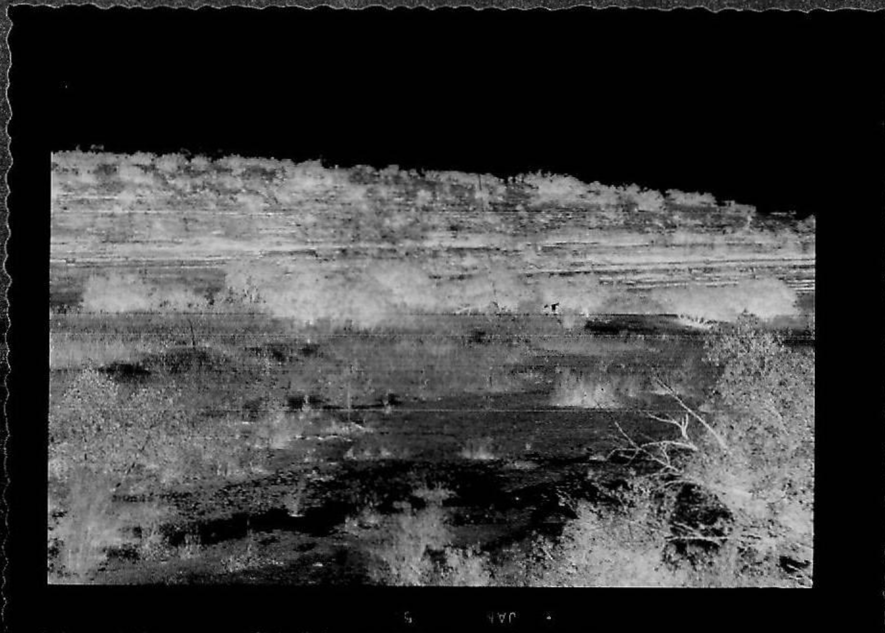


Figure 1
Cap Mountain ledges along west bank of James River

Figure 2
Cap Mountain topography

sandstone occurs in beds a few inches to 2 feet thick and weathers to a dull maroon color. In some beds the sand grains are coated with shiny black hematite.

Above this lower sandstone zone there is a sequence of maroon to dark brown, very sandy limestone in beds 1 inch to 1 foot thick, alternating with less sandy, brown limestone which contains white stringers of calcite. This sequence contains a few beds of buff, fine-grained, well-sorted, slightly calcareous sandstone.

These beds grade upward into the silty, slightly glauconitic, buff to gray, finely crystalline limestone which forms a large part of the Cap Mountain. This limestone is fossiliferous and contains splotches and streaks of yellow-brown limonite. In many places these splotches coalesce to form streaks parallel to the bedding. These streaks give the rocks a banded appearance. Some of the beds reach several feet in thickness and weather into rounded ledges which have a pitted appearance in many places.

In the upper part of the member the gray limestone contains more glauconite which gives the rock a green or reddish-brown speckled appearance depending upon the degree of alteration of the glauconite. These beds contain lenses composed essentially of white, trilobite shell fragments. (Collectively, these shell fragments are commonly designated trilobite "hash").

The lithology of this upper part of the member is quite similar to the lithology of the middle part of the Morgan Creek limestone.

Lion Mountain sandstone member

The Lion Mountain sandstone was named by Bridge (1937, p. 235) for Lion Mountain in the northwest part of the Burnet Quadrangle. Bridge defined the Lion Mountain as the top member of the Cap Mountain formation. Cloud, Barnes, and Bridge (1946, p. 154) reduced the Cap Mountain to member status and the Lion Mountain became the top member of the Riley formation.

According to Bridge, Barnes, and Cloud (1947, p. 114) this member has a maximum measured thickness of 50 feet in the Llano region.

The Cap Mountain - Lion Mountain boundary is transitional. In the thesis area this contact was drawn at the base of the first very glauconitic, quartz sandstone encountered in the measured section described in the appendix of this paper. This placement of the boundary resulted in a total thickness of 60 feet. Although this figure exceeds the maximum thickness indicated by Bridge, Barnes and Cloud (1947, p.114), it compares favorably with the thickness measured by George Dannemiller (1956, personal communication) in the Central James River area. Dannemiller's section was measured approximately 5.5 miles southwest of the section indicated above.

Lion Mountain outcrops in the Lower James River area form very gentle slopes between the James River and the first range of hills southeast of the river. These slopes extend into the re-entrants cut into the hills by stream erosion. This range of hills terminates near the east boundary of the area. The Lion Mountain exposures curve around this termination and trend southwest along the bases of the hills. Other exposures occur in the northeast part of the area north of James River and in the southeast part of the thesis area (Plate I).

Plate IV

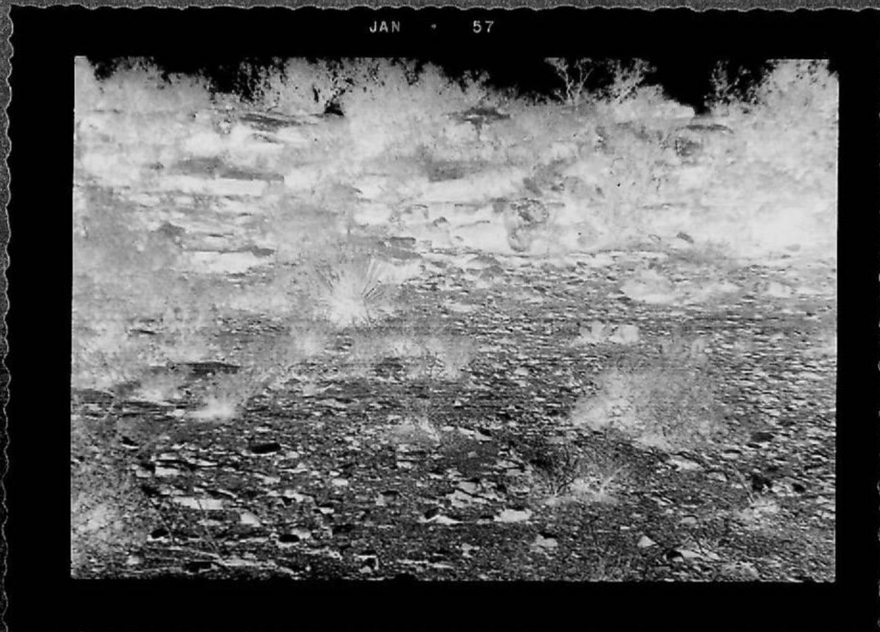


Figure 1
Lion Mountain - Welge contact

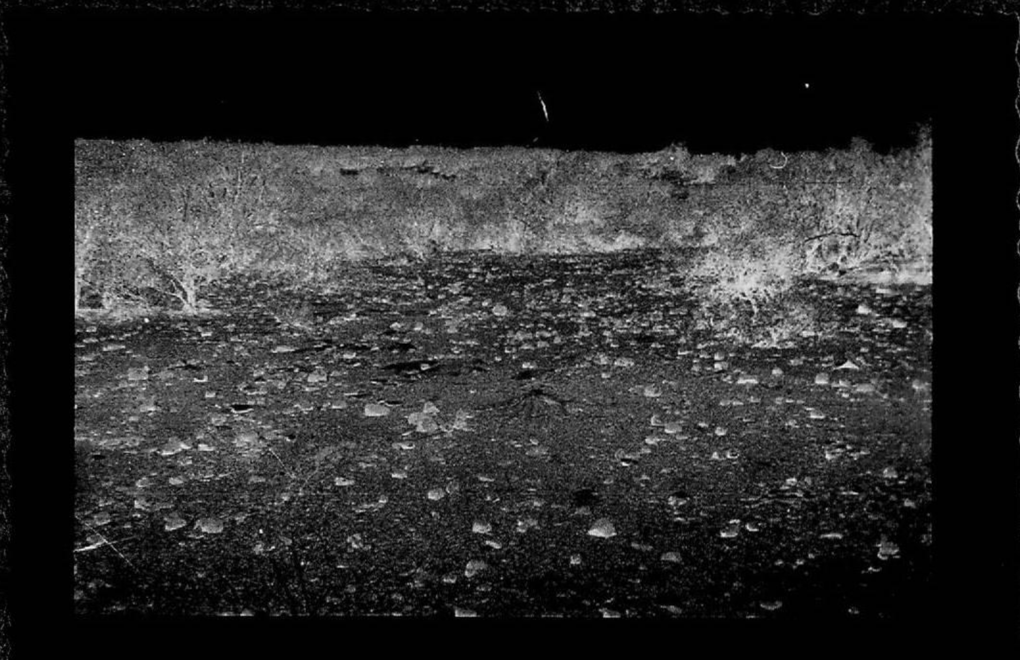


Figure 2
Black hematite nodules on weathered Lion Mountain slope

The Lion Mountain is composed of very glauconitic, fine to medium-grained, calcareous, quartz sandstone containing beds of very glauconitic, sandy limestone. Some of the beds of both the sandstone and the limestone are green or brown speckled depending upon the degree of alteration of the glauconite. The basal sand beds are characterized by lenses of fine to coarse trilobite "hash". Shiny, black nodules of hematite litter many of the weathered slopes of Lion Mountain.

Wilberns Formation

The Wilberns formation was named by Paige (1911, p. 23) for Wilberns Glen in Llano County. Cloud, Barnes, and Bridge (1946, p. 155) redefined the Wilberns and placed the upper boundary at the top of the Cambrian system. They further divided the Wilberns into four members which are:

San Saba limestone
Point Peak shale
Morgan Creek limestone
Welge sandstone.

In this thesis the large bioherms which were previously included by various geologists in the Point Peak shale are mapped as a separate unit.

According to Bridge, Barnes, and Cloud (1947, p. 114) the Wilberns formation varies in thickness from 540 to 610 feet in the Llano region, with an average thickness of 580 feet.

Welge sandstone member

The Welge sandstone member was named by Barnes (1944, p. 34) for the Welge Land Surveys in Gillespie County. According to Bridge, Barnes, and Cloud (1947, p. 114) the Welge varies in thickness from 9 to 35 feet in the Llano region, with an average thickness of 18 feet. In the Lower James River area a thickness of 22.5 feet was measured.

The Welge forms a prominent ledge which results in a rather abrupt change in the slopes of the hills south of the James River. This ledge may be easily traced on the aerial photographs. Some of the slopes have weathered back above the Welge to produce benches. In the north-east part of the area erosion has progressed sufficiently to form low, narrow, Welge - capped hills.

The Lion Mountain - Welge contact can be drawn rather sharply in most parts of the thesis area. The easily weathered glauconitic Lion Mountain contrasts noticeably with the more resistant, non-glauconitic, brown Welge sandstone. This contact is the boundary between the Riley and Wilberns formation.

The Welge consists of medium-grained, sub-rounded, buff to brown, quartz sandstone. Beds range in thickness from 6 inches to 4 feet. The sandstone is non-glauconitic and is generally friable. Joint fillings of limonite and hematite protrude from the weathered surfaces of some beds. Many exposed surfaces glitter noticeably due to numerour recomposed (?) quartz grains. Some of the uppermost beds of the member are slightly calcareous.

Morgan Creek limestone member

The Morgan Creek limestone was named by Bridge (1937, p. 236) for Morgan Creek in Burnet County. According to Bridge, Barnes, and

Cloud (1947, p. 115) the member varies in thickness from 70 feet to 160 feet in the Llano region, with an average thickness of 120 feet. In the Lower James River area the maximum thickness is estimated at 130 feet.

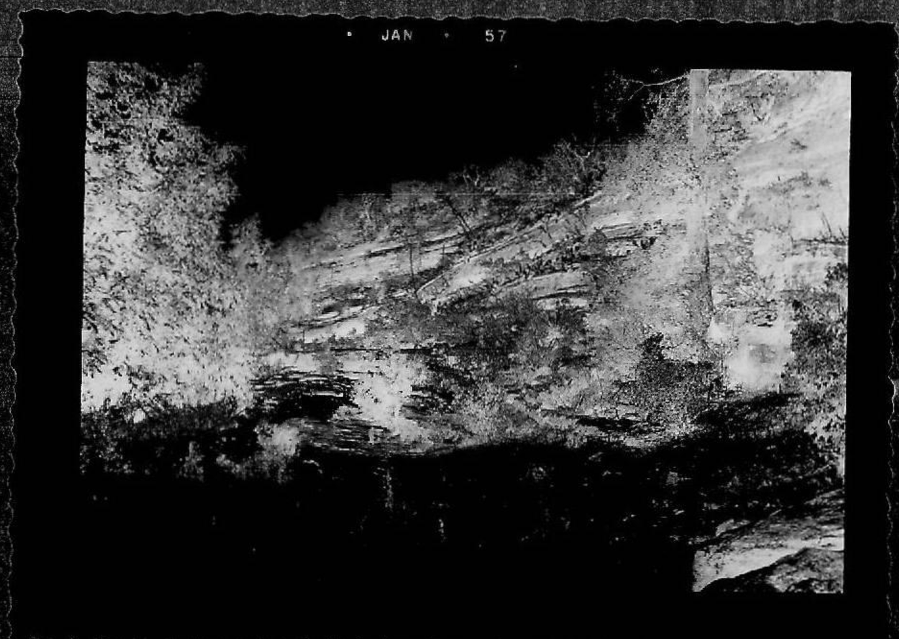
Outcrops of Morgan Creek limestone in the thesis area occur mostly southeast of the Simons fault (Plate I). Some of the hills in this part of the area are capped with Morgan Creek in a normal position. In other outcrops the member is in fault contact with various other members. Additional exposures of limited extent occur in the bluff along the south bank of the Llano River and in the bed of Mill Creek.

The Welge - Morgan Creek contact is gradational. It is commonly drawn at the base of the first purplish to rust - colored, arenaceous limestone bed encountered above the typical Welge lithology.

These coarse-grained, friable, basal beds grade upward into gray to greenish-gray, very glauconitic limestone. Some of the beds consist of almost white limestone which has a green to red speckled appearance due to the glauconite. Fine "hash" lenses are present in some beds. Thin interbedded gray shale layers appear in the upper part of the member.

Most of the Morgan Creek is fossiliferous. A zone containing the brachiopod Eoorthis texana occurs some 60 feet above the base of the member. In the thesis area this zone is exposed in the lowermost beds in the bluff along the south bank of the Llano River. In some places a zone of small stromatolitic bioherms occurs near the top of the Morgan

Plate V



Morgan Creek ledges in south bank of Llano River
100 feet east of Honey Creek fault

Creek. This zone is exposed in a stream bed some 700 feet east of the mouth of Mill Creek.

The bioherms are sub-spherical, average about one foot in diameter, and consist of sub-lithographic, greenish-gray to purplish limestone.

Point Peak shale member

The Point Peak shale was named by Bridge (1937, p. 236) for Point Peak near Lone Grove in Llano County. According to Bridge, Barnes and Cloud (1947, p. 115) the member is 270 feet thick at the type locality and averages about 160 feet in the Llano region. In the Lower James River area a thickness of 124 feet was measured.

In the northwest corner of the area, gentle, weathered slopes of the Point Peak are exposed along Mill Creek. Approximately 1000 feet upstream from the mouth of Mill Creek the lower part of the member forms a bluff along the south bank. This bluff is included in the section described in the appendix. Other Point Peak outcrops in the area include the exposure in the canyon north of Mill Creek and the Point Peak slope north of Martin fault.

The Morgan Creek - Point Peak contact is gradational and is placed approximately at the base of the shales and siltstones which overlie the more thickly bedded Morgan Creek limestones. Further, the contact is near the top of the zone of small bioherms which is found at some places in the top of the Morgan Creek.

The Point Peak consists of greenish-gray to lavender, calcareous shales interbedded with calcareous, greenish-gray to dull brown,

Plate VI

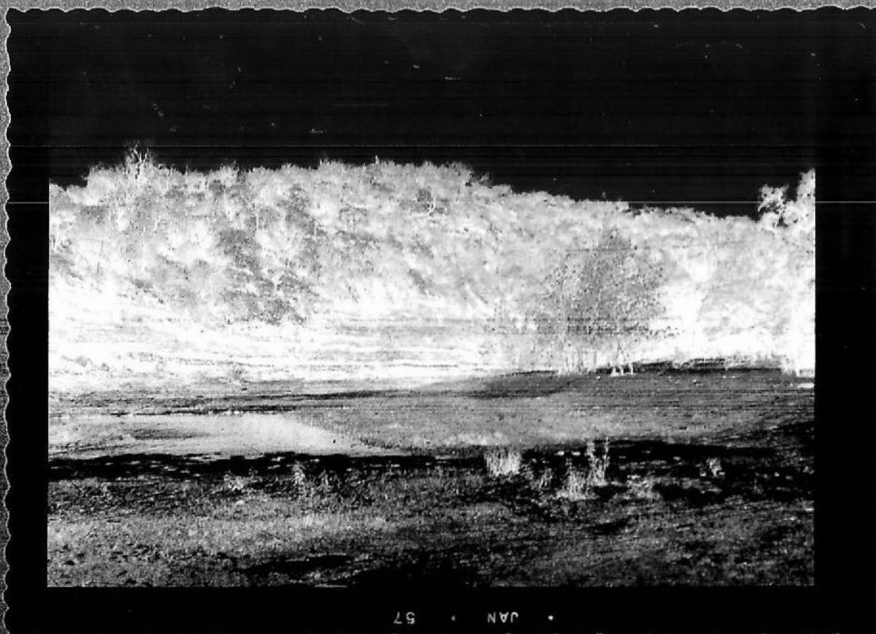


Figure 1
Point Peak bluff along south bank of Mill Creek

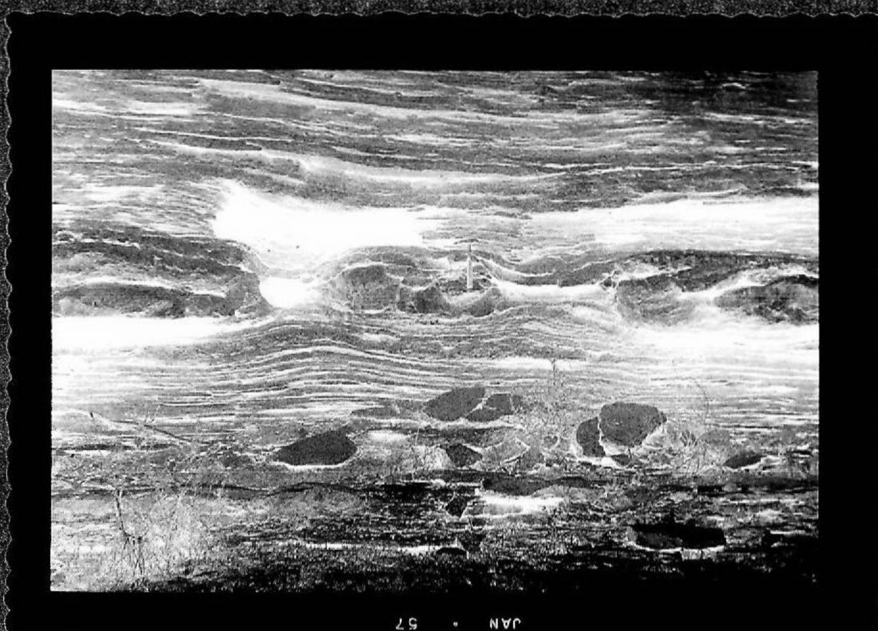


Figure 2
Small bioherms near base of Point Peak

glauconitic siltstones and fine to medium grained, glauconitic, tan to gray limestones. Some beds of medium grained limestone contain small lenses of fine grained limestone. In the upper part of the member 2-inch to 1-foot beds of intraformational conglomerate occur. The conglomerate consists of flattened pebbles of glauconitic, fine-grained limestone in a medium-grained limestone matrix. The pebbles range up to 3 inches in diameter and some are not parallel to the bedding.

About 16 feet below the top of the measured section a very fossiliferous bed occurs. The hash-like bed consists of brachiopod shells and shell fragments. This bed probably represents the Eoorthis zone referred to by Bridge, Barnes and Cloud (1947, p. 116) and by Cloud and Barnes (1948, p. 117).

Bioherm Zone

The thick bioherm zone at the top of the Point Peak member has previously been included, by various geologists, in the Point Peak or in the overlying San Saba limestone. In the thesis area the zone was mapped as a separate unit.

The bioherms are exposed as isolated masses; or coalesce to form ledges of considerable lateral extent; or form benches between the less resistant Point Peak and San Saba members. Individual bioherms attain a diameter of about 50 feet in the thesis area.

The bioherms are composed of micro-granular to sub-lithographic, buff to gray limestone which weathers to a brownish-gray color. On weathered surfaces the bioherms form roughly circular patterns. The

Plate VII

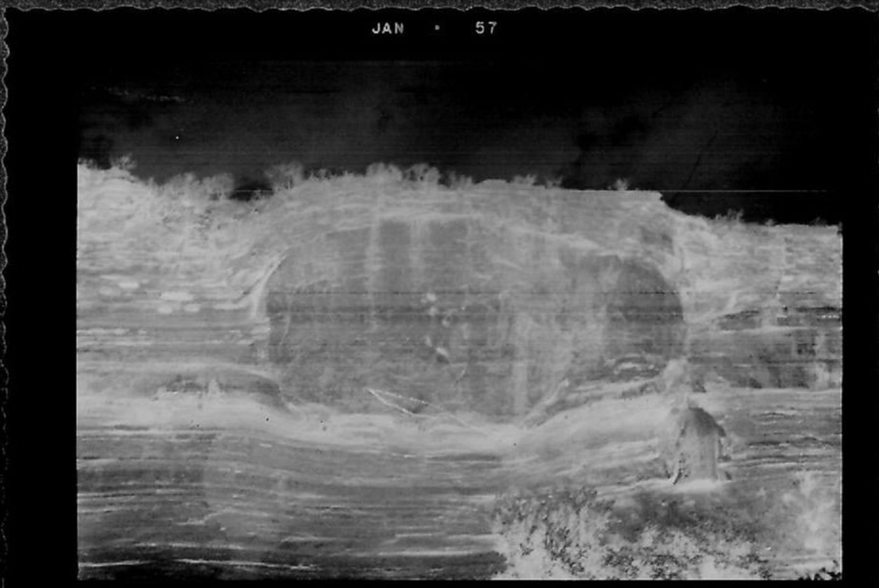


Figure 1
Bioherm at Point Peak - San Saba contact
in bluff along south bank of Llano River

Figure 2
Slumped bioherms in water along south bank of Llano River

Plate VIII

Figure 1
"Cabbage head" surface of large bioherm

Figure 2
San Saba beds arching over bioherms along James River

bioherms exhibit no megascopic internal structure and are considered to have been deposited by lime-secreting algae.

San Saba limestone member

The San Saba limestone was named by Bridge (1937, p. 237) for exposures along the San Saba River northwest of Camp San Saba in McCulloch County. Comstock (1890, p. 301-306) originally used the name as a series term in reference to all or part of the beds included in the present designation. The type section of Bridge is 280 feet thick. In the Lower James River area a thickness of about 290 feet was measured.

In the thesis area the San Saba forms many of the rounded hills north of the Simons fault. Although good exposures occur in some of the stream beds, much of the San Saba outcrop consists of resistant ledges protruding from weathered slopes.

The lower San Saba contact is placed at the top of the bioherm zone. The lower beds of the member terminate against and arch over the top of the bioherm masses. In areas where the bioherms are missing the boundary is drawn at the top of the highest significant shale in accordance with the precedent established by Cloud, Barnes, and Bridge (1946, p. 149).

The San Saba consists of 1-inch to 2-foot beds of sub-lithographic to medium-grained limestone containing 4-inch to 3-foot layers of sandstone concentrated in certain zones in the section. The limestones are white to brown, more or less glauconitic and the lower beds weather to a yellow-brown color. Fossiliferous zones are scattered throughout the member. Many San Saba slopes are littered with thin slabs of this yellowish limestone. The sandstones are white to buff, calcareous, fine-grained and are tough to friable. Intraformational conglomerates occur above the middle of the member. The conglomerates consist of very fine grained, grayish-brown limestone pebbles in a coarse grained white to buff limestone matrix. Some of the wafer-shaped pebbles reach 2 inches in diameter.

ORDOVICIAN SYSTEM

Upper and Middle Ordovician rocks are absent in the Lower James River area. The Lower Ordovician is represented by the Ellenburger group.

Ellenburger Group

The Ellenburger limestone was named by Paige (1911, p. 24) for exposures in the Ellenburger Hills in southeastern San Saba County. The Ellenburger was redefined as a group by Cloud, Barnes and Bridge (1946, p. 133) and divided into the Tanyard, the Gorman, and the Honeycut formations. According to Barnes and Bell (1954, p. 35) the Ellenburger has an average thickness of about 1740 feet in the Llano region.

In the Lower James River area the limestone and dolomite facies of the Ellenburger were mapped separately but were not assigned to formations. The Ellenburger was mapped and is here discussed as a group.

Rather extensive outcrops of the group are exposed in the thesis area north of the Simons fault. The limestone facies caps many of the rounded San Saba hills. The limestone is exposed as slightly protruding ledges on the hillsides and the hilltops are littered with loose flaggy blocks. The large dolomite outcrop in the southwestern part of the area is apparently conformable with the underlying limestone facies. From the northern edge of this exposure the plateau-like surface dips gently southward and is littered with the round boulders characteristic of weathered Ellenburger dolomite. In the southwest corner of the area some very low hills rise above the general surface elevation of the dolomite outcrop. These hills have comparatively little dolomite at the surface and are marked by weathered chunks of red chert and reddish soil. (The dashed line in the southwest corner of Plate I indicates the approximate boundary between the red material and the general dolomite surface.)

An estimated thickness of about 125 feet of Ellenburger is exposed to the area.

The San Saba - Ellenburger contact is gradational and is rather difficult to trace. In the thesis area an effort was made to draw the contact between the last appearance of glauconite in the San Saba and the first appearance of the uncoiled gastropod Lytospira gyrocera. In the uppermost San Saba glauconite is very scarce and may consist of single, scattered grains. In addition it is difficult to determine conclusively the lowest bed containing Lytospira gyrocera. These difficulties result in a vertical interval of some 30 feet within which the strata may be either San Saba or Ellenburger. The boundary is placed within this interval. Prior to 1954 this contact was considered the boundary between the Cambrian and Ordovician systems. Barnes and Bell (1954, p. 25) suggested that the Cambrian - Ordovician boundary should be placed within the San Saba member.

The Ellenburger group as exposed in the thesis area consists essentially of sub-lithographic, gray to brownish, fossiliferous limestone and medium-grained, gray or yellowish-gray to brownish dolomite. The limestone occurs in beds a few inches to 2 feet thick. In most localities the dolomite is not in place but occurs in loose, rounded to angular boulders on weathered surfaces.

Numerous irregular solution cavities occur in many of the weathered boulders. In some of the dolomite outcrop areas the ground is littered with chert fragments several inches in diameter and of various colors. Much of this chert glitters with drusy surfaces.

LIBRARY
A & M COLLEGE OF TEXAS
42

Plate IX

Figure 1
Ellenburger limestone

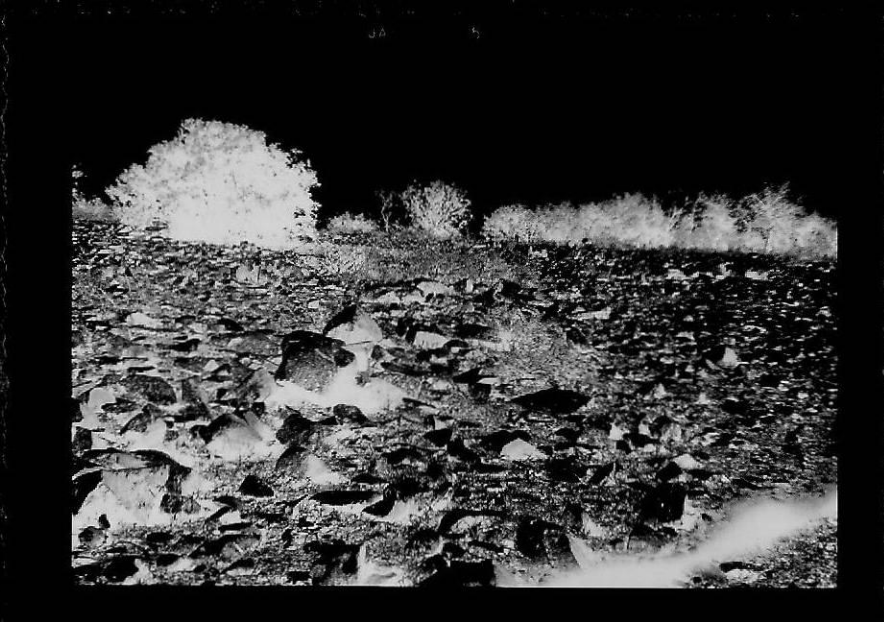


Figure 2
Dolomite boulders on weathered Ellenburger slope

MISSISSIPPIAN SYSTEM

A small outlier on the downthrown side of the Honey Creek fault (Plate I) contains the only Mississippian rocks exposed in the thesis area. The Chappel limestone and the Barnett formation are represented in this isolated mass.

Cloud and Barnes (1948, p. 154-187) mapped this outlier in their "Geology Of The Bear Springs Area, Mason County, Texas". According to those authors the Chappel limestone is collapsed to a certain extent into the Gorman formation of the Ellenburger group. No evidence of tectonic folding is discernible in the Ellenburger rocks west of the outlier. Further, along the west side of the outlier the Chappel dips southeast toward the Honey Creek fault. At the north end of the outlier the Chappel dips southwest. This evidence seems to indicate that the origin of the structure is not associated with tectonic folding or with fault drag. The origin of the structure is attributed to solution in the Ellenburger with resultant settling of the Chappel and Barnett into the underlying beds. The collapse structure was later cut by the Honey Creek fault. Erosion has removed all traces of Mississippian and later rocks from the upthrown side of the fault.

Chappel Limestone

The Chappel limestone was named by Sellards (1932, p. 91) for the type locality on Chappel Road 3 miles southeast of San Saba. According to Plummer (1950, p. 21) the thickness of the formation varies from 6 inches to more than 50 feet in the Llano region.

In the thesis area the Chappel has an estimated thickness of not more than 5 to 10 feet and consists of a tan to rose crinoidal limestone. The limestone is composed essentially of crinoid stems and stem fragments in a calcareous cement.

Both the Ellenburger - Chappel and the Chappel - Barnett contacts are unconformable.

Barnett Formation

The Barnett shale was named by Plummer and Moore (1922, p. 25) for Barnett Springs in San Saba County. Sellards (1932, p. 93) defined the Barnett to include all Mississippian rocks between the Chappel and Marble Falls formations. In the Llano region the thickness of the Barnett varies from 5 to 140 feet. According to Cloud and Barnes (1948, p. 160) the Barnett in the outlier described above has a thickness of about 140 feet.

The lower part of the formation consists of a gray crinoidal limestone. The crinoid stems are smaller than those in the Chappel. Higher in the section the crinoidal limestone is succeeded by buff to dark, petroliferous limestone and interbedded, calcareous, brownish shale. The shale weathers easily and in most places is seen only as loose fragments on weathered slopes.

PENNSYLVANIAN SYSTEM

The only strata of Pennsylvanian age in the Lower James River area form the top of the outlier described above. These rocks are referrable to the Marble Falls limestone.

Marble Falls Limestone

The Marble Falls limestone was named by Hill (1889, p. 289) for exposures at Marble Falls in Burnet County. According to Plummer (1950, p. 48) measured thicknesses of the Marble Falls in the Llano region range from 33 to 400 feet. The outcrop in the thesis area is poorly exposed and is limited in areal extent. The thickness is estimated at not more than 25 feet.

The exposure consists of dark gray, fine-grained limestone. The top of the outlier has a scattering of irregular chunks of dark gray chert which has weathered out of the formation.

According to Sellards (1932, p. 100) the Barnett - Marble Falls contact is disconformable.

CENOZOIC ERA

Quaternary

Recent

Rocks of Recent age in the thesis area are limited to unconsolidated alluvium, mantle, and a few masses of coarse conglomerate noted in the bed of Mill Creek.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The local structure of the Lower James River area is an integral part of the regional structure of the Llano region. A brief review of the structural history of the Llano region is presented as necessary background for the discussion of the structure in the thesis area.

REGIONAL STRUCTURE

The first known period of deformation in the Llano region occurred prior to the deposition of Upper Cambrian sediments. Precambrian sediments were metamorphosed and folded and igneous masses were intruded into them. Broad folds, trending northwest and pitching southeast, as well as smaller isoclinal and zig-zag folds in the Precambrian rocks were described by Stenzel (1932). These folds and the intensity of metamorphism indicate that the Precambrian strata were subjected to compressional forces of considerable magnitude.

According to Sellards (1934, p. 18-19) the Llano region underwent changes in level during Upper Cambrian and Lower Ordovician time which resulted in erosion, disconformities and overlaps. The absence of Silurian rocks and the remnants of Devonian strata indicate a flucuating sea level during those periods.

The thinning of the Barnett shale as it approaches the Llano uplift suggests uplift of the region in late Mississippian time. In some places the Marble Falls limestone rests on Ellenburger rocks. This unconformity denotes further uplift, probably during the post-

Mississippian - pre-Pennsylvanian time.

The second period of major deformation occurred during the Pennsylvanian period. This movement, which was responsible for the principal uplift in the Llano region, was dated by Sellards (1934, p. 97) as post-Bend and pre-Canyon in age.

The Pennsylvanian doming was accompanied or followed by extensive fracturing which developed a system of northeast-trending, normal faults. Cloud and Barnes (1948, p. 118-119) attributed the faults to tensional stresses and mentioned that the dips of the fault planes range from 60° to 90°.

Faults of this type control the structure in the Lower James River area.

STRUCTURE OF THE LOWER JAMES RIVER AREA

Major Faults

The geologic structure in the Lower James River area is dominated by six major faults. From northwest to southeast these faults have been named : (1) the Honey Creek fault, which is also called the Mason fault; (2) the Schmidt fault; (3) the Simons fault; (4) the Ziegler fault; (5) the Martin fault; and (6) the Schep Creek fault. The Ziegler, Martin, and Schep Creek faults were named by the present writer.

The faults trend northeast and are apparently normal with very high dips which approach the vertical.

For descriptive purposes the Simons fault may be considered the key fault of the area. Extensive faulting to the southeast has exposed the oldest rocks in the area. (In the absence of such faulting the strata would become progressively younger to the southeast as a result of the general southeast dip in the area). Various Upper Cambrian units have been brought into adjacent positions and the outcrop pattern is largely a function of the throws of the faults.

In contrast to the faulting in the southeast part of the area, the strata northwest of the Simons fault are relatively undisturbed and erosion has developed the outcrop pattern.

The Honey Creek fault cuts across the northwest corner of the area. Along the fault lower San Saba abuts the Mississippian - Pennsylvanian outlier previously described and upper Point Peak is in contact with Ellenburger limestone. Cloud and Barnes (1948, p. 154-187) on their "Geologic Map Of The Bear Springs Area, Mason County, Texas ", identified this limestone as the Gorman formation. This indicates an approximate throw of 1200 feet on the Honey Creek fault in the thesis area.

Striking southwest, the Schmidt fault enters the thesis area a few hundred feet east of the mouth of Mill Creek, crosses Mill Creek three times, and finally disappears in the San Saba near the west boundary of the area. Near the mouth of Mill Creek, upper Morgan Creek is faulted against upper Point Peak, giving the fault a maximum throw of about 150 feet. Parke (1953, p. 48) indicated a throw of 350 to 500 feet on this fault in the "Southwest Mason - Llano River

Area", which lies north of the Lower James River area. Alexander (1952, p. 48) named the Schmidt fault.

The Simons fault enters the thesis area about one mile east of the southwest corner. The fault strikes northeast through the center of the area, crossing the James River four times, and leaves the area about 0.6 of a mile west of the confluence of the James and Llano Rivers. Along the fault Morgan Creek is faulted against lower Ellenburger and upper San Saba. Near the Llano River lower Lion Mountain is in contact with lowermost Ellenburger and upper Cap Mountain is against upper San Saba. The throw of the fault varies from 200 to 630 feet. Parke (1953, p. 49) states that the fault has a throw of 800 feet in the "Southwest Mason - Llano River Area". Alexander (1952, p. 48) named the Simons fault. On the geologic map of Texas by Darton (1937) the Simons fault is traced northeastward from the Llano River a distance of approximately 45 miles. (The fault is not named on Darton's map).

The Ziegler fault is about 0.75 of a mile east of the Simons fault at the southern boundary of the thesis area and strikes northeast roughly parallel to the Simons fault. Near the center of the area the throw becomes very small and the fault splits into two minor faults. Along the fault Morgan Creek is faulted against San Saba with a maximum throw of approximately 175 feet.

The Martin fault lies about 0.6 of a mile east of the Ziegler fault at the southern boundary of the area and strikes northeast roughly parallel to the Ziegler fault. Along the fault Morgan Creek

Plate X

Simons fault cutting bluff along James River is faulted against lower San Saba with a maximum throw of approximately 150 feet.

The Schep Creek fault strikes northeast across the southeast corner of the area. Along the fault middle Morgan Creek is faulted against middle Cap Mountain and upper Morgan Creek is in contact with middle Hickory. The throw varies from 290 feet to 600 feet.

The southeast side of Ziegler fault is downthrown. The southeast sides of the remaining major faults are upthrown. Consequently, a horst is formed between the Ziegler and the Simons faults, and a graben is formed between the Ziegler and the Martin faults. These features exist only in the southern part of the area due to the bifurcation of the Ziegler fault near the center of the area.

Minor Faults

In addition to the six major faults, there are many steeply dipping minor faults. The overall pattern of the minor faulting is somewhat vague with strikes both northwest and northeast. There is also a tendency to curve along strike so that many of the faults are truncated at one or both ends by major faults and/or other minor faults.

The direction of displacement varies unpredictably. This inconsistency combined with the locally close spacing of the faults results in numerous small grabens and horsts.

The average throw is considerably less than 100 feet and many of the faults are contained within one stratigraphic member.

Detection Of Faulting

The major faults and some of the minor faults appear as dark lineations on the aerial photographs. Comparatively dense growths of vegetation along the fault zone produce such lineations. (These concentrations of vegetation are presumably due to a concentration of ground water in the fractured rocks of the fault zones. Two water wells drilled by Kurt Zesch in the north central part of the area yield a good supply of water from depths of less than 100 feet in the Simons fault zone). Faults so indicated on the photographs were easily traced on the ground.

Many of the minor faults southeast of the Simons fault displace the Welge ledge, which is quite prominent in that part of the area. Due to this displacement the faults are locally quite obvious, despite their small throws. However, many such faults are difficult to trace for any appreciable distance. Other indications of faulting that were used include the repetition or omission of strata, the abrupt termination of beds, erratic strikes and dips, and the obvious disruption of beds exposed in stream channels.

Age Of Faulting

The youngest formation exposed in the thesis area is the Pennsylvanian Marble Falls limestone. This formation is cut by the Honey Creek fault, which conclusively dates the Honey Creek fault as Pennsylvanian or later in age. Further, there is no indication, such as offsetting of faults by faults, that more than one period of faulting has occurred in the area. On direct evidence found in the thesis area the faulting, then, can only be dated as Pennsylvanian or later in age.

On the evidence of unfaulted beds of Canyon age (Upper Pennsylvanian) overlapping faulted Ellenburger beds in the western part of the Llano uplift, Cloud and Barnes (1948, p. 121) have dated the faulting on a regional basis as pre-Canyon in age.

Cause Of Faulting

Cloud and Barnes (1948, p. 118-119) presented the following hypothesis concerning the faulting. "The rocks of the Llano uplift are thought to have comprised a relatively resistant mass, around the eastern and southern sides of which developed the geosynclinal area (Llanoria geosyncline of Sellards, 1933) containing the Ouachita facies. The faulting in the Llano region probably accompanied the late Paleozoic folding that involved the sediments of the Llanoria geosyncline, movement in the geosynclinal area to the east and to the south placing the Llano area under torque and causing it to fracture. The theoretical tensional couples developed by active compression from the east and south would result in fractures aligned dominantly in the northeast quadrant, as faulting in the Llano region is. "

Cloud and Barnes did not amplify the above hypothesis. The implications of the term "tensional couples" are somewhat vague. However, the association of the faulting with the Ouachita orogeny, as suggested by those authors, seems plausible.

Possible explanations for the origin of the faulting include: (1) doming of the region; (2) tectonic folding of the Paleozoic strata followed by relaxation of the compressional forces; (3) uplift of the basement complex with northeast - trending zones of more positive uplift; and (4) down-warping of beds on the southeast flank of the region into the Llanoria geosyncline. As shown below, none of these hypotheses are fully compatible with the overall structure of the Llano region.

The theory of doming in the Llano region would account for the Pennsylvanian uplift of the region. This uplift is indicated by the absence of Permian, Triassic, and Jurassic beds over the region. Conversely, the regional northeast trend of the major faults in the region is rather strong evidence against doming as the principal cause of the faulting. Simple doming would be expected to develop a radial and/or peripheral fault pattern. Further, the Lower James River area is located on the southwest flank of the Llano uplift. Consequently, if the uplift were a dome the regional dip in the Lower James River area should be south or southwest. Actually, the dip is predominantly southeast.

Tectonic folding of the Paleozoic strata over the Llano region could have been accomplished by compressional forces associated with the Ouachita orogeny. Relaxation of the compressional forces after the folded strata had been lifted beyond the limit of self support would presumably have resulted in normal faulting. Several strong arguments against this theory include: (1) the apparent lack of intensive folding in the Llano region; (2) the fact that the major faults in the region cut the Precambrian strata as well as the younger rocks; and (3) the lack of thrust faulting or slippage along bedding planes in some of the weaker rock units, such as the Point Peak shale (It does not seem reasonable that compressional forces of the magnitude implied in this theory would have been so uniformly distributed and, at a certain critical point, so uniformly relaxed that only normal faulting resulted over an area as large as the Llano uplift).

Grote (1954, p. 34) described a broad, northeast-trending anticline in the Central Bluff Creek area, which is some eight miles northwest of the Lower James River area. He further described a zone of intensive faulting along the crest of the anticline. Grote suggested that this faulted anticline is the result of a zone of more positive uplift during the Pennsylvanian uplift of the Llano region.

This explanation does not seem applicable to the Lower James River area. The predominant southeast dip in the area indicates that if a similar zone of more positive uplift existed beneath the area, the area must lie wholly on one flank of the uplift. Thus the faulting in the thesis area would trend illogically along the flank rather than along the crest of the uplift.

A downwarping of strata into the Llanoria geosyncline along the southeast flank of the Llano uplift could have resulted in stretching of the strata and consequent normal faulting along a northeast trend. However, the geosyncline approximately paralleled the east and south sides of the uplift. It seems that there should be two fault systems, one trending east and one trending south, if downwarping of strata into the geosyncline caused the faulting.

It is concluded that the origin of the faulting in the Llano region is associated with the Ouachita orogeny, but no explanation of the mechanics of the faulting is offered. Subsurface and geophysical work of regional proportions, around the flanks of the Llano uplift, would probably clarify some of the enigmatic aspects of the structure of this region.

Folding

Small folds of extremely local nature were observed in beds above and below the bioherms at the top of the Point Peak. These folds are the result of compaction of sediments below the bioherms and differential compaction of material above the bioherms.

One isolated, anticlinal fold of limited areal extent occurs just south of the third intersection, from south to north, of the Simons fault and the James River. This fold strikes about N 65 W and disappears both to the northwest and southeast in fault zones. The northeast flank of the fold dips about 3 degrees and the southwest flank dips about 2 degrees. The fold can be traced only a few hundred feet. This fold affects the Cap Mountain limestone and the Lion Mountain sandstone.

The limited extent and isolated nature (which combine to preclude an analysis of a trend or pattern) make it difficult to determine the origin of the fold. The truncation by the faults denotes that the fold predates the faulting. Further, the strike of the fold seems incompatible with an origin related to the faulting. Differential compaction over a Precambrian granite knob is a possible explanation. Unfortunately, the fold occurs in a topographic low. This makes it impossible to check underlying strata for the divergence of dip that could be expected with such compaction.

GEOLOGIC HISTORY

GENERAL STATEMENT

The geologic history of the Llano region has been thoroughly reviewed by Paige (1911), Sellards (1932), Cloud and Barnes (1948), and various other workers. The following summary is based on these previous works.

SUMMARY

Precambrian marine sedimentation formed a thick sequence of sandstones, limestones, and shales in the Llano region. According to Stenzel (1934, p. 74-75) this sequence was folded, metamorphosed, and subjected to intrusion, all of which resulted in a framework of broad, northwest - trending folds. Subsequently, this framework was further subjected to two separate periods of intrusion: (1) batholitic intrusions, and (2) late dike intrusions. Granites associated with the batholitic intrusions have a coarse texture indicative of solidification at depth. From this evidence it is concluded that the Precambrian strata were originally much thicker than at the present time. None of the intrusive bodies penetrate Cambrian strata, which conclusively dates the intrusions as Precambrian. Precambrian rocks are not exposed in the thesis area.

Following a long period of subaerial erosion, during which the major folds were truncated and eolian sands accumulated, the Upper Cambrian sea transgressed the uneven Precambrian surface. Bridge, Barnes, and Cloud (1947, p. 113) stated that the relief on that surface may have been as much as 800 feet. The eolian sands were reworked and incorporated in the Hickory sandstone. Ripple marks and cross-bedding in the Hickory in the thesis area denote a shallow water environment of depostion.

During Lower Cap Mountain time the quartz clastic material became subordinate and the bulk of the sediments were carbonates. Varying amounts of galuconite and trilobite "hash" lenses in the limestone indicate a continuation of shallow water conditions. This continuation of a shallow water environment without the continued predominance of clastic sediments over the carbonates, which is normally expected in such an environment, may be attributed to depletion of the source of the quartz sands.

The general increase of sand in the Lion Mountain member was referred by Cloud and Barnes (1948, p. 112) to changes in sea level in late Riley and early Wilberns time. This increase reached a climax in the Welge sandstone.

The upward decrease of sand in the fossiliferous Morgan Creek limestone and the abundant glauconite in that member indicate a repetition of the shallow water environment in which the Cap Mountain was formed.

A widespread influx of argillaceous material followed. The quantity of this material exceeded the amount of carbonates being deposited and resulted in the Point Peak shale. Cloud and Barnes (1948, p. 112) pointed out that the shale grades into carbonate rocks to the east, which indicates a source to the west for the Point Peak sediments.

Paige (1912, p. 79) cited the intraformational conglomerates, the thin shale and limestone beds, and certain sun-cracked surfaces (which were not observed in the thesis area) of the upper Point Peak as evidence of very shallow water or perhaps periodically exposed surfaces such as tidal flats. The bioherms at the top of the member suggest perhaps slightly deeper water.

The bedded, fossiliferous limestones of the San Saba member indicate moderately shallow seas. Cloud and Barnes (1948, p. 112) proposed a continuously or intermittently exposed land mass to the west to explain the locally thick sands in the San Saba. In the Lower James River area such sands are restricted to relatively thin layers interbedded with the limestones. This seems to indicate an intermittently available supply of the clastics or a shifting current pattern.

Deposition was continuous across the Cambrian - Ordovician boundary in the thesis area. Throughout Ellenburger time generally shallow, warm seas existed. Cloud and Barnes (1948, p. 102) advanced the idea that the time of origin of the Ellenburger dolomite is penecontemporaneous with the deposition of the limestones or late in the diagenesis of the limestones. The same authors described the sedimentary environment as similar to that on the Bahama Banks today. The bottom was covered with lime-mud and the faunal distribution may have been related to the degree of firmness of the bottom. The patchy occurrence of fossils in the Ellenburger is cited in support of this supposition.

The absence of Middle and Upper Ordovician and Silurian rocks in the thesis area indicates lack of deposition during those intervals of time, or complete removal of the rocks in the subsequent pre-Devonian erosion. Cloud and Barnes (1948, p. 7) stated that at least 680 feet of Ellenburger strata were eroded away prior to invasion by the Devonian sea. This truncation is greater in the western part of the Llano region indicating a marked eastward tilting of the region. The Ellenburger outcrops in the Lower James River area are stratigraphically the highest strata which crop out in normal stratigraphic position in the area and are comparatively limited in areal extent. Consequently, the increasing east to west truncation is not obvious in the area.

Following or perhaps accompanying the tilting, the Devonian seas transgressed the Llano region from east to west as shown by younger Devonian rocks in the west and older Devonian rocks in the east. No rocks of Devonian age were recognized in the thesis area.

Slight uplift of the Llano region during the Mississippian period is manifested in the thinning of the Barnett shale as it approaches the Llano region. A greater pre-Pennsylvanian uplift resulted in the complete removal of the Barnett locally.

During the Pennsylvanian period the Llano region was subjected to a major uplift followed by apparently continuous sub-aerial erosion during the Permian, Triassic, and Jurassic periods. That long period of erosion completely removed all strata younger than Ellenburger in the thesis area, with one exception. The previously described outlier in the northwest corner of the area, which contains Chappel, Barnett, and Marble Falls rocks, escaped complete removal by collapse into the Ellenburger and further down-dropping by the Honey Creek fault.

Cretaceous seas transgressed the Llano region and deposition occurred on beds ranging in age from Precambrian to Pennsylvanian. Subsequent erosion has removed the Cretaceous strata from much of the Llano region and from all of the Lower James River area.

BIBLIOGRAPHY

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

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

Barnes, V. E. (1944) Gypsum in the Edwards limestone of Central Texas, Univ. Texas Pub. 4301, pp. 35-46

Barnes, V. E. and Bell, W. C. (1954) Cambrian rocks of Central Texas, San Angelo Geol. Soc. Cambrian field trip, March 19 - 20, 1954, pp. 35 - 69

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

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, pp. 233-237

Bridge, Josiah, Barnes, V. E., and Cloud, P. E. (1947) Stratigraphy of the Upper Cambrian, Llano uplift, Texas, Geol. Soc. Amer. Bull., vol. 58, pp. 109 - 124

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

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

Cheney, M. G. and Goss, L. F. (1952) Tectonics of Central Texas, Amer. Assoc. Petrol. Geol. Bull., vol. 36, pp. 2237-2265

Cloud, P. E., 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

Cloud, P. E. 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. Survey, 1st Ann. Rept., pp. 235 - 301

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

Fritz, Joseph Francis (1954) Geology of an Area Between Bluff and Honey Creeks, Mason County, Texas, M. S. Thesis, Texas A. & M. College

Grote, Fred Rankin (1954) Structural Geology of the Central Bluff Creek Area, Mason County, Texas, M. S. Thesis, Texas A. & M. College

Hendricks, Leo (1952) Correlation Between Surface and Subsurface Sections of the Ellenburger Group of Texas, Univ. Texas Bur. Econ. Geol., Report of Investigations - No. 11

Hill, R. T. (1887) The present condition of knowledge of the geology of Texas, U. S. Geol. Survey Bull. 45

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

McGrath, Bernard Dennis (1952) Geology of the Fredonia Area, McCulloch, Mason, and San Saba Counties, Texas, M. S. Thesis, Texas A. & M. College

Paige, Sydney (1911) Mineral Resources of the Llano-Burnet region, Texas, with an account of the Pre-Cambrian geology, U. S. Geol. Survey Bull. 450, 103 pp.

Paige, Sydney (1912) Description of the Llano-Burnet quadrangles, U. S. Geol. Survey, Geol. Atlas, Folio 183

Parke, Robert Preston (1953) Geology of the Southwest Mason-Llano River Area, Texas, M. S. Thesis, Texas A, & M. College

Plummer, F. B. (1940) Paleozoic of the Llano region, Excursions 53rd annual meeting of the Geol. Soc. Amer. and affililated societies, December 26-28, 1940, pp. 56 - 65

Plummer, F. B. (1943) A new quartz sand horizon in the Cambrian of Mason County, Texas, Univ. Texas Bur. Econ. Geol., Min. res., Circ. 22

Plummer, F. B. (1950) The Carboniferous rocks of the Llano region of central Texas, Univ. Texas Bull. 4329

Polk, Ted Pritchard (1952) Geology of the West Mason Area, Texas, M. S. Thesis, Texas A. & M. College

Roemer, Ferdinand (1846) A sketch of the geology of Texas, Amer. Jour. Sci., ser. 2, vol. 2, pp. 358 - 365

Roemer, Ferdinand (1848) Contributions to the geology of Texas, Amer. Jour. Sci., ser. 2, vol. 2, pp. 21 - 28

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

Sellards, E. H. (1934) Major structural features of Texas east of Pecos River, Univ. Texas Bull. 3401, pp. 11 - 136

Sellards, E. H. and Hendricks, Leo (1946) Structural Map of Texas, Revised, Third Edition, Univ. of Texas, Bur. of Econ. Geol.

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

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

Stenzel, H. B. (1935) Pre-Cambrian unconformities in the Llano region, Texas, Univ. Texas Bull. 3501

Tarr, R. S. (1890) Superimposition of the drainage in central Texas, Amer. Jour. Sci., ser. 3, vol. 40, p. 359 - 362

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

Van der Gracht, W. A. J. M. van Waterschoot (1931) The Permo-Carboniferous orogeny in South-Central United States, Bull Amer. Assoc. Petrol. Geol., vol. 15, pp. 991 - 1057

APPENDIX

SECTION 1 - 1

Section of the Cap Mountain member of the Riley formation beginning at base of bluff on east side of the James River, at the junction of the James and Llano Rivers, and measured to the top of the hill along bearing S 25° E.

	Thickness in feet
Riley formation:	
Cap Mountain limestone member:	
13. Covered to top of hill	5.8
12. Limestone, same as unit 11 except no limonite blotches, and ledges are slightly more prominent, 2-inch to 1-foot beds	10.1
11. Limestone, finely crystalline; medium gray; disseminated grains of glauconite which concentrate in stringers and blebs in many beds; limonite blotches; 2-inch to 1-foot beds	11.0
10. Limestone, mostly covered; exposed ledges harder perhaps due to less limonite; finely crystalline; silty or sandy; buff to dark grey weathering to dull brown; abundant limonite; interbedded with beds similar to those of unit 8	41.7

		Thickness in feet
9.	Limestone, finely crystalline; medium gray with scattered brown spots; silty; 1-inch to 4-inch beds alternating with beds similar to those in unit 8; the unit 8-type beds predominate perhaps 2 to 1	24.3
8.	Limestone, flat, partially covered ledges on slope of hill with blocky chunks loose on surface; finely crystalline; gray to buff with yellow to brown splotches; weathers to dull grayish-brown; slightly sandy; limonite blebs; few trilobite shell fragments; pitted surfaces; questionable fucoidal markings on some weathered surfaces; 2-inch to 1-foot beds	28.5
7.	Limestone, finely crystalline; blotchy white to brown; weathers dull brown; slightly sandy; yellow-brown blebs of limonite; 1-inch to 4-inch beds	2.0
6.	Limestone, very sandy with fine to medium quartz grains making up about 50% of the rock; maroon weathering to dull maroon or brown; some of the sand grains coated with hematite; 1-inch to 6-inch beds alternating with less sandy, brown limestone beds containing limonite blebs and white calcite stringers; the sand grains in these latter beds are fine and better sorted;	

	Thickness in feet
unit contains a few 2-inch to 6-inch beds of sandstone similar to those in unit 5	31.0
5. Limestone, finely crystalline; light gray to buff weathering light brown; scattered grains of dark green glauconite, some altered to brown specks; slightly sandy; sand grains very fine; 2-inch to 1-foot beds; thin caliche coating on weathered surfaces	5.0
4. Limestone, maroon weathering to dull maroon; very sandy, quartz grains well rounded, some coated with hematite; 1-inch to 6-inch beds	7.0
3. Sandstone, partly covered; well sorted, fine grained; buff; calcareous, contains visible calcite fragments; stringers of yellow-brown limonite parallel to bedding give banded appearance; 1-inch to 3-inch beds; alternating with maroon beds as in 2 except only 30% of grains coated with hematite; maroon beds 1 inch to 6 inches	4.8
2. Sandstone, fine to medium grains coated with shiny black to dark red hematite; contains blebs of limonite; maroon weathering to dull maroon; slightly calcareous; 1-inch to 2-foot beds;	

	Thickness in feet
alternating with 3-inch to 2-foot beds of buff sandstone, very fine sub-rounded quartz grains; slightly calcareous; contains brown limonite blebs. Oscillation type ripple marks on light colored beds; cross bedding in some maroon beds; light beds seem tougher than maroon beds.	24.9
1. Limestone, coarsely crystalline; light to dark brown and maroon with yellow limonite stains when fresh; weathers to dull maroon; sandy; fine to medium, well rounded quartz grains; interbedded with red and brown, thinly laminated, slightly calcareous, fine to coarse sandstone; quartz grains medium rounded, well sorted	15.5
Total thickness measured	212.4

The lowermost beds are in the river bed. The Hickory - Cap Mountain contact is not visible, but these lowermost beds are probably very near the boundary.

SECTION 2 - 2

Section of the Riley and Wilberns formations beginning at the base of the bluff on the east side of the James River, at the junction of the James and Llano Rivers, and measuring upstream along the James River bed approximately 1.5 miles, then measuring to the top of a hill on the south side of the river along the approximate bearing S70° E. The lower 90 feet, stratigraphically, of this section is not exposed. This covered interval, from the base of the bluff described above to the base of the first exposure in the west bank of the James River, 1600 feet upstream, was determined by alternately running hand level lines parallel to the average strike of the beds and Jacob staff traverses parallel to the average dip. Dr. M. C. Schroeder, Texas A. & M. College, assisted in the measurement of this section.

	Thickness in feet
Wilberns formation:	
Morgan Creek limestone member:	
37. Limestone, finely crystalline; gray with pink and green casts, weathers gray with reddish cast; sandy; contains disseminated green glauconite in amounts varying from slight to rather abundant; some beds contain fine "hash" lenses; beds 2 inches to 2 feet thick; this unit extends to top of hill	26.0

	Thickness in feet
36. Limestone, essentially a fine "hash"; purplish-red speckled weathering to blotchy red-brown with purplish tinge; some beds are much redder and crumbly; sandy; scattered green glauconite grains; shell fragments prominent on weathered surface; 4-inch to 1-foot beds	15.0
35. Limestone, very sandy; purplish-red weathering to dull rusty-red; contains blebs of limonite, some of which show concentric structure when broken; cross-bedded	5.0
Welge sandstone member:	
34. Sandstone, fine, sub-rounded quartz grains; buff to light brown with darker streaks; weathers yellowish-brown with darker brown blotches; some beds contain more limonite - become yellow; joint fillings of reddish-black hematite protrude in irregular pattern on weathered surface; friable; some surfaces glitter with quartz grains; uppermost beds slightly calcareous; 6-inch to 4-foot beds weather to rounded ledges	22.5

	Thickness in feet
Riley formation:	
Lion Mountain sandstone member:	
33. Covered	4.0
32. Sandstone, quartz and glauconite grains in equal amounts; very friable; calcareous; green speckled weathering to dull green	1.5
31. Covered slope - probably green, glauconitic, calcareous sandstone and brown limestone judging from float and soil	19.4
30. Limestone, sandy; irregular green and brown blotches; weathers to dull light brown; glauconitic	3.0
29. Covered, apparently sandstone	10.6
28. Limestone, fine to coarse "hash"; white; some glauconite; these "hash" beds crop out as 1-foot to 2-foot ledges with covered slope between	6.0
27. Sandstone, very calcareous; light, green-speckled gray; evenly disseminated glauconite; some shell fragments	7.0
26. Sandstone, fine to medium, well-rounded, quartz grains; calcareous; very glauconitic; considerable limonite; thin calcite veinlets;	

	Thickness in feet
weathered surfaces glitter due to quartz grains and calcite cleavage fragments; yellow-brown weathering to dull light brown; 2-inch to 6-inch beds; slope partly covered, littered with black hematite nodules	9.0
Cap Mountain limestone member:	
25. Limestone, finely crystalline; sandy; very fine glauconite evenly distributed; gray with greenish cast	2.0
24. Limestone, coarsely crystalline; sandy; greenish-brown speckled; glauconite mostly altered; coarse "hash" lenses up to 4 inches thick at angle to bedding	9.0
23. Limestone, finely crystalline; medium gray with faint brownish streaks; widely scattered green, glauconite grains; dark brown spots and streaks contain some unaltered glauconite; some beds have glauconite concentrated in irregular bands; 1-inch to 1-foot beds	10.8
22. Limestone, crystalline; glauconitic; green speckled to brownish; contains streaks of white to buff limestone free from glauconite	

	Thickness in feet
and limonite; scattered shell fragments; 2-inch to 6-inch beds	7.7
21. Limestone, coarse "hash"; white to buff with green and brown blotches; some beds of finer "hash" have more evenly distributed altered glauconite giving brown speckled look; thin bed of gray-green limestone at top of unit	5.5
20. Limestone, coarsely crystalline; contains broken shell fragments; thin "hash" lenses; white with brown spots containing unaltered green glauconite grains; 2-inch to 6-inch beds; interbedded with finely-crystalline, blotchy, greenish-brown limestone which weathers to a smooth, greenish-gray surface which resembles a weathered shale surface; scattered glauconite, some concentrated in streaks	4.8
19. "Hash", coarsely crystalline; recrystallized shell fragments; fossils not identifiable; glauconitic; limonite in spots and streaks; weathered surfaces spotted with replaced shell fragments; interbedded with finely-crystalline, dark greenish-brown, glauconitic, sandy limestone	1.7

		Thickness in feet
18.	Limestone, finely crystalline; green speckled with irregular brown speckled streaks; scattered yellow-brown limonite blotches; 2-inch to 1-foot beds	2.0
17.	Limestone, finely crystalline; dark greenish-gray weathering to light greenish-gray surfaces resembling weathered shale surfaces; fine, abundant glauconite very evenly distributed; slightly silty	7.0
16.	Limestone, finely crystalline; glauconitic; green and brown speckled with spots of purplish tinge; weathers to greenish or brownish gray; contains thick lenses of coarse, white "hash"; "hash" contains identifiable trilobite shell fragments; some beds composed entirely of this "hash"; some of the limestone beds contain scattered shell fragments; 2-inch to 1-foot beds	8.5
15.	Limestone, crystalline; slope partly covered; alternating light and medium gray plus lineation of limonite in some beds results in banded appearance; scattered blebs of limonite up to 0.5 inch in diameter; silty;	

	Thickness in feet
scattered single grains of glauconite; in some beds the lighter bands are composed partly of coarse grains which may represent recrystallized "hash"; contains coarsely crystalline "hash" lenses with larger, more abundant glauconite grains; "hash" lenses not more than 0.5 foot thick; 1-inch to 1-foot beds	15.0
14. Limestone, same as in unit 12, but some beds contain lenses of coarser, buff limestone	8.0
13. Limestone, finely crystalline; light to medium gray; silty; disseminated grains of glauconite; small blotches of limonite; some limonite crumbles out giving interior of rock slightly porous appearance; 2-inch to 4-inch beds	3.0
12. Limestone, micro-crystalline; silty; light gray weathering to blotchy grayish-brown; disseminated fine grains of glauconite; scattered red-brown specks probably altered glauconite; irregular blotches and smaller blebs of limonite; 2-inch to 1-foot beds	4.0
11. Limestone, finely crystalline; sandy; brownish-gray; disseminated glauconite grains, some altered giving red-speckled	

	Thickness in feet
appearance; bands up to 0.25 inch thick of coarser white to buff limestone which appears to be fine "hash"; top 0.5 foot of unit is "hash" of recognizable trilobite shell fragments - friable, crumbles under hammer; 2-inch to 6-inch beds	7.1

Foot of hill; crossing to west bank of James River; continuing downstream along west bank.

	Thickness in feet
10. Limestone, finely crystalline; silty; dove gray; fine disseminated grains of glauconite - some altered giving red-speckled appearance; in some beds the glauconite is slightly concentrated parallel to bedding giving finely banded appearance; 4-inch to 2-foot beds ..	8.5
9. Limestone, finely crystalline; medium to dark gray; disseminated glauconite grains; some beds have glauconite concentrated in blebs; contains lenses of coarser pinkish-buff limestone; weathers to greyish-brown with slight greenish cast; 1-inch to 2-foot beds interbedded with beds similar to those in unit 8	7.1
8. Limestone, finely crystalline; silty; blotches and streaks of limonite; light to medium gray weathering to brownish gray	10.9

	Thickness in feet
7. Limestone, micro-crystalline; very silty - probably 50% silt; snuff colored weathering to buff, rounded ledges; 1-inch to 6-inch beds; interbedded with 1-inch to 3-inch beds of darker, reddish-brown, silty, finely crystalline limestone which weathers to dark brown; contains few beds similar to those in unit 2	16.0
6. Limestone, finely crystalline; silty; light gray to buff weathering to brownish-gray; contains brown blotches and streaks of limonite; 6-inch to 4-foot beds; contains a few beds similar to those in unit 5	16.0
5. Limestone, finely crystalline; very silty or sandy; light reddish-brown weathering to buff or brownish-gray; some limonite in streaks giving banded appearance	4.5
4. Limestone, finely crystalline; silty; light gray to buff weathering to brownish-gray; contains brown blotches and streaks of limonite; interbedded with beds of darker gray, finely crystalline limestone with very little limonite and containing lenses of	

Thickness in feet

coarser limestone. Oscillation ripple marks occur 7.0 feet above the base of this unit - strike N70W, wave length 2.2 feet, amplitude 0.08 foot; 4-inch to 2-foot beds 30.5

3. Limestone, finely crystalline; silty; blotches and streaks of yellow-brown limonite; some beds contain disseminated grains of altered glauconite giving red speckled appearance; gray to buff weathering to grayish-brown; internal stylolites 0.4 inch high; 2-inch to 2-foot beds 8.0

2. Limestone, finely crystalline; light gray to buff weathering to brownish-gray; brown streaks and blotches of limonite; contains trilobite shell fragments; 6-inch to 4-foot beds weathering to rounded ledges 12.0

1. Limestone, finely crystalline; sandy; brown weathering reddish-brown; varying amounts of yellow-brown limonite blebs; contains 6-inch to 1-foot cross-bedded zones; interbedded with beds of sandy, buff limestone weathering brownish-gray with streaks and spots of limonite; grades upward into finely crystalline,

	Thickness in feet
gray to buff limestone with brown blotches of limonite containing green glauconite grains; 1-foot to 4-foot beds	25.0
From base of this unit to base of exposures at mouth of James River, the stratigraphic interval is covered	90.9
Total thickness measured	443.6

SECTION 3 - 3

Section of the Point Peak member of the Wilberns formation beginning at base of bluff on east side of Mill Creek, about 1000 feet upstream from the junction of Mill Creek with the Llano River, and measured up hill along bearing S 2° E.

	Thickness in feet
Wilberns formation:	
Point Peak member:	
22. Limestone, medium crystalline; grayish-green with reddish cast in spots; contains a few flattened, rounded pebbles up to 3 inches in length at angle to bedding; larger pebbles are finer limestone of same color as matrix; small pebbles of glauconite; disseminated glauconite grains; small white calcite inclusions; scattered limonite blotches; top of this unit at base of big bioherms near top of hill - beds distorted by bioherms; 4-inch to 1-foot beds	11.5
21. Covered slope littered with shale fragments and pieces of siltstone	4.6
20. Limestone, finely crystalline; grayish-green; contains abundant fragments of small brachiopod shells and some unbroken shells which protrude	

		Thickness in feet
	on weathered surfaces; disseminated glauconite grains; blotches of yellow-brown limonite	1.4
19.	Conglomerate, crystalline greenish-gray limestone matrix; greenish-brown pebbles contain both altered and unaltered glauconite; pebbles at angle to bedding; yellow-brown streaks and blotches of limonite in matrix; considerable disseminated glauconite; pebbles are 0.4 inch to 3 inches long; 2-inch to 1-foot beds	6.0
18.	Shale and siltstone, same as in unit 9	9.0
17.	Limestone, finely crystalline; greenish-gray; contains flattened pebbles up to 3 inches long parallel to bedding; pebbles are composed of darker limestone; streaks of limonite in matrix; interbedded with shale; 2-inch to 4-inch beds	4.8
16.	Shale and siltstone, same as in unit 9	2.7
15.	Limestone, finely crystalline; light tan weathering to light brown-mottled gray; contains flattened pebbles up to 2 inches in diameter; pebbles contain altered, and a little unaltered, glauconite; considerable	

		Thickness in feet
	disseminated altered glauconite in matrix; blotches of limonite	1.5
14.	Limestone, medium crystalline; tan to light gray weathering to light brown with dark brown spots; blotches of yellowish-brown limonite; abundant disseminated altered glauconite giving reddish-brown speckled appearance; contains 0.25 x 1-inch lenses of greenish, finely crystalline limestone; lenses contain specks of green glauconite; 6-inch to 1.5-foot beds	3.8
13.	Shale and siltstone, same as in unit 9, except top 5 feet of unit 13 contain more glauconitic siltstone	17.3
12.	Conglomerate, same as in unit 10	0.5
11.	Shale and siltstone, same as in unit 9	7.4
10.	Conglomerate, finely crystalline greenish-gray limestone matrix; flattened pebbles up to 2 inches long of very glauconitic siltstone; pebbles at angle to bedding	0.5
9.	Shale, silty; calcareous; brownish, greenish-gray and lavender; thin laminae; interbedded with glauconitic, calcareous, greenish-gray	

		Thickness in feet
	siltstone and non-glauconitic calcareous, dull brownish-gray siltstone; shale weathers to rubble-littered slope with siltstones protruding in 1-inch to 4-inch beds; siltstones weather to small blocks	14.8
8.	Siltsone, calcareous; pale greenish-gray to lavender weathering to dull green; contains scattered calcite cleavage fragments; 0.25 inch to 2 inch laminae; contains finely crystalline, grayish-green, slightly glauconitic, limonitic, limestone; limestone occurs as 4-inch to 2-foot beds at 4-foot to 6-foot intervals	25.0
7.	Bioherms, about 1 foot in diameter; sub-lithographic limestone; greenish-gray with slight purplish cast; bioherms occur as lenses 4 feet to 6 feet long; siltstone beds above and below curve around the bioherms	2.0
6.	Siltstone, same as in unit 2	6.2
5.	Limestone, same as in unit 3	1.0
4.	Bioherms, sub-lithographic limestone, greenish-gray with slight purplish cast in spots; bioherms few inches to 1 foot in	

	Thickness in feet
diameter; occur as lens	1.4
3. Limestone, medium crystalline; brownish-gray weathering to dull light brown; disseminated glauconite gives green speckled appearance; scattered limonite blebs	1.0
2. Siltstone, calcareous; greenish-gray weathering to dull green; fine disseminated glauconite; scattered calcite cleavage fragments; 0.25-inch to 1-inch laminae; weathers back to irregular face with ledges above and below protruding	2.0
Morgan Creek member:	
1. Limestone, medium crystalline; light brownish-gray weathering to buff with greenish cast; scattered grains of green glauconite; contains rounded grains or brownish calcite; base of this unit forms bottom of Mill Creek	3.0
Total thickness measured	127.4

SECTION 4 - 4

Section of the San Saba member of the Wilberns formation beginning at the mouth of an intermittent stream, which enters Mill Creek from the south, and measuring upstream along the bed of this stream to the top of the hill. The mouth of this intermittent stream is in the most westerly sharp corner of the Donp - Zesch property fence approximately 3400 feet upstream along Mill Creek from the Donp deer cabin and 1800 feet downstream along Mill Creek from the west boundary of the thesis area.

	Thickness in feet
Ellenburger Group:	
27. Limestone, poorly exposed to top of hill; estimated thickness about 100 feet.	
Wilberns formation:	
San Saba member:	
26. Limestone, sub-lithographic; light gray to buff weathering to medium gray; contains small pockets and stringers of calcite; some beds contain stringers of limonite; fossiliferous	19.2
25. Limestone, fragmental; coarsely crystalline white calcite matrix; light gray to buff, sub-lithographic limestone fragments; fragments average about 0.25 inch with scattered larger fragments up to 0.5 inch;	

		Thickness in feet
	weathers to dirty gray ledges 2 inches to 4 inches thick	5.0
24.	Limestone, finely crystalline; dark greenish gray; contains a few small scattered limestone pebbles of same lithology; abundant green glauconite giving green-speckled appearance	0.8
23.	Limestone, sub-lithographic; light gray to buff weathering to medium gray; contains small pockets and stringers of calcite; some beds contain stringers of limonite; 2-inch to 1-foot beds	14.0
22.	Limestone, sub-lithographic; light gray weathering to yellow-brown with gray blotches; irregular inclusions of yellow-brown limonite; contains scattered red grains of altered glauconite; 2-inch to 1-foot beds	8.7
21.	Covered	19.7
20.	Limestone, coarsely crystalline; light gray; contains coarsely crystalline inclusions which may be replaced shell fragments; contains approximately 25% green, granular	

		Thickness in feet
	glauconite which results in green-speckled appearance; at base of unit is 1.5-inch layer of alternating 0.25-inch bands of green glauconite and medium crystalline gray limestone; 2-inch to 4-inch beds	4.8
19.	Limestone, finely crystalline; dark greenish gray; glauconite composes almost 50% of rock; limonite stains; grades into reddish-brown, medium crystalline limestone containing much less glauconite and white inclusions of coarsely crystalline calcite	1.8
18.	Covered	5.0
17.	Limestone, finely crystalline; buff to medium gray; contains irregular bands of yellow-brown limonite giving layered appearance; contains scattered flat pebbles of calcite up to 1 inch in diameter; weathers to fluted surface with yellow limonite crusts between the 0.25-inch grooves; 4-inch to 1-foot beds	2.2
16.	Limestone, finely crystalline; dove gray weathering to light gray with brown blotches; yellow-brown stringers of limonite; contains	

		Thickness in feet
	scattered pebbles of yellowish-brown, finely crystalline limestone up to 0.4 inch in diameter; 2-inch to 6-inch beds	7.3
15.	Covered	2.8
14.	Conglomerate, coarsely-crystalline limestone matrix; flattened finely crystalline, brownish-gray, limestone pebbles at various angles to bedding; pebbles up to 2 inches long; some pebbles contain concentrations of granular, green glauconite; matrix contains scattered grains of green glauconite; blebs and streaks of limonite; 4-inch to 1-foot beds	5.0
13.	Conglomerate, coarsely-crystalline limestone matrix; finely crystalline yellowish-brown limestone pebbles at various angles to bedding; pebbles up to 0.5 inch in diameter; matrix contains blotches and streaks of limonite; contains beds of more coarsely crystalline white to buff limestone which contain disseminated glauconite and a few brownish pebbles similar to those in conglomerate; 2-inch to 2-foot beds	20.0
12.	Covered	5.0
11.	Limestone, coarsely-crystalline; white to gray;	

	Thickness in feet
contains considerable limonite as specks and blebs giving yellow spotted appearance; disseminated green glauconite grains up to 1 mm in diameter; weathers to medium grayish-brown; 4-inch to 1-foot beds	6.5
10. Covered slope, littered with slabs and flat fragments of medium gray limestone 2 inches to 4 inches thick	21.0
9. Limestone, coarsely crystalline; medium gray to medium brown weathering to gray with brown blotches; approximately 20% of rock composed of fine to coarse "hash"; coarse "hash" contains identifiable trilobite fragments; fine "hash" contains rounded, oolitic-like grains of green glauconite, partly altered to brown; 3-inch to 2-foot beds; ledges weathered slightly more rounded than ledges lower in section	37.9
8. Sandstone, very fine grained; calcareous; buff weathering to yellowish-brown; limonite concentrated parallel to bedding gives yellow-brown banded appearance; contains a few beds of same lithology which are buff with reddish-brown banding; grades upward into a very friable,	

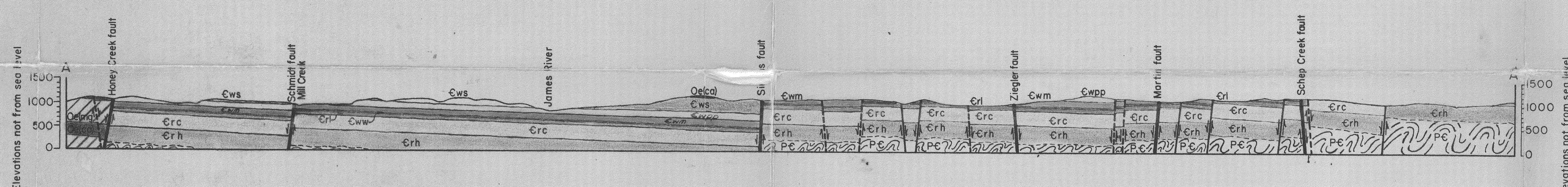
	Thickness in feet
white sandstone which weathers to light gray; 4-inch to 3-foot beds	25.4
7. Limestone, finely-crystalline; slightly sandy; light to medium gray weathering to gray with brown blotches; scattered fine grains of glauconite; scattered unidentifiable shell fragments; contains yellow-brown stringers of limonite; 1-inch to 4-inch beds	4.4
6. Limestone, coarsely-crystalline; sandy; white, mottled with yellow-brown stringers of limonite; weathers to porous, crumbly reddish brown	2.0
5. Limestone, very sandy; clear to white, well-sorted, sub-rounded, fine quartz grains; fine disseminated glauconite; gray to buff with brown blotches	1.7
4. Limestone, coarsely-crystalline; white to light gray weathering to brownish-grey; red specks and stringers of iron oxide; contains numerous trilobite fragments and unidentifiable fragments; 1-inch to 1-foot beds	5.5
3. Covered	35.3
2. Limestone, finely-crystalline; contains lenses	

	Thickness in feet
of coarsely crystalline, white limestone; contains 4-inch to 6-inch thick lenses of trilobite "hash"; scattered specks and streaks of limonite; some beds highly weathered, crumbly; 2-inch to 1-foot beds	7.5
1. Limestone, finely crystalline; silty; medium grey weathering to light gray with brown blotches; streaks of limonite; 1-inch to 6-inch beds	21.5
Total thickness measured	290.0

Lower contact not visible but lowermost beds arched indicating proximity to top of bioherm zone. The thickness of the lower unit in this section is subject to error due to the erratic strikes and dips resulting from this warping of beds.

mp-P
8830

Plate I



GEOLOGIC MAP AND SECTION OF THE LOWER JAMES RIVER AREA, MASON COUNTY, TEXAS

Scale 1/20000

0.5 0 1 Mile

1700 850 0 8500 Feet

EXPLANATION

QUATERNARY		Qr	Recent alluvium
PENNSYLVANIAN (Lower Pennsylvanian)	Bend Series, Marble Falls Group	Pmf	Limestone member
MISSISSIPPIAN (Lower Mississippian)		Mb	Barnett shale
		Mc	Chappel limestone
			UNCONFORMITY
ORDOVICIAN (Lower Ordovician)	Ellenburger Group	Oe(mg)	Ellenburger dolomite
		Oe(ca)	Ellenburger limestone
CAMBRIAN (Upper Cambrian)	Wilberns Formation	€ws	San Saba limestone member
		€wppb	Bioherms
		€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
			UNCONFORMITY
PRECAMBRIAN		P€	Undifferentiated

Major fault (U/D)

Inferred major fault (U/D)

Minor fault (U/D)

Inferred minor fault (U/D)

Observed contact

Inferred contact

Strike and dip of beds

Stream

Intermittent stream

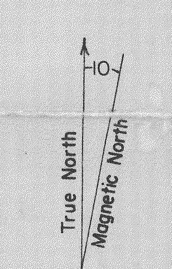
County road

Ranch road

Property line

Location of measured section

House



Approximate mean declination

Base from U S Department of Agriculture, Soil Conservation Service, aerial photographs, 1948

Geology by Kenneth Sliger, 1956

Sliger 1957 S633