# GEOLOGY OF THE BIG BEND OF THE LLANO RIVER AREA
# MASON COUNTY, TEXAS

A Thesis

By

Guilford James Wilson, Jr.

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Chairman of Committee

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T A B L E  O F  C O N T E N T S

# LIST OF ILLUSTRATIONS

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The property owners within the thesis area were most generous in allowing free access to their land and were also helpful in describing geographic features.

The maps, stereoscope and other instruments used in the project were the property of the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas.

# A B S T R A C T

The thesis area, which is located on the southwestern flank of the Llano uplift approximately seven miles south of Mason, Texas, is underlain by rocks of Precambrian and Late Cambrian age.

Precambrian rocks exposed in the thesis area consist of one metamorphic unit, a gneiss, and one igneous unit, a medium-grained granite. The Upper Cambrian strata cropping out in the thesis area are divided into two formations, the Riley and the Wilberns.

The Riley formation is further subdivided into the Hickory sandstone member, the Cap Mountain limestone member, and the Lion Mountain sandstone member. Four members comprise the Wilberns formation which are: the Welge sandstone member, the Morgan Creek limestone member, the Point Peak shale member, and the San Saba limestone member.

The Precambrian deformation consists of tight folds with a northwest-southeast trend. The Paleozoic rocks have a northeast strike and have dips of less than ten degrees unless immediately associated with faults. Faulting is prevalent in the thesis area; two major faults are present and many minor faults are associated with them. A broad shallow syncline, probably a remnant of regional warping, is located between the two major faults.

A transgression of Paleozoic seas over an eroded Precambrian surface is evident in the thesis area. Younger Paleozoic and Mesozoic rocks once covered the thesis area but have since been removed by erosion. The faulting in the thesis area is younger than any of the rocks now remaining and probably occurred in Middle Pennsylvanian time.

The only economic resource present in the area is ground water which furnishes water for domestic and ranch use. No oil or profitable ore deposits have as yet been found.

# INTRODUCTION

## LOCATION AND ACCESSIBILITY

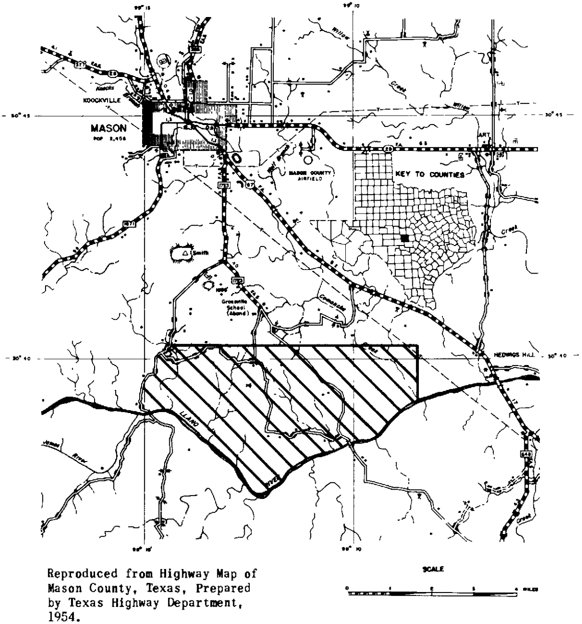
The Big Bend of the Llano River Area is situated on the southwestern flank of the Llano uplift approximately seven miles south of the city of Mason, in Mason County, Texas. The southern boundary of the approximately eighteen square mile area is the Llano River. The western boundary follows the James River road (Fig. I) from its crossing at the Llano River north to its intersection with Peters Creek. The eastern boundary is a line from the intersection of Comanche Creek and the Llano River to a point one and one half miles due north. The northern boundary is a line due west from the point just mentioned to the intersection of Peters Creek and the James River Road.

All but a few parts of the thesis area are readily accessible. The area can be entered by either of three roads. The James River Road serves the western part and the Simonville Road, which becomes Farm Road 1723 to the north, serves the eastern part. The Ridge Road passes through the center of the thesis area and is connected to both the James River and Simonville Roads.

## PROCEDURE AND METHODS OF FIELD WORK

The field work for this thesis was accomplished between June 16 and August 2, 1956.

The mapping of the area was done on United States Department of Agriculture aerial photographs with a scale of approximately 1:20,000. Each photograph was covered with acetate and mounted on a piece of cardboard. The thesis area covers five photographs in the DFZ-5E series,




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

LOCATION OF THE BIG BEND OF THE LLANO RIVER AREA,
MASON COUNTY, TEXAS

numbers 182, 50, 23, 49, 96, which were dated either November 2, 1948, or November 25, 1948.

With the aid of pocket and table stereoscopes, many tenative contacts and faults were noticed which were later verified by field observation.

A Brunton Compass, with a pre-set magnetic declination of ten degrees east, was used to determine all dips and strikes shown on the geologic map. Many of these dips and strikes are averages of several readings taken near the same point.

Two stratigraphic sections were measured (Appendix) in the thesis area, one of which could be slightly in error because of minor faulting. Additional sections were not measured because of poor outcrop exposures or extensive faulting. Measurements were made with a hand level and a stadia rod and several traverses were required with each section.

Studies of cross-bedding in the Hickory sandstone made by Goolsby (1957), are referred to in the detailed description of the Hickory sandstone member. Difficulty was encountered in measuring dips in the basal part of the Hickory sandstone member, as cross-bedding can be confused with normal bedding planes.

Two structure cross-sections accompany the geologic map (Plate I), which have horizontal distances taken from the aerial photographs and elevations estimated from field and stereoscope observations. Their locations were selected in an attempt to best illustrate the structure found in the Big Bend of the Llano River Area.

## SUMMARY OF PREVIOUS GEOLOGIC STUDIES

The first geologic account of the Llano region was made by Ferdinand Roemer in the years 1845 through 1848. Roemer was traveling through the region with a small group of German colonial explorers attempting to gather scientific data and to gain information that would be of interest to prospective German imigrants. He gathered fossils, by which he was able to recognize the older Paleozoic, Carboniferous, and Cretaceous rocks.

In 1861, B. F. Shumard reviewed and confirmed Roemer's descriptions and also described his (Shumard's) Potsdam group, which was of Late Cambrian age. Shumard also measured a number of sections and made fossil descriptions which proved very valuable for later geologic investigations.

It was not until 1874 that any additional work was published on the Llano region. In this year, Buckley classified and described the granitic rocks of the area and reviewed the geology along with a discussion of the mineral resources.

Walcott, in 1884, confirmed the Cambrian age of the Potsdam group and also conducted studies of the igneous and metamorphic rocks of the region. He named the metamorphic rocks the Llano group and designated the igneous rocks as pre-Potsdam in age.

In a series of papers from 1887 to 1890, Hill first made a review of Texas geology and later correctly named and described rocks of Carboniferous age near Marble Falls, Texas. Hill (1890) also made a study of Cretaceous rocks of the Llano region and discussed the processes of erosion of these rocks.

The Texas Geological Survey was formed in 1889 and the geology and mineral resources of this region were discussed by T. B. Comstock (1889-1890) in the First and Second Annual Reports of this newly formed survey. Comstock, in these early writings, introduced several new names such as the Riley Series, San Saba Series, Packsaddle schist and the Valley Spring gneiss.

The drainage patterns of the Llano region were discussed by Tarr (1890) when he described some of the general topographic features of Texas.

In 1911 and 1912, Sidney Paige, while working for the United States Geological Survey, reviewed all the previous geological work and, after revising portions of it, presented the first comprehensive geologic study of the Llano region. Paige (1912), introduced the terms Wilberns, Cap Mountain and Ellenburger into the geology of the region and described the rocks included within each unit. He also did extensive work on the Precambrian rocks and designated them as Algonkian in age.

The first geologic map of the state of Texas, which included the Llano region, was published by the Bureau of Economic Geology of Texas in 1916 and was prepared by Udden, Baker and Bose.

Deen (1931) described the Upper Wilberns reefs and noted that they frequently cap the highest hills. This relationship holds true in the thesis area.

Dake, Bridge and Ulrich (1932) presented a study of the older Paleozoic rocks of the Llano region in which they attempted to clarify and revise Paige's (1912) descriptions. They also presented correlations of faunal zones of this region to similar formations of surrounding regions.

The Precambrian rocks of the Llano region were redescribed by Stenzel (1932) when he revised previous concepts of their manner and sequence of origin.

Also in 1932, Sellards, Adkins and Plummer reported on the stratigraphy of Texas and reviewed the Precambrian, Cambrian and Ordovician systems of the Llano region.

A companion report to the one just mentioned, which discussed the structural and economic geology of Texas and Paleozoic deformation of the Llano region, was published in 1934 by Sellards and Baker. Shortly afterwards Stenzel (1935) discussed the structural relationships of the Precambrian rocks of the Llano region.

In 1937, a new geologic map of Texas, the first since Udden, Baker and Bose's in 1916, was published by the United States Geological Survey and was prepared by a group of geologists under the supervision of N. H. Darton (Darton et al, 1937).

Bridge (1927) studied portions of the western side of the Llano uplift and introduced the Lion Mountain sandstone member of the Cap Mountain formation. Also in 1937, Bridge and Girty combined efforts and reviewed and discussed Roemer's original work.

Lochman (1938) made a comprehensive study of the fauna of the Cap Mountain formation of the Llano region.

In 1939, Barnes and Parkinson published a paper on the presence of ventifacts in Mason, Blanco, and Llano Counties, describing their locations and possible mode of occurrence.

Plummer (1939) advanced some theories on the occurrence of travertine deposits in the Llano region.

Cheney (1940) discussed the broad structural problems of the area to the north of the Llano uplift and advocated the revision of formations of Pennsylvanian age based on faunal evidence and unconformities.

Large circular masses of Precambrian rock of the Llano region, generally termed "Massifs", were studied by Keppel (1940) and several theories of origin were offered.

Bridge and Barnes (1941) discussed and defined four separate members of the Wilberns formation and correlated them to other portions of the Llano uplift.

Plummer (1941) reviewed the Carboniferous rocks of the Llano region and named and defined the Chappel formation. He also proposed a two-fold division of the Barnett formation and three-fold division of the Marble Falls formation.

In 1941, Goldich did extensive chemical and petrographic work on granitic rocks and offered a theory of development of the granites of central Texas. He also commented on Keppel's (1940) work and offered his own thoughts on the crystallization of the granites in this region.

In 1942, a comprehensive study of rocks of the Central Mineral Region, as a possible source of building stone, was made by Barnes, Dawson and Parkinson. Included in their report were locations and descriptions of rocks best suited for this use.

"A new quartz sand horizon," located in Mason County, Texas, was described by Plummer in 1943. Barnes (1943) described central Texas soapstone and serpentine and included a review of the Precambrian stratigraphy in which he introduced the term Big Branch gneiss, located in Llano County. Barnes also in 1943 described the gypsum found in Cretaceous limestones and briefly reviewed the underlying Paleozoic rocks, still retaining the Lion Mountain sandstone as the upper member of the Cap Mountain formation.

Decker (1944) made a detailed study of Late Cambrian graptolites from Mason County, Texas.

The Devonian rocks of central Texas were described and divided by Barnes, Cloud and Bridge (1945). Barnes in 1945 reported on the phosphorite deposits in the eastern Llano uplift in central Texas.

Cloud, Barnes and Bridge (1945) proposed a revision of the Upper Cambrian of the Llano region by making the Riley series a formation and including within it three members, the Hickory sandstone member, the Cap Mountain limestone member and the Lion Mountain sandstone member. They also redefined the upper contact of the overlying Wilberns formation and proposed a revision of the Ellenburger stratigraphy.

The adaptability of the Hickory sandstone and the Ellenburger limestone as water reservoirs was discussed by Plummer in 1946.

Bridge, Barnes and Cloud in 1947 completed their work on the Upper Cambrian rocks of the Llano uplift and fully described and defined the two formations and seven members of the Upper Cambrian. This work is still the recognized reference on this section.

In 1948, Cloud and Barnes presented a study of the Ellenburger group of the Llano region and divided it into three formations, the Tanyard, the Gorman and the Honeycut.

Wilson (1949) presented a comprehensive report on the _Elvinia_ zone in the basal Wilberns limestones of the region.

The Carboniferous rocks of the Llano region were thoroughly studied by Plummer in 1950, and a detailed report on the stratigraphy and paleontology, along with maps of the Llano region, was presented.

Blank (1951) observed certain weathering features of the Precambrian rocks of the Llano region and presented detailed reports of them.

The main tectonic features of central Texas were investigated by Cheney and Goss (1952), and they suggested that the Llano uplift is an up-tilted part of an extensive structural axis named the Concho Arch.

Polk and Alexander (1952) did separate detailed studies of the geology in areas west and south, respectively, of Mason in Mason County, Texas.

In 1953, Barnes, Cloud and Duncan reported the discovery of Upper Ordovician rocks in central Texas. They named the unit the Burnam limestone and attempted to correlate it with other Ordovician rocks.

Duvall and Parke (1953) did separate detailed studies of geology in areas southwest of Mason in Mason County, Texas. A detailed geologic study by Parke (1953) overlaps the thesis area on the western border. Frits and also Grote (1954) mapped and described in detail areas farther west in Mason County, Texas.

Barnes and Bell (1954) gave a complete resume of the rocks of the Llano uplift from Precambrian up through Pennsylvanian time.

Flawn (1954) in a progress report proposed that the fundamental element in the basement rock of Texas is the Texas Craton which he stated can be dated as of "Middle Precambrian" time.

A complete report on the faunas of the Riley formation in central Texas was presented by Palmer (1954) in which he attempted to correlate the Riley formation inter-regionally.

A final report on the basement rocks of Texas was presented by Flawn (1956) in which he included maps indicating the general nature of the basement rocks of the Llano area.

The lead deposits of the Upper Cambrian of the Llano region were investigated by Barnes in 1956.

# PHYSIOGRAPHY

## GEOMORPHOLOGY

The Big Bend of the Llano River Area is located south of Mason, Texas, on the southwestern flank of the Llano uplift. The Llano region is structurally an uplift but through erosion it has become topographically a broad basin surrounded by a high flat rim of undisturbed Cretaceous rocks.

Within the basin the domal uplift of Precambrian and Paleozoic rocks has been broken by numerous faults, many of which bring rocks of different ages to the same level. Erosion has removed some of the less resistant rocks and has left the more resistant granites and limestones as high rugged hills and ridges which lie below the level of the surrounding Cretaceous rim.

According to some studies, the average elevation of the Llano uplift is close to 1600 feet. The highest points are about 2200 to 2300 feet above sea level and the lowest about 900 feet, thus allowing for a maximum relief of 1300 to 1400 feet.

In the Big Bend of the Llano River Area the highest elevation is estimated to be 1750 feet and the lowest elevation 1300 feet above sea level, allowing for a maximum relief of 450 feet.

The thesis area can be divided into four physiographic types: (1) the high bioherm-capped hills and fault-line scarp along the northern and extreme southwestern part of the area, (2) the ragged and irregular hills of Precambrian granite and gneiss to the east, (3) the low plateau and lowlands in the middle and southern parts of the area, and (4) the cuestas and rejuvenated streams in the southwestern part of the thesis area.

The northern portion of the thesis area is a very hilly surface with a stromatolitic bioherm unit capping all the steep hills. This condition holds true on all the high elevations in the area with the exception of a large hill in the extreme southwestern portion which is capped by Cap Mountain limestone. The first geomorphic unit is abruptly separated from the other units by a fault line scarp that extends in a northeast-southwest direction across the thesis area.

In the eastern portion of the area, is located the second unit which is the hilly, often ragged, area consisting of granitic and gneissic rocks. The granites are intrusive bodies that are generally lenticular in shape and have a general northwest to southeast orientation as does the banding found in the gneiss unit. Where rock outcrops do not occur in this unit the "soil" is composed of coarse feldspar and quartz grains or a finer sand-like weathered gneiss. This unit contains Comanche Creek which is intermittent and is choked with "granite wash".

Neither of the two units just mentioned is under cultivation and grass for grazing is limited under the present drouth conditions.

The third geomorphic unit lies in the central and southern portions of the thesis area. Faulting has had considerable effect on the geomorphology of this unit. The area varies from rocky cuestas, directly south of the fault line scarp previously mentioned, to relatively flat sandy lowland along the Llano River. This unit is composed principally of Hickory and Cap Mountain rocks that have weathered to a red sandy soil which is used extensively for farming.

The fourth unit lies in the southwestern part of the area and includes the irregular erosional land-form called "Corn Pasture Flats".

The more resistant Cap Mountain limestone forms a series of cuestas that crop out as several parallel sets of low ridges.

Apparently there has been some post-Cretaceous uplift which rejuvenated the Llano River, thus causing all of its tributaries to incise their meandering channels to keep pace with the lowering of the larger stream.

The rejuvenation of one of these streams has caused the erosional feature called "Corn Pasture Flats". This is an elongated, nearly closed, oval valley in which the uppermost red sandstone beds of the Hickory member have been exposed by erosion of the overlying Cap Mountain limestone. From initial observations of aerial photographs it appeared that some structure might be present, but subsequent field observations of the dips of the strata indicated the land-form to be a product of differential erosion.

Most of this fourth unit is under cultivation and where the topography is too hilly for farming rather abundant brush and grass are available for grazing.

DRAINAGE

Tarr (1890) made the first study of the drainage patterns of the Llano region and concluded that the drainage was consequent upon the Cretaceous surface and superimposed upon the rocks now exposed.

The thesis area is drained by tributaries of the Llano River, which are superimposed upon the Precambrian and Paleozoic rocks. Peters Creek is located in the western portion of the area and Comanche Creek in the eastern portion.

Peters Creek is a fairly large superimposed stream which originates outside of the thesis area. At several points along its course to the Llano River, the flow of the creek is altered by fault line scarps.

Many of the smaller streams in the central portion of the thesis area, near the big bend of the Llano River, are subsequent and in some cases insequent in type.

Comanche Creek is a wide stream whose bed is filled with granite wash and large gneiss boulders. Like Peters Creek this stream originates outside the thesis area. Comanche Creek is superimposed upon the Precambrian gneiss all the way to its junction with the Llano River.

CLIMATE AND VEGETATION

The thesis area is located in a semi-arid region of Texas and the climate is sub-humid. The vegetation is typical of that which is found in rocky terrain with uneven precipitation throughout the year.

The average rainfall in Mason County is 20 to 30 inches per year and the temperature ranges from below 30°F in the winter to over 100°F in the summer with a mean yearly temperature of 70°F.

The rainfall varies greatly during the year with the majority of the rains falling in the spring and winter months. Often much of the rainfall will come in a span of a few days and most of it will drain off.

The vegetation of the thesis area can vary somewhat with the type of rock or soil on which it grows.

According to Polk (1952, p. 8), who did work in a similar and nearby area, the main grasses of the county are buffalo, needle, curly mesquite, and crowfoot.

Fritz (1954, p. 15) compiled a complete list of other plants common to Mason County which are also found in varying amounts in the thesis area.

| Common Name | Scientific Name |
|---|---|
| Catsclaw | Acacia greggi |
| Agarita | Berberis trifoliolata |
| Mexican persimmon | Diospryos texana |
| Cedar | Juniperus mexicana |
| Tasajillo (rat-tart cactus) | Opuntia leptocaulis |
| Prickly pear | O. lindheimeri |
| Mesquite | Propepis juliflora |
| Shin (scrub) oak | Quercus mohriana |
| Post oak | Q. stellata |
| Red oak | Q. texana |
| Live oak | Q. virginiana |
| Spanish dagger | Yucca treculeana |
| White brush | Aloysia lisistrina |

The above vegetation is listed and further described with the discussion of stratigraphy of each rock unit.

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

## GENERAL STATEMENT

In the Big Bend of the Llano River Area only Precambrian, Upper Cambrian and Quaternary rocks are exposed. According to Paige (1912, p.25) and Sellards, Adkins and Plummer (1932, p. 31) a probable age for the Precambrian rock could be Algonkian. Flawn (1956, p. 27) reported the results of radioactive age determinations made on Precambrian granites of the Llano region and stated that,

> "On the basis of these age determinations the batholithic granites exposed in the Llano uplift have an age of about 1,000 million years and the intruded sedimentary rocks are still more ancient."

Paleozoic rocks younger than Upper Cambrian are not present in the thesis area. Some recent stream conglomerates and alluvium occur. The geologic column is as follows:

- Quarternary System
    - Recent alluvium and river conglomerate
    - Older alluvium
- Cambrian System
    - Wilberns formation
        - Point Peak shale member
        - Morgan Creek limestone member
        - Welge sandstone member
    - Riley formation
        - Lion Mountain sandstone member
        - Cap Mountain limestone member
        - Hickory sandstone member
- Precambrian rocks
    - Igneous rocks

Medium-grained granite (Oatman Creek?)

Gneiss (Valley Spring?)

PRECAMBRIAN ROCKS

In the Big Bend of the Llano River Area both igneous and metamorphic rocks of Precambrian age are exposed. These exposures consists of a pink medium-grained granite unit and pink medium-grained gneiss unit.

## Metamorphic Rocks

In an early discussion of the metamorphic rocks of the Llano region, Walcott (1844, p. 431) proposed the term Llano group to include a series of metamorphosed sedimentary rocks exposed in the Llano uplift. Comstock in 1889 divided these metamorphosed rocks into two units, the Valley Spring gneiss and the Packsaddle schist. The type localities of these units are at Valley Spring and at Packsaddle Mountains, respectively, both located in Llano County, Texas.

Paige (1912, p. 25) later revised the two units but retained the names that were assigned by Comstock. In addition to his redefinition of these rocks, Paige (1912, p. 25) offered his own theories as to their occurrence, in which he proposed that the Valley Spring gneiss was older than the Packsaddle schist and that perhaps the Valley Spring gneiss contained not only metamorphosed sedimentary rock but igneous rock as well.

The next major revision of metamorphic rocks of the Llano region was undertaken by Stenzel (1932, p. 143-144), Stenzel stated that the Valley Spring gneiss was igneous in origin and was intruded into the Packsaddle schist, thus inferring that the Packsaddle schist was the only sedimentary formation in the Precambrian rocks of the region.

According to Sellards, Adkins and Plummer (1932, p. 32), the separation of the Valley Spring gneiss from the overlying Packsaddle schist can be based

"...in part on the more massive character of the gneiss, and in part upon its greater content of acidic materials. The gneiss, however, not only contains schist but grades into schist in such a way as to make definite separation at many localities difficult or impossible."

The Big Branch gneiss was described by Barnes (1943, p. 56) as a third metamorphic unit which is exposed along the Big Branch of Coal Creek in Gillespie and Blanco Counties. According to Barnes (1943, p. 56), the Big Branch gneiss can be described as a dark gray, medium- to fine-grained, quartz-diorite gneiss which has intruded both the Valley Spring gneiss and the Packsaddle schist.

Flawn (1956, p. 29) discussed the age of the metamorphic rocks in which he stated that these rocks were "invaded by granites about 1000 million years ago" thus making the metamorphosed rocks of the Llano region at least this old.

The only metamorphic unit present in the thesis area is a pink medium-grained gneiss.

## Gneiss Unit

### Occurrence and relationships

The outcrops of the gneiss unit are confined to the eastern portion of the thesis area where the unit forms a very rugged rocky topography (Plate II, Fig. 1). The general strike of the gneiss unit is in a northwest-southeast direction with a few local deviations. The

PLATE II

Exposures of Precambrian gneiss

Figure 1.—Large rugged exposure of Precambrian gneiss located next to Comanche Creek on the Jack Walker ranch.

Figure 1.—Joints striking north 20 degrees east within the Precambrian gneiss unit in the southern portion of the Jack Walker ranch.

strike ranges from 50 to 70 degrees west of north and dip from 40 degrees northeast to 90 degrees. In one portion of the gneiss outcrop the strike changes abruptly to north 60 degrees east. It is thought that faulting is responsible for this erratic change in strike which will be discussed in greater detail later in the thesis.

The gneiss outcrop extends beyond the eastern limits of the thesis area. Within the area mapped, it is bounded either by Precambrian granites or Paleozoic sedimentary rocks. The contacts with the intrusive granitic masses are not sharp but present a transition zone that appears to be a result of the intrusion. The contact with the sedimentary rock is an unconformity resulting from the overlap of the Cambrian sediments upon the Precambrian surface.

In one portion of the gneiss exposure numerous joints are present (Plate II, Fig. 2; page 18) having a strike of north 40 degrees east.

<u>Megascopic description and relationships</u>

The gneiss unit is principally a massive, very hard, fine-grained, non-calcareous, pink gneiss. A megascopic examination suggests that the principal mineral is pink microcline and the second most abundant mineral clear quartz. The dark minerals appear to consist chiefly of biotite and possibly magnetite. The biotite content varies and forms layers which give the banded appearance to the gneiss. In some exposures the dark minerals which constitute the bands weather out, thus removing the banding and giving the weathered rock the appearance of a quartzite. Some excellent exposures of the massive gneiss are present along Comanche Creek one mile south of the Willman ranch house (Plate II, Fig. 1; page 18).

The gneiss unit is well exposed along the Llano River where water action has maintained a semi-fresh exposure. Also along the river the relationships of the pegmatitic and aplitic dikes and quartz veins can be observed (Plate III, Figs. 1 & 2).

The pegmatite dikes are composed principally of large grains of milky quartz and a considerable amount of microcline and plagioclase. Some dark minerals were present but were not large enough to be determined megascopically. In many of the dikes graphic granite was found.

Aplite dikes were also found within the gneiss unit. The aplite was rather fine-grained and it was difficult to determine the constituents from field observation. It appeared that the main constituents were equidimensional grains of microcline, possibly some orthoclase, quartz, and minor amounts of either biotite or muscovite.

The quartz veins were not as common as the dikes mentioned above and consisted chiefly of milky quartz and some gray, slightly translucent quartz.

The quartz veins and pegmatite dikes ranged in width from a few inches to several feet, whereas the aplite dikes ranged from several inches up to a foot in width.

Microscopic description

A thin section of the equigranular pink gneiss, from the prominent gneiss exposure along Comanche Creek (Plate II, Fig. 1; page 18) on the Hoerster ranch, was prepared.

The gneiss consists of quartz, microcline, plagioclase, biotite and ilmenite. The anhedral quartz grains average 0.5 mm across with some very small quartz inclusions in plagioclase grains.

Ilmenite is the only noticeable opaque mineral present in the section and has an average grain size of 0.2 mm (Plate IV, Figs. 1 & 2).

PLATE III

Aplite and pegmatite dikes

Figure 1.—Aplite dikes intruded into the gneiss unit exposed in the dry Llano River bed on the Jack Walker ranch.

Figure 2.—Pegmatite dikes of different ages exposed in the dry Llano River bed on the Jack Walker ranch.

PLATE IV

Photomicrographs of gneiss showing ilmenite grains

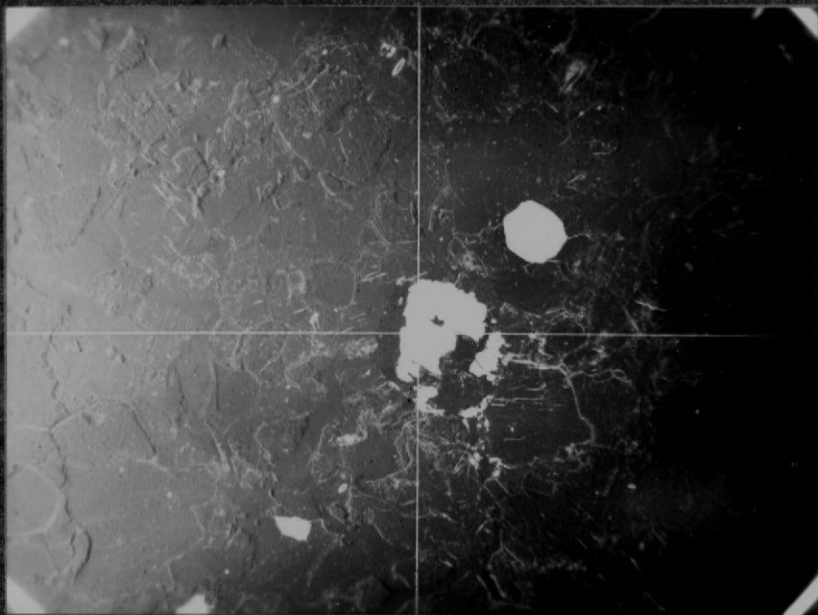


Figure 1.--Several ilmenite grains from the gneiss unit shown in plane light (30X).

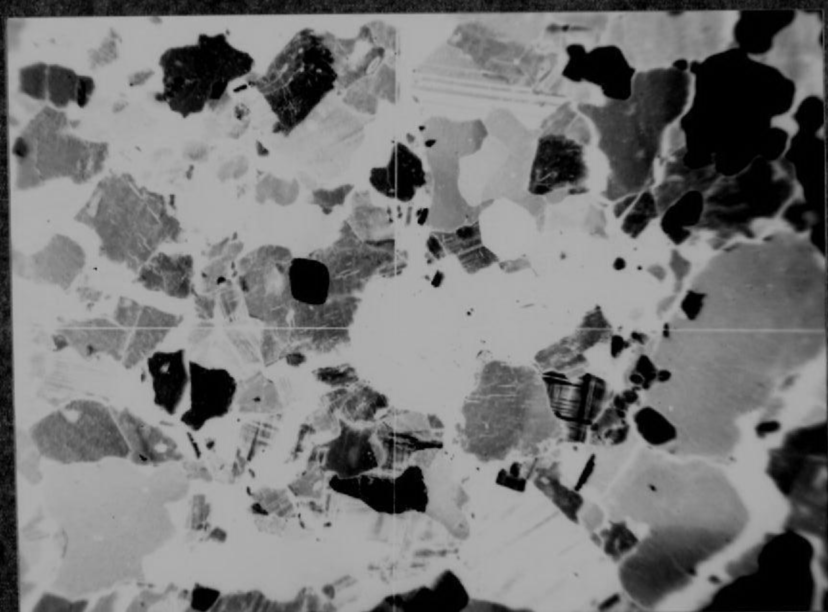


Figure 2.--The above ilmenite grains under X-nicols with an additional display of other constituents of the gneiss (30X).

All of the ilmenite grains in the thin section showed some alteration to leucoxene, which appeared as an opaque white material surrounding the majority of the grains.

Microcline was quite common in the thin section; however, most of the grains were small in comparison to the other minerals, measuring only 0.2 mm across (Plate IV, Fig. 2).

Biotite was abundant in the gneiss thin section, (Plate V, Figs. 1 & 2). Some of it contained zircon inclusions which appeared to be radioactive and were surrounded by pleochroic halos (Plate VI, Figs. 1 & 2). The biotite flakes ranged from 0.5 mm to 0.74 mm long and 0.14 to 0.18 mm thick.

The plagioclase present in the thin section was oligoclase with a maximum extinction angle of 9 degrees.

Several grains with most of the optical properties of apatite were noticed; however, without conclusive proof they must be considered doubtfully apatite.

The feldspars comprise about 60 percent of the section, quartz about 30 percent, biotite 6 percent and ilmenite 4 percent.

The thin section obtained from the thesis area is somewhat similar to the thin section of the Valley Spring gneiss near Llano in Llano County, Texas, described by Barnes, Dawson and Parkinson (1942, p. 120) except that considerably more quartz is present in the thin section from the thesis area. The slight alterations of biotite to chlorite described by them were also noticed in the thesis-area section; however, no titanite was present.

# PLATE V

Photomicrographs of gneiss showing biotite grains

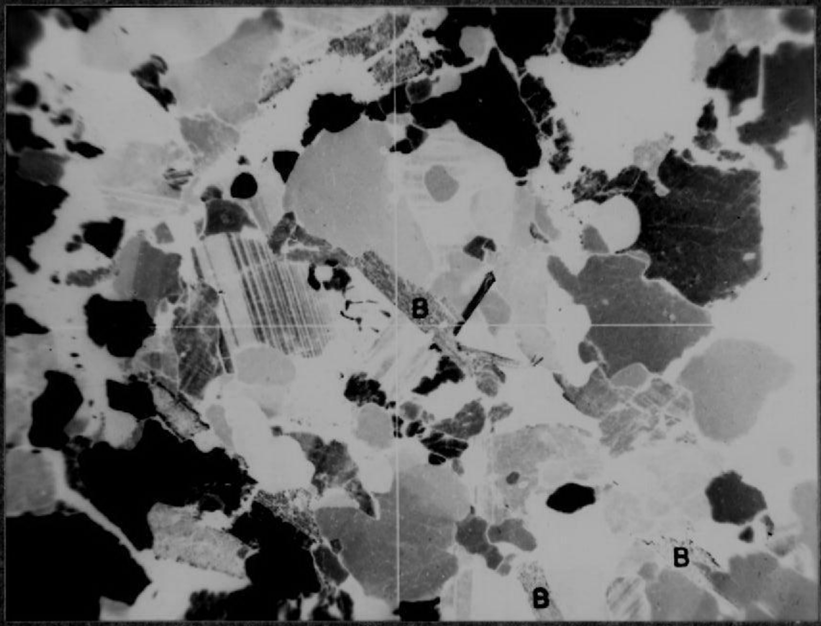



Figure 1.--Relationship of numerous biotite (B) grains found in the gneiss unit shown under X-nicols. Note the Carlsbad and Albite twining present in the plagioclase (30X).

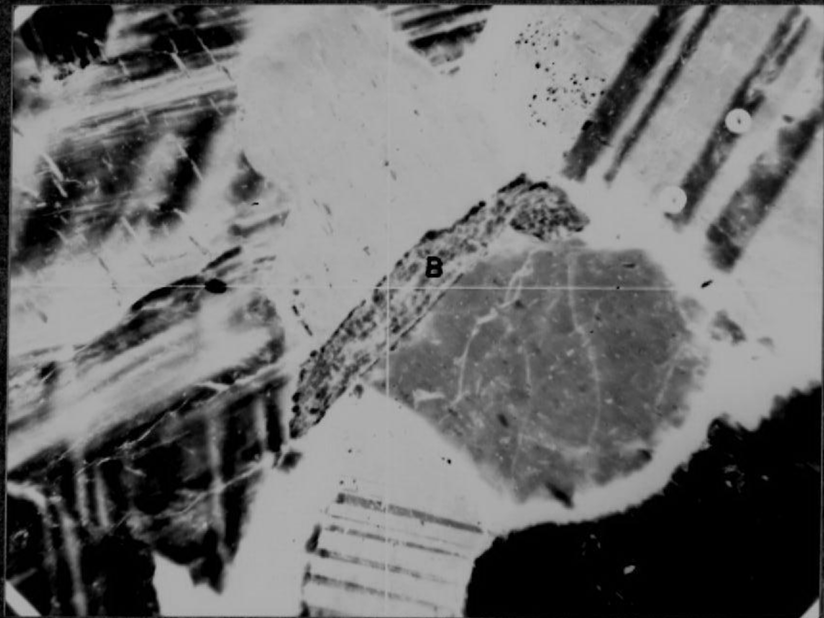



Figure 2.--A biotite grain (B) displaying typical tabular habit and cleavage of biotite (B) under X-nicols (110X).

PLATE VI

Photomicrographs of gneiss showing pleochroic halos in biotite

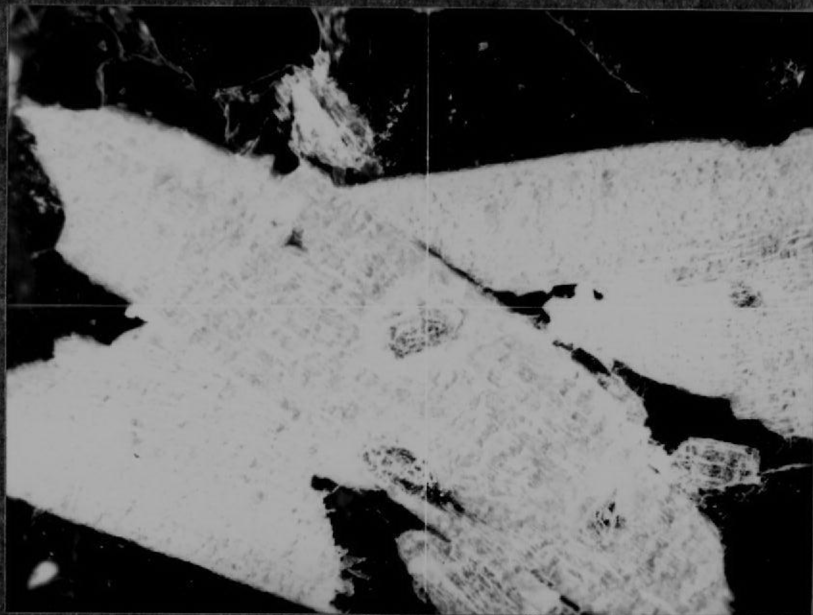


Figure 1.—Pleochroic halos around zircon inclusions under ordinary light which display possible radioactive cracks in biotite found in the gneiss unit (110X).

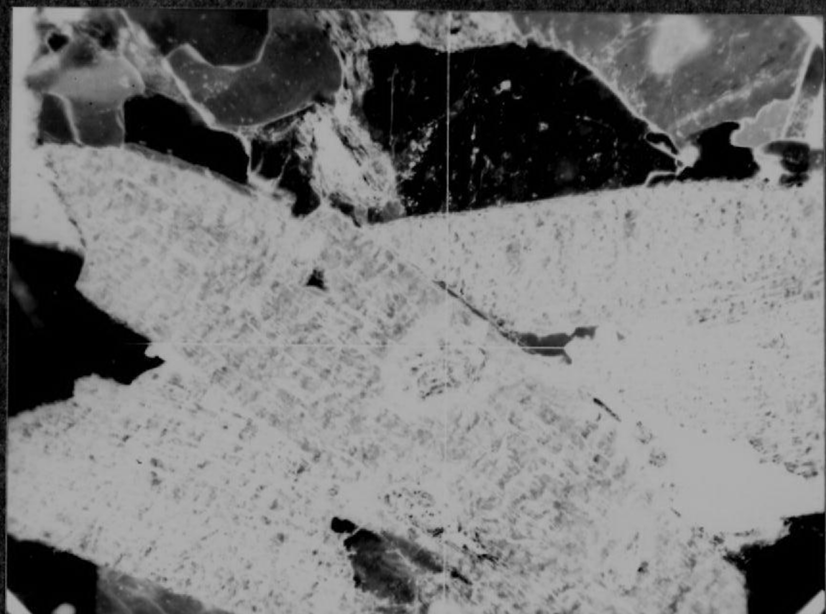


Figure 2.—The above biotite under X-nicols (110X).

On the other hand, the gneiss 9.5 miles northeast of Mason described by these same authors (1942, p. 121) appears to be very different from the thesis area section.

Topography and vegetation

The topography of the gneiss unit, as previously mentioned, is generally very rocky with random boulders covering the outcrop. The soil derived from the weathered gneiss is, under the present drouth conditions, of little value for farming and grazing. A few scrub oak, mesquite, cedar and prickly pear survive on this soil.

## Igneous Rocks

Igneous rocks and their occurrence in the Llano region were mentioned in literature as early as 1846 by Roemer in his description of his journey across Texas. Several other early geologists such as; Schumard (1861), Buckley (1874), Walcott (1884) and Comstock (1889-1890) published early descriptions of the igneous rocks of the Llano region. It was not until Paige (1912, p. 25) gathered all the random descriptions and supplemented them with his own work, that a comprehensive account of the igneous rocks of the region was presented. Paige (1912, p. 25) described three types of granites which were: (1) a very coarse-grained, homogeneous granite, (2) a medium- to fine-grained granite, including some coarse-grained varieties, and (3) an opaline quartz-porphyry.

Stenzel (1932, p. 143-144) suggested that the igneous rocks exposed throughout the Llano uplift could be divided into two classes as follows: (1) batholithic intrusions, comprised of various granites and their aplite and pegmatite dikes, and (2) the later dike intrusions comprising the opaline quartz porphyry and felsites. Stenzel (1932, p. 144) further divided the batholithic intrusions (from oldest to youngest) into: (1) Town Mountain, a coarse-grained to porhyritic granite with large flesh-colored feldspars, (2) Oatman Creek, a medium-grained, gray to pink cataclastic granite, and (3) Sixmile, a fine-grained, gray, biotite granite.

Keppel (1940) made an extensive study of steep-walled, almost circular bodies of granite called massifs. He (Keppel) proposed some theories on the origin of the textural patterns of these circular masses. These theories were considered unsatisfactory by Goldich (1941, p. 710), who made detailed chemical analyses of central Texas granites. Goldich (1941, p. 697) also criticized Paige's method of classifying granites on variations in texture since he (Goldich) claims texture can vary even within single masses of granitic rocks.

The only granite present in the thesis area is a medium-grained pink granite which is exposed in two locations.

## Medium-Grained Granite

### Occurrence and relationships

The medium-grained granite in the thesis area is exposed along the Llano River on the Jack Walker ranch and also on the Jimmy Zesch ranch east of the Simonville Road. The granite mass located on the Zesch ranch invaded the gneiss unit but the contact is obscured in most places by soil. Where the contact is visible it appears to be sharp with no transition zone between the two rock units. The granite mass located on the Walker ranch in the bed of the Llano River has a wide transitional contact with the gneiss unit.

The method of formation of this type of transition zone is a matter of considerable conjecture among igneous petrologists even during the present day.

Perhaps the term migmatitic would describe the nature of the rocks contained in this transition zone. According to Turner (1948, p. 305),

"For rocks of mixed origin, Sederholm's (1907, p. 110) term migmatite (mixed rock) is convenient. In many migmatites the granitic (or granodioritic) and the metamorphic components are clearly distinguishable; in others, soaking of the original host rock in the magmatic liquids has largely blurred their separate identities. The term migmatite is purely descriptive and may be applied equally well whether the granitic component has been injected from an external source or is the result of fusion in situ."

Migmatites may evolve in three general ways, according to Turner (1948): (1) development by an injection of a magma, (2) development by magmatic soaking, and (3) development by differential fusion.

The rocks of the transition zone (Plate VII, Figs. 1 & 2) have been invaded and altered in structure and composition. Whether solutions invaded the altered rock from below or solutions were developed from the rock itself and caused an alteration, is not known. A xenolith (Plate VII, Fig. 1) with sharp boundaries, found in the transition zone, would tend to support the idea that this zone resulted from invasion of the original rock by magma or by solutions or gases from the outside, rather than by differential fusion of the rock itself (Dr. H. R. Blank, personal communication).

If the above thinking is valid then the zone is probably a zone of metasomatism which was caused by the invading granitic mass. Solutions or gases from the intrusive mass could have caused an alteration through an ionic transfer within the country rock. It would be neces-

# PLATE VII

Transition zone between granite and gneiss

Figure 1.—A xenolith found in the transition zone between the Precambrian granite and gneiss units in the bed of the Llano River on the Jack Walker ranch.

Figure 2.—Exposure of transition zone rock that has been intruded by aplite dikes, located in the bed of the Llano River on the Jack Walker ranch.

sary to study the rocks of the transition zone in greater detail than was possible in this study to adequately determine their genesis. Therefore, no definite conclusions can be drawn concerning these rocks from the present study; only suggested origins can be offered.

Megascopic description

The medium-grained granite is equigranular with grains from 1-3 mm in diameter. The minerals most easily seen megascopically in the granite are microcline, quartz and biotite. The most abundant mineral present is microcline, which gives the rock a rich pink color. Second in abundance is colorless quartz. Biotite is the only dark mineral readily recognizable megascopically.

The granites are cut by numerous pegmatite dikes but not quite as profusely as is the gneiss unit. Barnes, Dawson and Parkinson (1942, p. 79) described some pegmatite dikes, at Streeter in Mason County, Texas, which contain topaz, tourmaline and cassiterite. No microscopic examination was made of the pegmatites in the thesis area.

Microscopic description

It was difficult to obtain an unweathered rock sample from which a thin section could be prepared; however, a sample was taken from the granite exposure in the bed of the Llano River, 200 yards southwest from the mouth of Comanche Creek on the Walker ranch.

The essential minerals found in the thin section are microcline, quartz, plagioclase, and biotite which has been considerably altered. Additional minerals found are fluorite, zircon, and chlorite which is believed to contain some needle-like crystals of rutile (?).

The most abundant minerals are anhedral grains of microcline that have their characteristic "grid structure" (polysynthetic twining) obscured by a microperthite structure. Most of the grains of microcline in the thin section are very large, many of them measuring 2.0 mm across. Many of these large grains have small inclusions of quartz and plagioclase (andesine).

The anhedral grains of quartz are also relatively large in the thin section with grains of 2.0 mm in diameter (Plate VIII, Figs. 1 & 2). However, numerous small grains of quartz are found that measure only 0.2 mm in diameter. The extinction of the quartz is relatively sharp. Several basal sections of quartz were noticed in the thin section (Plate VIII, Fig. 2).

The plagioclase is andesine which was determined from a maximum extinction angle of 19 degrees and an index of refraction greater than balsam. In comparison with the quartz and microcline grains the andesine grains are small and are only 0.20 mm across.

Large grains of altered biotite are present in the thin section, some grains being 1.5 mm long in the direction of the cleavage. Some of the biotite has been altered to chlorite which contains needle-like crystals, probably of rutile. The rutile was identified by its high birefringence and parallel extinction.

Fluorite, distinguished by its high relief and perfect octahedral cleavage, was found in the thin section. Barnes, Dawson and Parkinson (1942, p. 79-86) mention the presence of fluorite in their descriptions of granites from Mason County.

Zircon appears as small inclusions in several of the andesine and altered biotite grains.

With the exception of the type of plagioclase found in the thin

# PLATE VIII

## Photomicrographs of granite


Figure 1.--Anhedral quartz grains (Q) associated with altered biotite (B) in the Precambrian medium-grained granite under X-nicols (110X).


Figure 2.--One of several basal sections of quartz, under X-nicols, found in the Precambrian medium-grained granite. Note the polysynthetic twining (P) in the microcline surrounding the quartz grain (110X).

section the granite closely resembles in composition those described from Mason County by Barnes, Dawson and Parkinson (1942, p. 79-86). It would be difficult to decide whether its composition is closer to that of the Town Mountain or Oatman Creek granites, but because of the texture of the granite it is possibly Oatman Creek.

The general composition of the granite thin section is 60 percent feldspar, 32 percent quartz, 7 percent of altered biotite and approximately 1 percent each of fluorite and chlorite.

Topography and vegetation

The granite exposures are fairly resistant to weathering and are exposed as large boulders and domes of igneous rock (Plate IX, Figs. 1 & 2). The soils around granite exposures are composed chiefly of angular pieces of pink feldspar and quartz.

The vegetation on these soils is very limited, with scant amounts of grass and a few scrub oaks and mesquites.

## CAMBRIAN SYSTEM

In the Big Bend of the Llano River Area, rocks of Late Cambrian age crop out over a considerable portion of the area. The Riley formation rests unconformably upon the irregular Precambrian surface. The Wilberns formation conformably overlies the Riley formation.

### Riley Formation

The Riley formation was described by Cloud, Barnes, and Bridge (1945, p. 154) and its type locality is in the Riley mountains in southeastern Llano County. It is the oldest Paleozoic formation present in the Llano uplift and is Late Cambrian in age. Cloud, Barnes, and Bridge (1945,

PLATE IX

Exposures of Precambrian granite

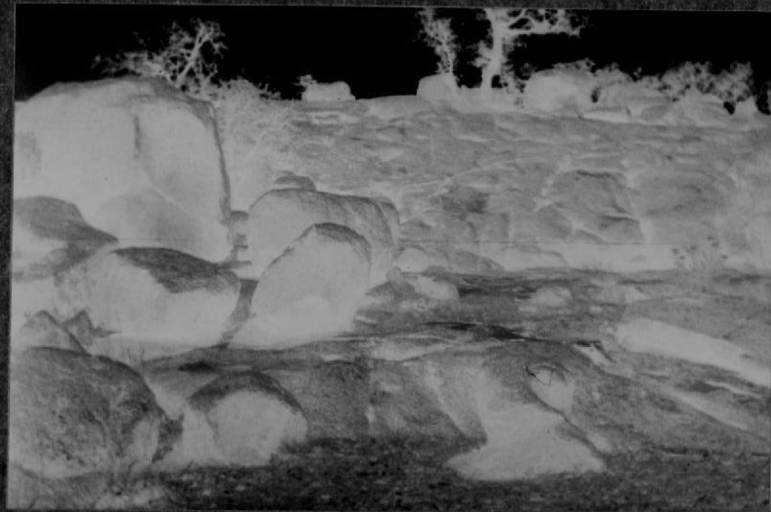


Figure 1.—Large granite exposure located 600 yards southeast from the Jimmy Zesch ranch house.

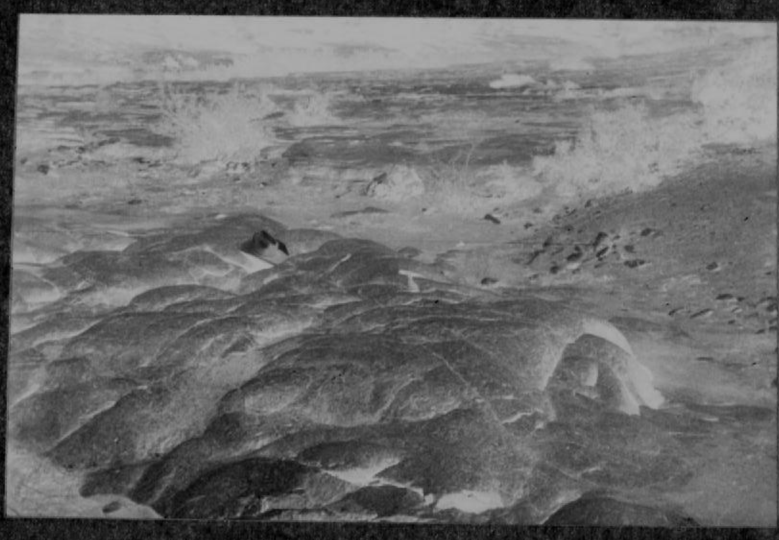


Figure 2.—Granite exposure near the Hickory-Precambrian contact in the Llano River bed on the Jack Walker ranch.

p. 154) prefer to designate the Riley formation as, "all of the Cambrian strata in Central Texas beneath the Wilberns formation".

The term Riley was used previously by Comstock (1890) and later by Paige (1912, p. 21) with reference to the "Riley Series"; however, Cloud, Barnes and Bridge (1945, p. 154) re-defined the rocks as the Riley formation and divided them into three members. These are, from oldest to youngest; (1) the Hickory sandstone, (2) the Cap Mountain limestone, and (3) the Lion Mountain sandstone.

The thickness of the Riley at the type locality is 780 feet. Because of the irregular Precambrian surface on which it was deposited, it may be as thin as 200 feet but the average thickness is estimated to be 680 feet.

In the thesis area, it was not possible to measure an entire section of the Riley formation, but the estimated thickness is approximately 550 to 600 feet.

Hickory Sandstone Member

Definition and thickness

In 1890, Comstock first used the term Hickory to name the sandstone series that occurred along Hickory Creek in Llano County. Paige (1912, p. 42) dropped the series classification that Comstock had used and redefined the Hickory sandstone as a formation.

Cloud, Barnes and Bridge (1945, p. 154) in their revision of Upper Cambrian rocks gave the Hickory sandstone member status and placed it at the base of the Riley formation.

There is a great variation in the thickness of the Hickory sandstone member and according to Bridge, Barnes and Cloud (1947, p. 112) it can range from 415 feet thick to a "feather edge", with an average thickness of 350 feet. There are several reasons for this wide variation, such as topography of the Precambrian surface, depositional irregularities and gradation laterally into the overlying Cap Mountain member.

Depths of producing sands of water wells on the Leroy Schmidt ranch indicate that the Hickory is over 400 feet thick in the thesis area.

Lithology

The irregular Precambrian surface on which the Hickory sandstone rests can have a relief of 800 feet in some places, according to Bridge, Barnes and Cloud (1947, p. 113). This irregular Precambrian surface is illustrated on the eastern part of the Jimmy Zesch Ranch where two hilltops consist of Hickory outliers surrounded by Precambrian gneiss. In a stream valley adjacent to these hills the Hickory sandstone also crops out. This latter exposure is over 100 feet lower topographically than the hilltop outcrops.

Only one good exposure of the Hickory-Precambrian contact was found in the thesis area, this being in the bed of the Llano River about .7 of a mile downstream from the Simonville Road bridge (Plate X, Fig. 1). At the contact, the Hickory sandstone member occurs as a very coarse, light tan to pale orange, conglomeratic sandstone, with subrounded pebbles ranging from 2 mm to 8 mm in diameter. The pebbles of this basal portion present a raised rough surface on the weathered surface of the rock.

Ventifacts, which are sometimes found at or near the Hickory-Precambrian contact, were not found anywhere in the thesis area.

PLATE X

Lower part of the Hickory sandstone member

Figure 1.—Hickory-Precambrian contact as exposed in the Llano River bed on the Jack Walker ranch. The hammer rests on granite.

Figure 2.—Cross-bedding in the lower part of the Hickory sandstone member located on the north bank of the Llano River on the Jimmy Zesch ranch.

The coarse, poorly sorted, non-calcareous sandstone found at the base of the member gradually becomes relatively better sorted upward in the section. This light gray to tan sandstone also becomes thicker and contains more cross-bedding (Plate X, Fig. 2). The individual sand grains are frosted and faceted and are frequently stained. Two joint systems, striking north 10 degrees west and north 55 degrees east, respectively, were noticed along the Llano River on the Jimmy Zesch ranch but were not found at other Hickory sandstone outcrops (Plate XI, Fig. 1).

A white, hard, finer-grained sandstone occurs near the middle of member. Some thin, light green shale beds alternate with the light-colored sandstone (Plate XI, Fig. 2). The shale beds show slight amounts of glauconite which does not commonly occur in the Hickory member.

Near the middle of the member several beds showing symmetrical ripple marks (Plate XII, Figs. 1 & 2) are found. Below these ripple-strata are beds of intraformational conglomerate, which consist of angular fragments of sandstone with a random orientation in a sandy matrix. Phosphatic brachiopods are also found in these conglomerates.

The upper part of the Hickory sandstone is a zone of dark red to brownish red, poorly sorted, sometimes cross-bedded, thick-bedded sandstone (Plate XIII). The red color of the sandstone is derived from the iron oxide that coats the clear quartz sand grains which are well rounded and in most cases poorly sorted.

The Hickory sandstone outcrop covers approximately one-fourth of the thesis area but because of weathering much of the outcrop has been disintegrated to soil. A section (Appendix) was measured along the Llano River extending from the base to the middle part of the Hickory sandstone.

PLATE XI

Features in the Hickory sandstone member

Figure 1.—Two intersecting joint systems in the lower part of the Hickory sandstone member in the bed of the Llano River on the Jimmy Zesch ranch.

Figure 2.—Slightly glauconitic shale interbedded with white sandstone in the middle of the Hickory sandstone, located on the southern part of the Leroy Schmidt ranch along the Llano River.

PLATE XII

Ripple marks in Hickory sandstone member

Figure 1.—Large symmetrical ripple marks found in the middle of the Hickory sandstone member on the Leroy Schmidt ranch on the Llano River bank.

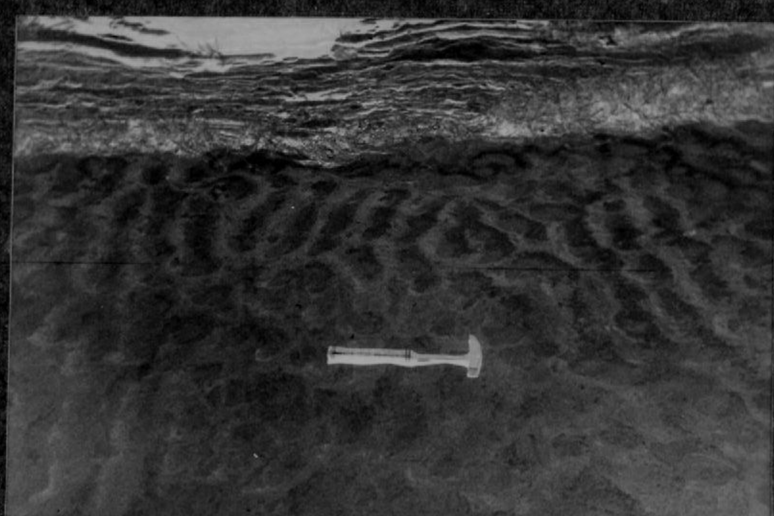


Figure 2.—Small symmetrical ripple marks from the same location as above.

PLATE XIII

Ferruginous Upper Hickory sandstone member located in the northeastern part of the Jimmy Zesch ranch.

This section of 144.8 feet could be somewhat in error because of minor faulting.

The Hickory sandstone, in general, is soft, friable, non-calcareous, and poorly cemented in the middle and lower portions. There are many small fractures in the lower portion that have been filled with a fine-grained white sand.

Goolsby (1957) has recorded and plotted cross-bedding in the Lower Hickory located along the Llano River in the thesis area. The equal area projection method was used which is described by Billings (1954, p. 110-113). The foreset laminae had average angles of inclination of 30 degrees and the topset laminae for the most part were insignificant. Ninety foreset beds (Fig. 2) from the north bank of the river were plotted on the upper hemisphere of an equal area projection. The resulting plots indicated the beds to have a relatively unidirectional strike and dip. Goolsby (1957) has concluded from his studies that the cross-bedding was essentially due to the rapid deposition of desert sediments at the mouths of a fast, intermittent streams which emptied into a relatively quiet ocean.

Topography and Vegetation

In the thesis area, the Hickory sandstone crops out on the low plateaus, and with the exception of the two outliers on the Jimmy Zesch ranch the member has little relief.

The basal and upper portions of the Hickory sandstone, when weathered, form a sandy soil which is used extensively for farming. The middle portion of the member which contains intraformational conglomerates and ripple-marked sandstone ledges is more resistant to weathering.

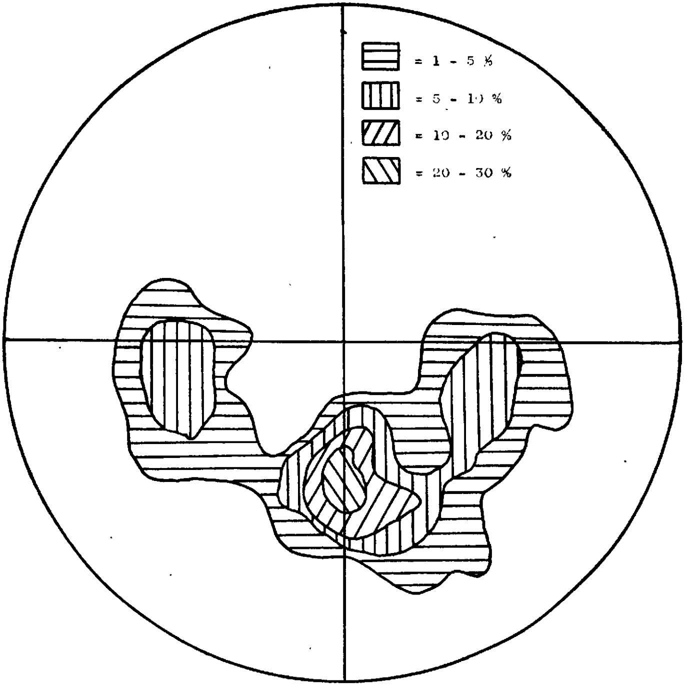



Figure 2. Contour diagram of the poles of 90 cross-bedding foreset beds plotted on the upper hemisphere of an equal area projection. These foreset beds in the Lower Hickory sandstone member are exposed on the north bank of the Llano River on the Jimmy Zesch Ranch ( Goolsby, 1957 ).

The uncultivated parts of the Hickory sandstone outcrop foster a dense vegetation, which includes; live oak, mesquite, bee brush, shin oak, tasajillo, white brush, prickly pear, and Mexican persimmon.

Cap Mountain Limestone Member

Definition and Thickness

The Cap Mountain formation was named and described by Paige in 1911. The type locality is at Cap Mountain in Llano County. Paige in his original work referred to the Cap Mountain as a separate formation and included the Lion Mountain as a member of the Cap Mountain formation. In their revision, Cloud, Barnes and Bridge (1945, p. 154) reduced the Cap Mountain formation to member status and called it the middle member of the Riley Formation.

The thickness of the Cap Mountain member varies from 135 feet to 455 feet with an average thickness of 280 feet, according to Bridge, Barnes and Cloud (1947, p. 113). In the thesis area the exposed thickness ranges from 10 feet to 200 feet. Faulting is the main reason for these moderate thicknesses.

Lithology

The lower boundary of the Cap Mountain limestone, according to Bridge, Barnes and Cloud (1947, p. 113), is placed at the distinct topographic and vegetational change which is easily seen on aerial photographs. However, in the thesis area, these distinct changes were not always evident, so a different method was preferred by the author. The contact was placed at the first appearance of the predominantly red and buff calcareous sandstone and silty limestone ledges. This contact with the

Hickory sandstone member is gradational and the boundary is often placed arbitrarily.

The basal part of the Cap Mountain limestone member consists of reddish-brown, medium-grained sandstone and arenaceous or silty, tan to gray limestone. These basal limestones and sandstones are fairly resistant to weathering.

The middle part of the member is fine-to-medium-grained, silty, glauconitic, light gray, massive limestone containing minor amounts of corneous brachiopods. Although both the middle and upper parts of the Cap Mountain limestone member are silty in nature, some ledges in the middle part of the member often approach siltstones in composition.

The upper part of the Cap Mountain limestone is principally a fine-to-medium-grained, slightly arenaceous, fossiliferous, glauconitic, silty, light gray, massive limestone. The chief difference between the middle and upper parts of the member is the present of interbedded coquinoid limestone, known as "trilobite hash", in the upper part.

In both the middle and upper parts of the member the limestones give a very characteristic honeycomb or mottled effect upon weathering and display numerous trails and burrows (Plate XIV, Figs. 1 & 2).

A well developed dendritic structure was found on a piece of silty limestone, believed to be from the Cap Mountain limestone. The constituent mineral is probably pyrolusite or some other manganese oxide mineral (Plate XV).

Topography and Vegetation

The Cap Mountain tends to cap cuestas and low hills in the thesis area, the more resistant portions of the member being the capping rock.

PLATE XIV

Cap Mountain limestone member

Figure 1.—Honeycomb or mottled appearance of weathered Cap Mountain limestone member, 1000 yards west of the August Schmidt ranch house.

Figure 2.—Additional example of weathered Cap Mountain limestone member from above location. Note the fault terminating the limestone ledges.

PLATE XV


Excellently developed dendritic structure found on the Cap Mountain member outcrop immediately south of the Schep Creek fault on the Leroy Schmidt ranch.

Small portions of the Cap Mountain limestone outcrop were being farmed in 1956, but not to the same extent as the Hickory sandstone member.

The Cap Mountain limestone member does not support as heavy a vegetation in the thesis area as does the Hickory sandstone member. However, grasses, mesquites and Mexican persimmon were quite common, with smaller amounts of scrub oak, prickly pear, turkey pear, and catsclaw.

Lion Mountain Sandstone Member

Definition and Thickness

When Bridge (1937, p. 234) named and described the Cap Mountain formation he included the Lion Mountain as the upper member of the formation. In their revision of the Upper Cambrian, Cloud, Barnes and Bridge (1945, p. 154) gave the Lion Mountain member status and called it the upper member of the Riley formation. The type locality of the Lion Mountain sandstone member is at Lion Mountain in the northwest portion of the Burnet Quadrangle in Burnet County, Texas.

In the thesis area, the thickness of the Lion Mountain sandstones member probably exceeds the 50 foot maximum that the above writers placed upon it. Duvall (1953, p. 29) states that he measured 103 feet of Lion Mountain sandstone but he also believed that some underlying Cap Mountain limestone might have been included in his measurement.

It is estimated that 75 feet of Lion Mountain limestone member is exposed in the thesis area, although it was not practicable to measure a section of this unit.

Lithology

The lower contact of the Lion Mountain sandstone member was described by Bridge, Barnes and Cloud (1947, p. 114) as gradational but conveniently located at the lower edge of the sparsely vegetated Lion Mountain bench.

In the thesis area, the lower contact of the Lion Mountain sandstone member was placed where there was a noticeable change in slope from the gentle bench of the Lion Mountain sandstone member of the steeper and rockier slope of the Cap Mountain limestone member.

The basal portion of the member consists of a light gray to greenish gray, glauconitic, hard limestone interbedded with "trilobite hash". The limestone is thin to medium-bedded and is generally fairly resistant to weathering. These limestone beds are the only resistant part of the Lion Mountain sandstone member and the remainder of the beds weather to a deep red sandy soil.

The middle part of the member consists of thinly bedded, coarse, highly glauconitic sandstone alternating with thin beds of "trilobite hash" and thin layers of greenish-yellow shale (Plate XVI, Fig. 1).

The upper part of the Lion Mountain sandstone member crops out as a sparsely vegetated bench (Plate XVI, Fig. 2) covered by a few slabs of "trilobite hash" and numerous red to black hematite nodules (Plate XVII). These hematite nodules were from 1/2 inch in diameter up to 6 inches in diameter and are probably the weathering product of the highly glauconitic sands near and in the uppermost part of the member. Numerous corneous brachiopods or their molds are found in the nodules.

The uppermost five to ten feet of the Lion Mountain sandstone member in the thesis area was composed of a green sand that had an extremely high glauconite content.

PLATE XVI

Lion Mountain sandstone member

Figure 1.—Thinly-bedded shale between beds of "trilobite hash" found in the middle part of the Lion Mountain sandstone member on the northern part of the Leroy Schmidt ranch.

Figure 2.—Typical bench formed in the upper part of the Lion Mountain member located on the northern part of the Leroy Schmidt ranch.

PLATE XVII

Hematite nodules on a barren Lion Mountain sandstone bench.

Topography and Vegetation

The Lion Mountain sandstone member outcrop weathers to a sparsely vegetated bench that is covered with small slabs of "trilobite hash" and numerous hematite nodules. Spotty patches of grass occur on these benches but generally most of the growth is scrub oak. Cactus does not grow well on this soil but some prickly pear, tasajillo and Mexican persimmon are found.

## Wilberns Formation

The Wilberns formation is now comprised of four members that overlie the Riley formation. The name Wilberns was suggested by Paige (1911, p. 6) who derived it from Wilberns Glen in Llano County, Texas. The Wilberns formation that Paige (1912, p. 47) described does not contain the present fourth member, the San Saba limestone. Paige explained his reasons for not including the San Saba limestone with the other Cambrian rocks when he stated, (1912, p. 53) that there was considerable difficulty in placing a San Saba-Ellenburger contact and because of their similar lithologic character, the San Saba was included with the Ellenburger limestone of Ordovician age.

In 1945 Cloud, Barnes and Bridge (1945, p. 149) revised this earlier work and placed the upper boundary of the Wilberns formation at the top of the San Saba limestone member; however, they retained the lower Wilberns boundary that Paige (1912, p. 46) had established.

Bridge, Barnes and Cloud (1945, p. 149-150) further described the five members of the Wilberns formation which were, from oldest to youngest: (1) Welge sandstone member, (2) Morgan Creek limestone member,

(3) Point Peak shale member, (4) San Saba limestone member, and (5) the Pedernales dolomite member.

In a later publication, Barnes and Bell (1954, p. 35) proposed the dropping of the fifth member, the Pedernales dolomite, and placing it entirely within the San Saba limestone member.

Only the lower three members of the Wilberns formation are found in the thesis area.

According to Bridge, Barnes and Cloud (1947, p. 114), the Wilberns formation has a thickness of from 540 to 610 feet and the average thickness is considered to be 580 feet. In the southeast corner of the Llano uplift, only 360 feet are present because of truncation. Only part of the formation was measured in the thesis area.

## Welge Sandstone Member

### Definition and Thickness

In 1944, Barnes (1944, p. 34) named the basal sandstone of the Wilberns formation the Welge sandstone from the Welge Land Surveys in Gillespie County, Texas.

At its type section, on Squaw Creek one half mile north of the Gillespie County line, the Welge sandstone member is 27 feet thick. In the thesis area approximately 20 feet crop out. Duval (1953, p. 32) has measured 17 feet of the Welge sandstone member in an area northwest of the Big Bend of the Llano River Area.

### Lithology

At the Welge sandstone outcrop in the thesis area the sharp lower contact with the Lion Mountain sandstone was placed where the soft greenish to purplish glauconitic sandstone of the Lion Mountain member changed to a massive, orange-brown, slightly argillaceous, medium-grained sandstone of the Welge member.

The brown weathered surface of the Welge sandstone displayed numerous burrow marks and molds of phosphatic brachiopods. The sandstone had a siliceous cement and was non-calcareous except for the top few feet. Only minor amounts of glauconite were present in the member. A very noticeable feature of the individual sand grains composing the member was the recomposed faces that glittered in the sunlight.

The principal distinction between the Hickory and Welge sandstones is the relatively better sorting of the Welge member.

Topography and Vegetation

The Welge sandstone member forms a distinct scarp (Plate XVIII) which is easily recognizable throughout the thesis area.

Duvall (1953, p. 33) observed that the Welge sandstone member appears to form the resistant foot of a cuesta rising above the bench formed by the Lion Mountain sandstone member.

Much like the Hickory sandstone member, the Welge sandstone member supports a relatively dense vegetation which consists of scrub oak, mesquite, Mexican persimmon and white brush with lesser amounts of prickly pear and turkey pear.

## Morgan Creek Limestone Member

Definition and Thickness

Paige (1912, p. 47) included this limestone member at the base of his Wilberns formation. The Morgan Creek limestone member was first described by Bridge (Bridge, Barnes, and Cloud, 1947, p. 113) from a type

PLATE XVIII

Characteristic ledge of the Welge sandstone outcrop found 500 yards southwest of the Leroy Schmidt ranch house.

locality in Burnet County, Texas, just north of the junction of the north and south forks of Morgan Creek.

Bridge, Barnes, and Cloud (1947, p. 114) placed the Morgan Creek limestone member above the Welge sandstone member and described it as being from 70 to 160 feet thick with an average thickness of 120 feet.

It is estimated that the thickness of the Morgan Creek in the thesis area is 110 feet.

Lithology

The contact between the Morgan Creek limestone and Welge sandstone members is gradational and therefore is arbitrary. The contact was placed, by this author, at the first-occurring purplish-maroon, arenaceous limestone beds.

The basal part of the member consists essentially of purplish-maroon, thin- to medium-bedded, coarse-grained, arenaceous, moderately resistant limestone. These lower beds grade upward into a medium-bedded, more resistant, glauconitic, slightly fossiliferous, gray limestone that forms ledges on the slope.

A five to ten foot zone of Eoorthis texana beds is present about 50 feet above the base of the member. This zone contained a few well-preserved fossils in contrast to other fossiliferous zones found in the member which contained abundant fossils. Most of these fossiliferous or "hash" zones have small well-formed calcite crystals contained within them.

Above the Eoorthis zone the gray limestones become interbedded with shales which have become severely weathered and altered to caliche at most outcrops.

The upper part of the member is characterized by a three to six foot thick zone of small bioherms (Plate XIX) that have been considered to be immediately below the contact with theoverlying Point Peak shale member. These so-called "baby" bioherms range from 15 to 30 inches in diameter and at many places they are surrounded by a soft greenish-yellow shale that is completely weathered to caliche.

Topography and Vegetation

The outcrop of the member is sparsely vegetated and occurs commonly as a steep slope. Shin oak, spanish dagger and scrub oak comprise the major part of the vegetation with lesser amount of prickly pear, agarita, catsclaw and turkey pear.

Point Peak Shale Member

Definition and Thickness

Bridge (Bridge, Barnes and Cloud, 1947, p. 115) first described the Point Peak shale member on an isolated hill about four miles northeast of Lone Grove in Llano County, Texas.

According to Bridge, Barnes and Cloud (1947, p. 115-116), the Point Peak shale member is 270 feet thick at the type locality and averages 160 feet thick; however, in some areas it can be as thin as 25 feet. A section of the Point Peak shale member was measured on the Leroy Schmidt ranch about 7 miles south of Mason. A thickness of 136.9 feet of Point Peak and 17 feet of bioherms was measured (Appendix).

Lithology

The Point Peak shale member was mapped as two separate units, one being the shale facies and the other being the stromatolitic bio-

PLATE XIX

Small resistant bioherms found in the uppermost part of the Morgan Creek limestone member 500 yards southeast of the August Schmidt ranch house.

herm zone. Bridge, Barnes and Cloud (1947, p. 116) include the bioherms in the Point Peak shale member; however, some authors prefer to place them in the San Saba limestone member. The absence of the San Saba limestone in the area makes this problem beyond the scope of this paper. Therefore, the bioherm unit is considered to be in the Point Peak shale member.

The shale portion of the Point Peak shale member is thinly bedded, undulating, greenish-brown, with thin limestone stringers occurring throughout (Plate XI, Fig. 1).

The lower contact of the Point Peak shale member with the Morgan Creek limestone member has been arbitrarily placed at the point of change from limestone to shale. The contact for the purposes of this paper was placed at the first prominent shale outcrop above the "baby" bioherms (Plate XIX; page 57) in the uppermost part of the Morgan Creek limestone member.

The thin limestone ledges found in the basal Point Peak shale member are finer-grained than the underlying Morgan Creek limestone member; however, on first inspection they frequently look identical. There are several one-foot ledges in the upper basal Point Peak shale member that have a coarse texture and appearance. The coarse texture may be derived from dolomite crystals that are present in the limestone.

Frits (1954, p. 68) questioned the accuracy of describing the lower part of the Point Peak clastics as shales since he feels they more closely approximate siltstones. In the thesis area it was noticed that some of the finer clastics in the lower portions of the member could well be called siltstones because of their lack of fissility.

PLATE XX

Features of the Point Peak shale member

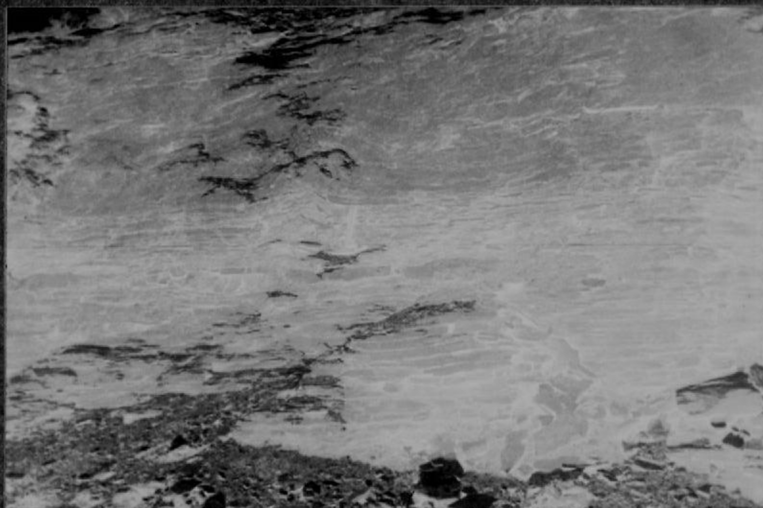


Figure 1.--Thin undulating shale beds of the Point Peak shale member found on the road cut 600 yards south-southeast of the August Schmidt ranch house.

Figure 2.--Symmetrical ripple marks at same location as above.

Some of the limestone ledges near the middle of the member are ripple marked (Plate XX, Fig. 2; page 60). These ripple marks strike in a northwest direction and measure eight inches from crest to crest.

Associated with these ledges of limestone are small (Plate XXI, Fig. 1) "cabbage head" bioherms that measure three to six inches in diameter and are surrounded by intraformational conglomerate. Most of the middle portion of the Point Peak shale member has intraformational conglomerate ledges scattered throughout the outcrop. These conglomerates are described in detail in the measured section in the Appendix.

The upper portion of the Point Peak shale member occurs as a steep slope covered with caliche and boulders of bioherms.

The bioherm zone, which was mapped separately, occurs on the highest elevations in the thesis area. Seventeen feet of bioherm zone were measured in the measured section (Appendix) but some of the other ridges have greater thicknesses of the unit.

The limestone that comprises these bioherms is a hard, gray, micro-granular to sublithographic rock with "cabbage head" structure ranging in diameter from one to three feet. The rock surrounding the bioherm structures is a coarse-grained, slightly arenaceous, brownish-gray glauconitic limestone. Since these bioherms (Plate XXI, Fig. 2) cap the ridges of the thesis area, they are subject to intense erosion and do not exhibit the excellent stromatolitic structure that can often be observed in the bioherms elsewhere in Mason County.

Topography and Vegetation

The slopes of the Point Peak shale member outcrop in the thesis

PLATE XXI

Bioherms

Figure 1.--"Cabbage head" bioherms found in limestone ledges near the middle of the Point Peak shale from the road cut 600 yards southeast from the August Schmidt ranch house.

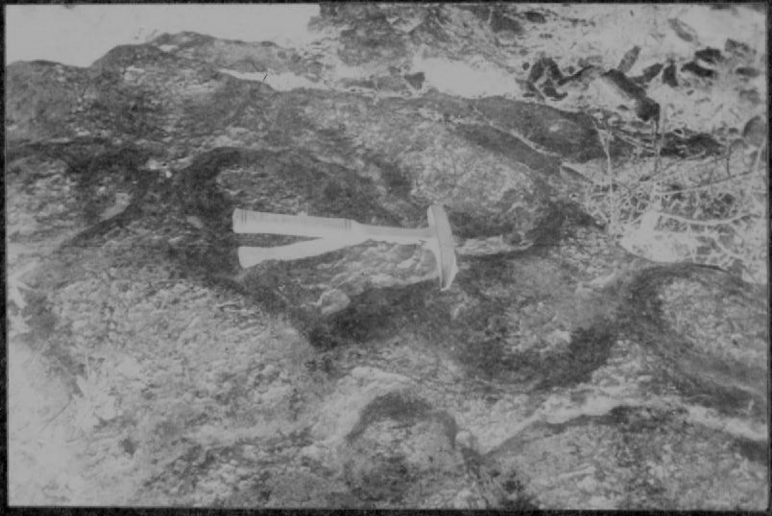


Figure 2.--The massive bioherm unit capping all of the highest hills in the thesis area.

area are generally rather steep and become steeper as the thick upper bioherm zones are approached.

The steep slopes of the Point Peak member in the area provide a poor soil for vegetation. The poor soil development could be caused in part by the constant erosion of the thin soil cover, thus not allowing it to become mature, and in part by the relatively high caliche content present on the outcrop.

On the bioherm zone at the top of the Point Peak member and on the Morgan Creek member outcrop a fair amount of vegetation is present which contrasts with the thinly vegetated slopes of the shale and limestone parts of the Point Peak member.

A thin growth of mesquite, scrub oak and Mexican persimmon is found on the outcrop in the thesis area. The vegetation found on the bioherm outcrop includes agarita, Spanish dagger, prickly pear, turkey pear, Mexican persimmon and some scattered catsclaw.

## QUATERNARY

### Alluvium and River Conglomerate

Along the Llano River there are several areas of alluvial deposits which were probably derived from drainage of the land to the north and from flood deposits from the Llano River.

Older stream gravels, of probable Tertiary or Pleistocene age, are also present in the area at higher elevations than the present flood plain of the river.

Another recent deposit that was observed along the river was a river conglomerate that was well cemented with a sandy matrix and contained large well-rounded boulders of most rock types common to the Llano region (Plate XXII).

PLATE XXII

Recent river conglomerate found along the Llano River on the Leroy Schmidt ranch.

# STRUCTURAL GEOLOGY

## GENERAL STATEMENT

The Llano region can be described as an eroded structural dome which exposes in its center a Precambrian basement complex. The elliptically shaped dome has affected an area of over 100 miles in diameter. Erosion has removed some of the Paleozoic and younger rocks from the center of the uplift and exposed a faulted complex of Precambrian and Paleozoic rocks, surrounded by a high rim of flat-lying Cretaceous rocks. The Big Bend of the Llano River area is located on the southwestern flank of the Llano uplift.

Major deformation in the Llano region occurred twice, once during the Precambrian, and once during Pennsylvanian time. Other less obvious deformation probably took place also.

Tight folding of the Precambrian gneiss is evident in the thesis area, which indicates deformation of these rocks by strong compressive forces. Granitic intrusions of these gneisses occurred several times before the Paleozoic Era. This folded intruded complex of basement rocks is separated from the overlying Paleozoic rocks by an extensive unconformity and the trends of the Precambrian deformation are not generally reflected in the overlying rocks.

According to Cloud and Barnes (1948, p. 121), the major faulting in the Llano region took place in the Late Paleozoic before Canyon time, probably near the end of Strawn time. The faults generally have a northeast-southwest strike which is shown in the thesis area. Most of the faults are normal and have fault plane dips from 60 to 90 degrees with displacements ranging from a few feet to 3000 feet.

Folding is also found in the Paleozoic rocks of the Llano region and it commonly occurs as broad gentle warps with no tight folding. One of these broad downwarps is present in the thesis area. Some very local folding has been reported as a result of drag along faults or slumping into limestone sinks and possible compaction around bioherm structures. None of these latter types of folding has been detected in the thesis area.

Plummer (1940, p. 58) described seven classes of local structure common to the Llano region. They are: spur ridges, normal faults, grabens, buried ridges, sharp flexures, symmetrical anticlines, and reef masses. Several of these structures occur in the thesis area and will be discussed in detail.

## Precambrian Deformation

### General Statement

According to Stenzel (1934, p. 74),

"The Precambrian rocks of the Llano uplift should be divided into three series from the point of view of structure. The series in order, No. I being the oldest are as follows:

III. Late dike intrusions, comprising the opaline quartz-porphyry and felsites.

II. Batholithic intrusions, comprising the various granites and their aplite and pegmatite dikes.

I. Folded frame metamorphic rocks, comprising the schists, including marbles and gneisses."

The only Precambrian rocks present in the thesis area are the fine-grained pink gneiss and the medium-grained pink granite, therefore, only the structural relationships of these units will be discussed.

Stenzel (1934, p. 74) mentioned that the average strike of the gneiss in the Llano region was northwest-southeast with average dip of

45 degrees. The general strike of the gneiss in the thesis area agrees with Stenzel's statement.

## Local Structure

In the thesis area, the local Precambrian structure consists of a series of tight folds in the gneiss unit which have been intruded by granite masses. The gneisses and granites are exposed in the eastern portion of the thesis area only. The general strike of the gneiss banding is north 50 to 60 degrees west, except where faulting has altered the direction of strike. The dips found in the folded gneiss are relatively steep throughout the unit, ranging from 40 degrees northeast up to 90 degrees. The pitch of the folded gneiss was not discernible in the thesis area.

There appear to be tight, slightly overturned folds within the gneiss unit as indicated by the pattern in which the strikes and dips of the gneiss appear upon exposure. The gneiss has dips of 60 degrees northeast in the western part of the exposure and toward the east the dips become vertical and then return to 60 degrees northeast. It appears that there would be at least one syncline and one anticline within the gneiss exposure in the thesis area.

A fault in the gneiss was detected principally from an abrupt change in the strike. This fault is located in the extreme eastern portion of the thesis area on the Hoerster ranch. The strike of the gneiss along the fault changes from north 60 degrees west to north 60 degrees east. Several other faults are found in the gneiss to the north of this fault but they are merely extensions of fault traces found in the bordering Paleozoic. The displacement of these faults in the gneiss is not determinable and can only be inferred from the direction of displacement found in the Paleozoic rocks.

The question arises as to whether the faulting detected in the gneiss is Precambrian or Paleozoic in age. It appears that where a fault involves displacement of Paleozoic rocks it must be no older than Paleozoic. However, in the case where the faulting cannot be easily connected with younger rocks, as in the fault on the Hoerster ranch, it appears that the faulting could possibly be Precambrian in age.

Another problem to be considered is whether the displacement in the gneiss was entirely vertical or whether horizontal movement was involved. These points are matters of debate but it is doubtful if, with the evidence at hand, they can be resolved.

The granitic rocks found in the thesis area are exposed only in two locations. Observation of these exposures indicates that the granite must have intruded the gneiss rocks. A transition zone along the Llano River on the Walker ranch would certainly indicate such an intrusion. This transition zone has been discussed in a previous part of the thesis.

## Paleozoic Deformation

### General Statement

According to Cloud and Barnes (1948, p. 119), the major fault trends of the Llano uplift are in the northeast-southwest quadrants. Folding has not been generally recognized in the Llano region; however, broad gentle warps have been reported by various authors on the Llano uplift. In the thesis area, there is some evidence for a broad shallow syncline which will be discussed later.

## Detection of Faulting

In many instances faults were located by abrupt terminations of beds along their trend, repetition and omission of strata and indications of variations in the normal strike and dip of beds. Very little fault breccia was found associated with faults in the thesis area.

The faults in the thesis area frequently were initially observed from variations in the vegetation which were often quite noticeable on aerial photographs. Some straight lines of vegetation which were noticed on the aerial photographs and thought to be faults were, upon field observation, found to be merely solution-widened joints that probably retained more moisture than the normal outcrop.

Many fault traces were difficult to follow over great distances because of the cultivated fields they would pass through.

## Faulting

The faulting in the thesis area is mostly normal in nature and in some instances becomes very complex. The major trend of the faults is northeast-southwest with an average strike of north 50 to 70 degrees east. There are two major faults, or at least faults traceable for long distances, located in the thesis area, the Peters Creek fault and the Schep Creek fault. The Peters Creek fault is herein named for Peters Creek within the thesis area, and the Schep Creek fault was named by Sliger (1957, p. 48).

To the north of the thesis area, a graben occurs between the Peters Creek and the Schep Creek faults, the former being downthrown to the southeast and the latter downthrown to the northwest (Fuller, 1957, personal communication). Southwestward, however, the throw of the Peters

Creek fault changes, and in the thesis area this fault is downthrown to the northwest with a maximum throw of close to 300 feet. The Schep Creek fault, although everywhere downthrown to the northwest, changes in throw from a minimum of 100 feet on the Dan Willman, Jack Walker and Jimmy Zesch ranches in the northeastern part of the thesis area to a maximum of 400 feet on the Leroy Schmidt ranch to the southwest.

These changes in throw suggest that, relative to the rocks northwest of the Peters Creek fault, the block between the Peters Creek and Schep Creek faults has been tilted downward toward the northeast, and that the next block, southeast of the Schep Creek fault, has been tilted even more in the same direction.

The Peters Creek fault is quite prominent in several localities but it does not form a continuous scarp as does Schep Creek fault. Much of the Peters Creek fault trace passes through fields, thus making an accurate location of the fault difficult. At one point on the August Martin ranch the resequent scarp is exposed along Peters Creek.

Along the Schep Creek fault are found many sliver faults which are most prevalent on the Leroy Schmidt ranch. This fault (Schep Creek fault) appears to divide into at least three branches near the Llano River and no explanation is evident for the occurrence of this phenomenon. The dips of the faulted rocks are the steepest found in the thesis area with some dips as high as 16 degrees to the southeast (Plate XXIII, Figs. 1 & 2). The trace of the Schep Creek fault is not straight but curves considerably in several locations. One of the curves in this fault is located where the fault terminates one end of the broad shallow syncline which has an axis almost perpendicular to the fault trace. It appears that

PLATE XXIII

The Schep Creek fault

Figure 1.—Steeply dipping beds of Morgan Creek limestone on the fault trace of the Schep Creek fault on the Leroy Schmidt ranch along the Llano River bank.

Figure 2.—Another view of the faulted rocks at the same location.

the Schep Creek fault could have been deflected slightly by the more resistant backbone effect offered by the broad syncline.

To the southeast of the Schep Creek fault, a branch of this fault remains essentially parallel to the major fault. This lesser fault is downthrown to the northwest and between it and the Schep Creek fault are several minor faults with predominantly northeast-southwest strikes. These minor faults have displacements of less than 80 feet in some instances and they are difficult to trace through fields. Because they are included entirely within the Hickory sandstone member, it is often difficult to determine the relative movement.

To the southeast of the Schep Creek fault on the O. G. Kimbriel ranch is located another zone of rather intense minor faulting. These faults have a northeast-southwest to east-west strike and appear to be in some manner connected with a larger fault that terminates them. The fault trace of the larger terminating fault is very distinctive along the Llano River on the O. G. Kimbriel ranch (Plate XXIV, Figs. 1 & 2). The minor faulting connected with this larger fault could have been caused by compressional stresses between the terminating fault and another larger fault to the northwest.

On the southern tip of the thesis area, where the Llano River makes its big bend, is located an area of intense faulting. These northeast-southwest trending faults have little displacement but they are numerous and joints are present. This zone of intense faulting is terminated to the northwest where the Schep Creek fault crosses the Llano River.

Other faults of a minor nature are found in the thesis area that are oriented with the major fault trends but their connection is not

PLATE XXIV

Fault within Hickory sandstone member

Figure 1.—A well exposed fault trace within the Hickory sandstone member located along the bank of the Llano River on the O. G. Kimbriel ranch.

Figure 2.—A close-up view of the above fault.

apparent. This faulting appears to have occurred at random and only to relieve local tensional stresses.

Several fault contacts are found in the thesis area, the most obvious ones being where the fault trace is the boundary between the Precambrian and Paleozoic rocks. The most striking example of such a contact is located just southeast of the Jimmy Zesch ranch house adjacent to the Simonville Road (Plate XXV).

## Folding

A fold in the Paleozoic rocks of the Big Bend of the Llano River area is present in the steep-sided hills located in the north-central part of the thesis area. A broad shallow syncline is indicated from the dips of the rocks which surround these hills. Dips were difficult to obtain from the strata in the hills because of the absence of ledges still in place. The dips, which do not exceed 10 degrees, are not everywhere indicative of a syncline but the overall picture presented by them outlines a broad shallow syncline. The axis of the structure as can best be determined strikes approximately north 30 degrees west. The northwestern end of the syncline, which is the nose of the structure, is not located on the thesis area but the outcrop pattern and dips indicate a plunge to the south. The southeastern end of the syncline is terminated by the prominent obsequent fault scarp of the Schep [illegible] fault which appears to have been deflected slightly by the increased resistance of the warped rocks.

There is no indication of any other Paleozoic folding in the thesis area. The syncline is of such dimensions as to be connected to a regional warping which has been suggested for the Llano region. From

PLATE XXV

Upturned Hickory sandstone along the Hickory-Precambrian fault contact southeast of the Jimmy Zesch ranch house adjacent to the Simonville Road.

the evidence at hand, it can only be assumed that the structure is part of a downwarp with undetermined limits.

## Age of Faulting

Since all of the rocks present in the thesis area are displaced by the faults it can be presumed that the faults are younger than any of the rocks. A possible exception is the fault which disturbs the structure of the Precambrian gneiss (p. 68).

According to Cloud and Barnes (1948, p. 121),

"...in the western part of the Llano uplift in the vicinity of Calf Creek, unfaulted beds of Canyon age overlap faulted rocks of Ellenburger age. The major late Paleozoic faulting is thus indicated to have taken place before Canyon time. The present authors do not know of evidence to indicate whether the faulting was in progress during Strawn time or was a post-Strawn and pre-Canyon event."

The age of the faulting in the thesis area is post-Point Peak, so it is logical to assume that its age is probably similar to that suggested by Cloud and Barnes (1948).

## Origin of Faulting

It has been suggested by Cloud and Barnes (1948, p. 118) that the faulting in the Llano region accompanied the late Paleozoic folding of the sediments in the Ouachita geosyncline located to the south and east.

Barnes (1956, p. 13) later described the normal faulting found in the Llano region as follows:

"A channel trending around the eastern and southern sides of the Llano area collected sediments during part of the Paleozoic, during the early Pennsylvanian, then became a trough of geosynclinal accumulation of sediments, and about the middle of the Pennsylvanian the sediments in the trough were folded, producing the Ouachita foldbelt. At this time the Llano uplift was extensively faulted, the faults all being normal and dipping between 60 and 90 degrees. The fault blocks are tilted in various directions mostly less than 10 degrees, but some small blocks along main faults are more steeply tilted."

The resultant of the forces described by Barnes (1956) probably put the entire Llano region under torque thus causing fracture in the rocks.

Paige (1912, p. 10) originally proposed that the faulting found in the Llano region was due to compression. Later, Cloud and Barnes (1948, p. 118) described the faulting as due to tensional stresses. Cheney and Goss (1952, p. 2263) have suggested that the grabens in the Llano region were formed at a different time than the horsts.

However, relatively tensional stresses have probably acted in the faulting of the thesis area, as indicated by the tilted block between the Peters Creek and Schep Creek faults.

The general dip of the strata in the thesis area is to the southeast; however, since the area lies on the southwestern flank of the Llano uplift it would be expected that the strata would have a dip to the southwest. The reason for this occurrence is not clear but either the intense faulting or the broad warping of the rocks could explain the unexpected dip.

# GEOLOGIC HISTORY

It would appear that a relatively thick sequence of Precambrian sediments once covered the Llano region. This thick series of sedimentary rocks was subsequently deeply buried, metamorphosed with varying intensity and then extensively intruded by igneous rocks.

Fossils are non-existent in the Precambrian sequence of rocks.

Flawn (1956, p. 27) reported that zircon age determinations indicate that the granites which intrude the metamorphosed series are 1,000 million years old. These age determinations, if correct, would make the metamorphosed sediments at least this old.

During the late Precambrian or Early Cambrian time the intruded metamorphosed Precambrian complex was uplifted and severely eroded. Driekanters found by Barnes and Parkinson (1940, p. 665) indicate that the Llano area had been uplifted for a considerable period of time before Late Cambrian (Hickory) deposition began.

The Hickory sandstone member was deposited on a very uneven Precambrian erosional surface that, according to Bridge, Barnes and Cloud (1947, p. 113), had relief approaching 800 feet. The early Paleozoic seas invaded the region and reworked the sands of "eolian origin" to form the basal part of the Hickory member. Cloud and Barnes (1948, p. 111) express doubt as to whether the Hickory actually represents eolian sedimentation.

It cannot be disputed that the seas had invaded the Llano area by Middle Hickory time, as indicated by the presence of marine fossils and ripple-marked sediments. However, the intraformational conglomerates and ripple marks in the middle part of the member would indicate that the seas were shallow throughout most of the deposition of the Hickory sandstone member.

The gradational contact between the Cap Mountain limestone and Hickory sandstone members is evidence of the continuance of the submergence. The land surface must have continued its slow subsidence because of the calcareous sediments of the Cap Mountain limestone member. Only moderate depths were approached because sand and glauconite were still deposited.

The nature of the sediments of the area of subsidence indicates an alternation of condition of the water during the deposition of the detrital sediments of the Lion Mountain sandstone member. The glauconite present in the member indicates relatively still water while the numerous "trilobite hash" zones indicate periods of very active wave action.

The contact between the Lion Mountain sandstone and Welge sandstone is abrupt, perhaps representing a diastem, a disconformity or at least an interruption in deposition. Glauconite is not found in the deposit comprising the Welge sandstone unit.

The Morgan Creek limestone was deposited under conditions of diminishing detrital sediments and an increase of calcareous materials. A warm sea of moderate depth is indicated in Morgan Creek time because of the glauconitic character of the limestones along with the abundance of fossils and bioherms.

Argillaceous sediments were deposited to form a major part of the Point Peak shale member. Cloud and Barnes (1948, p. 112) described the argillaceous materials as coming from the west. The intraformational conglomerates found in the Point Peak shale member indicate the presence of widespread flats of limy mud that were frequently flooded by the tides. The dense limestones and thick bioherm sequence reveal that the seas returned to a moderate depth and were warming.

Rocks from Late Cambrian to Quaternary in age were not found within the thesis area; therefore, the following discussion of the geologic history has been taken principally from literature dealing with the Llano region.

The warm seas present during the deposition of the bioherms continued into the San Saba limestone deposition with more detrital material being laid down.

Sedimentation from Cambrian to Ordovician time was continuous. The warm, moderately shallow seas persisted during the deposition of the Ellenburger limestone, whose formation in shallow water is suggested by ripple marks and intraformational breccias which were described by Cloud and Barnes (1948, p. 33). These same authors (1948, p. 113) describe the sea bottom as being a "generally soft bottom of pure carbonate muds" during Ellenburger deposition.

Perhaps the greatest truncation of Ellenburger rocks and "probably the longest period of Paleozoic emergence of the Llano region occurred before Devonian time" (Cloud and Barnes, 1938, p. 113). This emergence is evidenced by the fact that no rocks of Upper Ordovician or Silurian age are found in the Llano region. Some Devonian sediments are found to the east and west of the uplift but the rocks are very thin, for the most part filling solution cavities in the underlying Ellenburger limestone.

"Marine invasions occurred at several times during Mississippian and Pennsylvanian time", (Cloud and Barnes, 1948, p. 113) and deposited sediments on the truncated Ellenburger surface. The thinning of the Mississippian Chappel and Barnett formations suggests a positive movement in the Llano region (Sellards, 1947, p. 48).

The Pennsylvanian Marble Falls formation was deposited on an eroded and truncated Barnett formation. Paige (1912), describes the black shales at the top of the Pennsylvanian as suggesting a return to extensive swamplike conditions. A full record of the Mississippian and Pennsylvanian deposition is not present because of widespread post-Pennsylvanian erosion.

A pre-Canyon disturbance which broke the Llano region into an extensive system of northeast-southwest-trending faults is indicated by the remaining Pennsylvanian rocks.

Permian, Triassic, and Jurassic rocks are not present in the Llano region and this period represents a time of profound erosion and uplift. The entire Llano region was truncated, thus allowing the Cretaceous seas to deposit sediments on Precambrian, Cambrian, Ordovician, and Carboniferous rocks.

The Cretaceous rocks have since been eroded from the center of the uplift and form a high rim around the exposed Precambrian and Paleozoic rocks.

There are only random records of Tertiary or later events in the Llano Region.

In the Big Bend of the Llano River Area a rejuvenation of the Llano River and the streams emptying into it indicates a recent uplift in the general region of the thesis area. Stream gravels at high elevations on the O. G. Kimbriel and Jimmy Zesch ranches and incised streams along the Llano River indicate a rejuvenation of the drainage of the thesis area after Cretaceous time.

Along the Llano River on the Leroy Schmidt ranch there are some Recent river gravel conglomerates (Plate XXII; page 65) that are composed of every rock type present in the surrounding area.

# ECONOMIC GEOLOGY

The most important resource of the Big Bend of the Llano River Area is ground water. This ground water is obtained principally from the Hickory sandstone, an important aquifer throughout the Llano uplift. The water is used not only to irrigate crops but also to replenish cattle tanks, (small reservoirs) which have contained little or no water during the past several years.

The possibility of oil being present in the area is remote, as Cloud and Barnes (1948, p. 33) indicated by stating that,

"...petroleum will probably not be found by drilling in the Llano region because of the complex faulting of the potential source beds and their present exposure to the atmosphere."

Within the Llano region some Lower Paleozoic and Precambrian rocks have been used for building stones or road metal; however, none of the rocks present in the thesis area have been used as yet for such purposes.

No ore deposits of economic importance have yet been discovered on the thesis area.

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# A P P E N D I X

A section of Middle and Lower Hickory sandstone which begins on the Llano River about .7 miles east of the Simonsville Road bridge and ends on the top of an isolated hill about .1 miles north from the O. G. Kimbriel ranch house. The section was measured with the assistance of J. L. Goolsby.

Thickness in feet

Riley formation

Middle Hickory sandstone member (Goolsby, 1957)

5. Sandstone, sandstone conglomerate and minor shales. This unit consists of light to dark tan, friable, poorly exposed sandstones, sandstone conglomerates and thinly bedded shales. These rocks tend to weather into rectangular blocks. In the sandstone the quartz grains are subrounded and are fair to well sorted and are cemented with iron oxide. Abundant phosphatic brachiopods are found in the sandstone. The sandstone conglomerate is a hard, orange to dark reddish brown, thin to medium bedded rock. Many angular fragments of middle Hickory are found along with phosphatic brachiopods oriented at random angles. The matrix of the rock is a medium-grained sand with abundant iron oxide. On several slumped ledges ripple marks are noticeable but are too badly weathered to measure. The shale portion of the unit is light unit is light gray to pale

green, soft, thinly bedded, silty and exhibits fucoidal material. . . . . . . . . . . . . . . . . . 35.1

Follow creek bed southeastward down to its junction with the Llano River. This part of the section has many small faults and accurate measurements could not be obtained.

4. Sandstone and shale. Predominantly sandstone, yellowish-brown, hard, thinly bedded; quartz grains subrounded and medium-grained; limonite appears to be absent; some few phosphatic brachiopods. This unit is well exposed in deeply cut stream bank. The shale is pale-gray to white, fairly soft, thinly bedded, with some fucoids and poorly developed symmetrical ripple marks. . . . . . . . . . . . . . . . . . . . . . . . 28.4

Lower Hickory sandstone member (Goolsby, 1957)

3. Sandstone, dull white, hard, resistant, massively bedded, quartz grains subangular with some pink microcline and mica evident, poorly sorted, some individual grains show frosting, cross-bedding present, but poor. Several fault planes are present in the unit with white, calcareous, fine-grained sandstone along the planes. Fine-grained white sandstone at 74.0 feet above the base of the section. . . . . . . . . . . . . . . . . . . . . . . 18.9

Shift: 200 yards down Llano River to the northeast.

2. Sandstone, gray with some local red and reddish-brown layers, hard, resistant, massively bedded.

Medium to coarse, quartz grains subrounded with iron oxide coating, some small amounts of pink microcline and mica, locally well developed cross-bedding. Reddish to brown colored sandstone at 53.0 to 59.2 and 25.6 . . . . . . . . . . . 57.4

1. Conglomerate, brown to pink; weathering to darker brown, massive with poorly sorted angular quartz, no apparent cement. The average diameter of the grains is 1 inch. Occurrence of pink microcline increasing (becoming almost arkosic) with large fragments of pink microcline, with all pebbles at random angles to bedding planes. Contact with medium-grained pink granite. 5.0

Total thickness measured. . . . . . . . . . . . 144.8

A section of the Point Peak shale member on the Leroy Schmidt ranch (7 miles south of Mason, Texas) at the road cut on Ridge Road. The section was measured with the assistance of Dr. M. C. Schroeder.

| | Thickness in feet |
|---|---|
| Wilberns formation | |
| Point Peak shale member | |
| 19. Bioherm, olive gray to dark gray, massive, sublithographic to microgranular limestone. The bioherms are not well preserved since they cap a ridge. The bioherms appear to be 20 to 30 feet in diameter. The "cabbage head" structures are severely weathered and give a very rough appearance. . . . . . . . . . . . . . . | 17.0 |
| 18. Covered slope. This unit is a slope covered with float of intraformational conglomerate, sublithographic limestone boulders and numerous shale fragments partially altered to caliche. The abundance of caliche would indicate that the slope is composed mainly of shales and siltstones with thin limestone and conglomeratic limestone ledges. At 132.0 to 131.5 feet above the base of the section a thin ledge of fine- to medium-grained limestone is visible. From 145.0 to 147.5 feet a shale is apparent but weathered too extensively to describe. At 146.0 to 146.5 and 147.0 to 147.5 there are two ledges | |

of intraformational conglomerate with shale interbedded between the conglomerate. From 147.5 to 199.0 the rock is mainly concealed with only a few thin (6 inches) limestone ledges exposed at 155.0, 160.0, 161.0 and 170.0 feet. A relatively good ledge of fine-grained gray limestone is exposed from 179 to 180.0 feet . . . . . . . . . . . . 83.5

17. Limestone and intraformational conglomerate. This unit differs from the other conglomerates described in the section in that the fragment size is much larger than was generally found. Fragments ranged from 1/4 to 2 inches in diameter, some fragments being lithographic limestone. . . . . . . . . . . . . . . . . . . . . . . . 0.7

16. Siltstone, light tan to white, undulating, extremely thinly bedded, which weathers badly to caliche. This caliche covers all but the lower few feet of the unit. Undulating siltstones are similar to those found in unit 9 . . . . . . . . 11.7

15. Shale (possibly siltstone). Dark olive green, silty, slightly indurated, undulating, thinly bedded, almost platy, weathers easily. The unit changes at 89.0 feet to a greenish-brown siltstone. At 92.0 to 92.4 feet there is a thin ledge of intraformational conglomerate in a matrix of fine-grained gray limestone. The shale

near the top of the unit gets more silty. Above the conglomerate ledge small tight fold structures are present with dip on the limbs up to 90 degrees. On the bedding planes of both the shales and siltstones are small mica flakes that have a glittering texture . . . . . . . . . . . . . . . . . 7.5

14. Conglomeratic limestone with included "cabbage head" bioherm structures. The limestone is fine- to medium-grained, gray limestone with flat olive-green limestone fragments oriented horizontally except immediately adjacent to the "cabbage head" structures. The bioherms are small, ranging in diameter from three to six inches and composed of microgranular to sublithographic limestone.. . . . 0.5

13. Covered slope. Essentially weathered shale fragments that have been altered to caliche. . . . 3.5

12. Limestone. Very similar to unit 10 except the ripple marks are better exposed allowing some representative measurements to be made. The ripple marks have a wave length of 20 cm and amplitude of 2 cm. . . . . . . . . . . . . . . . . . 1.0

11. Shale, interbedded with stringers of gray fine-grained limestone, very similar to unit 9 except the limestone stringers appear to be more evenly spaced throughout the unit. The top three feet of the unit are covered with caliche. . . . . 4.0

10. Limestone, greenish-brown, hard, fine-grained, has a coarse texture upon weathering. This effect is caused by differential weathering of a recrystallized "fossil hash" lens, of which small portions appear to be almost sublithographic in nature and hardness. The limestone is ripple marked on its upper side but no measurements of the marks were made . . . . . . . . . . . . 1.0

9. Shale, olive-green to light green, interbedded with stringers of fine-grained gray limestone. Some yellowish-brown to tan, undulating siltstones are present ranging in thickness from 1/4 to 3 inches. Undulation of the siltstones were apparently caused by compaction over the limestone stringers. Abundant white to pale green caliche was being formed from the shale. The bedding planes of the shales and siltstones have mica flakes. The unit occurs with limestone interfingering the shale at the base and with shales interfingering with siltstones and limestone stringers at the top . . . . . . . . . . . . . . . 9.2

8. Limestone, light gray, weathers to medium dark gray, glauconitic with some limonite stains, medium-bedded, medium-grained limestone. This unit is non-fossiliferous with large amounts of glauconite, some weathered to limonite . . . . . . 2.5

7. Concealed shale, same as unit 5. . . . . . . . . . . 2.3

6. Bioherm, same as unit 4. . . . . . . . . . . . . . . 1.0

5. Concealed shale. A small section with abundant caliche present. . . . . . . . . . . . . . . . . . 1.0

4. Bioherms, olive-gray, weathering to darker gray, hard, micrograular to sublithographic, appearing to be slightly more resistant than those described in unit 1. . . . . . . . . . . . . . . . . . . . . . 0.5

3. Covered slope. A caliche-covered slope that appears to be shale because of the abundant shale fragments being altered to caliche. This is the approximate contact between the Point Peak shale member and the Morgan Creek limestone member of the Wilberns formation. . .. . . . . . . . . 7.0

Total Point Peak member measured. . . . . . . . . 153.9

Morgan Creek limestone member

2. Limestone, grayish-purple, medium-grained, bedded, with alternating thin lenses of fossil fragments occuring up to 8 inches thick. . . . . . . . . . . . 7.5

1. Bioherms, purplish-green to greenish gray, sublithographic, surrounded by glauconitic limestone. The bioherms are more resistant than the surrounding rock and a slight relief can be noticed. . . . . . . . . . . . . . . . . . . . . . . . 1.0

Total Morgan Creek member measured. . . . . . . 8.5

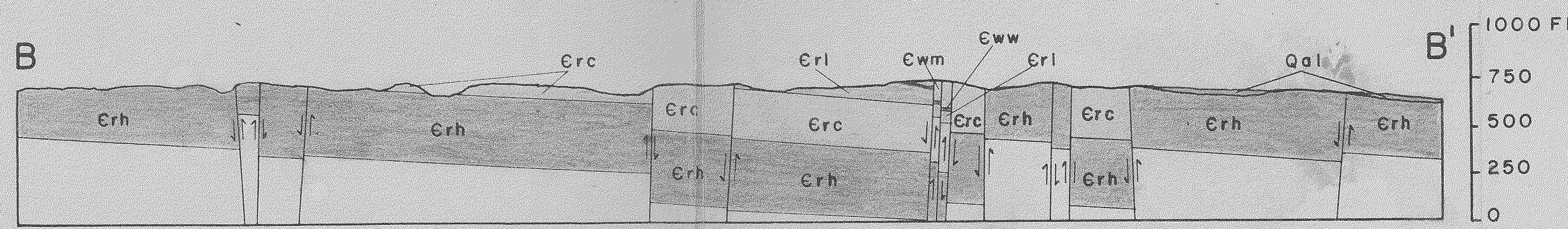
Total thickness measured. . . . . . . . . . . . . 162.4

PLATE I

# GEOLOGIC MAP OF THE BIG BEND OF THE LLANO RIVER AREA, MASON COUNTY, TEXAS


## STRUCTURE SECTIONS

SECTION A-A'
(elevations estimated)




SECTION B-B'
(elevations estimated)

SCALE 1:20000

0 — 1/2 — 2 MILES

0 850 1700 3400 5100 6800 9500 10200 FEET

VERTICAL SCALE: 3 X horizontal scale; 0 = arbitrary datum

## EXPLANATION

### GEOLOGIC COLUMN

QUATERNARY

- Qs — River sand
- Qal — Alluvium

CAMBRIAN — Upper Cambrian

Wilberns Formation

- Ꞓwpb / Ꞓwp — Point Peak shale member (Bioherms at top)
- Ꞓwm — Morgan Creek limestone member
- Ꞓww — Welge sandstone member

Riley Formation

- Ꞓrl — Lion Mountain sandstone member
- Ꞓrc — Cap Mountain limestone member
- Ꞓrh — Hickory sandstone member

UNCONFORMITY

PRECAMBRIAN — Precambrian

- pꞒmg — Medium-grained granite
- pꞒg — Gneiss

### SYMBOLS

- Normal fault; u, upthrown side; d, downthrown side
- Inferred normal fault
- Observed contacts
- Strike and dip of strata
- Property line
- Intermittent stream
- Flowing stream
- A—A' Structure section line
- Spring
- Flowing well
- Windmill
- Stock tank
- Cemetery
- Ranch building
- Improved earth roads
- Unimproved earth roads
- TS Thin section locality
- Measured section