GEOLOGY OF THE SQUAW CREEK-MARSHALL CREEK AREA, MASON COUNTY, TEXAS

A Thesis

By

ISAAC WAYNE WOOLSEY

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Approved as to style and content by:

Horace R. Blank
(Chairman of Committee)

S. A. Lynch
(Head of Department)

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A B S T R A C T

The Squaw Creek-Marshall Creek area is a rectangle of approximately 20 square miles located in the southeastern part of Mason County, Texas. U. S. Highway 87 crosses the area near its eastern boundary. The area is located on the southwestern flank of the Llano uplift and rocks of Precambrian, Paleozoic, Mesozoic, and Cenozoic age are exposed within it.

The Precambrian rocks consist of a gneiss unit, a schist unit, a coarse-grained granite, and a fine to medium-grained granite.

Upper Cambrian and Lower Ordovician rocks make up the Paleozoic strata exposed in the area. The Upper Cambrian rocks are divided into two formations; the Riley formation that includes (from oldest to youngest) the Hickory sandstone, Cap Mountain limestone, and Lion Mountain sandstone members; the overlying Wilberns formation that includes (from oldest to youngest) the Welge sandstone, Morgan Creek limestone, Point Peak shale, and San Saba limestone members. The Ordovician rocks are represented by the lower part of the Ellenburger group.

Nearly flat-lying beds of Cretaceous age extend into the area from the south and represent the rocks of Mesozoic age. An arkose conglomerate that is believed to be of Lower Cretaceous age is found cropping out at the base of the Cretaceous hills.

The Cenozoic rocks are represented by stream and alluvial deposits. A small narrow hill composed of a caliche conglomerate and located in the northeastern part of the area is believed to be a stream

deposit of Tertiary age. Recent alluvium composed of wash from the Cretaceous hills covers a wide belt at the base of these hills.

The Paleozoic rocks exposed in the area have an average strike of N. 40° E. and a dip of 2°-5° SE.

Two major faults occur in the thesis area, the Loyal Valley fault in the eastern portion and the Squaw Creek fault in the northwestern portion. Numerous minor faults occur with the major faults and form highly faulted zones. The faults are normal and have steep dips and a prevailing northeast-southwest trend. They have a varying throw and form horsts and graben within the faulted zones.

A complex jointing system occurs in the area and is especially well developed in the broad Cap Mountain limestone belt in the central portion.

Folding is restricted to the small local folds due to differential compaction of the sediments above the bioherm zones.

The most important resource of the area is the grazing land. No ore deposits or petroleum have been found.

GEOLOGY OF THE SQUAW CREEK-MARSHALL CREEK AREA,

MASON COUNTY, TEXAS

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

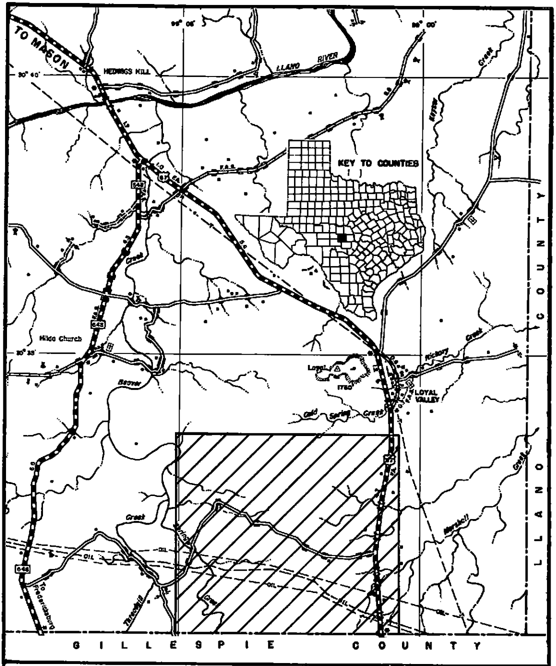
LOCATION

The Squaw Creek-Marshall Creek area is a rectangle of approximately 20 square miles located in the southeastern part of Mason County (see fig. I). It is bounded by latitudes 30°30' and 30°34' North and by longitudes 99°00' and 99°06' West. The Mason-Gillespie County line coincides with the southern boundary and U. S. Highway 87 crosses the area about 0.3 miles west of and parallel to its eastern boundary. Squaw Creek crosses the southwestern corner of the area and just out of the area to the west it connects with Threadgill Creek to form Beaver Creek. Beaver Creek meanders into and out of the northwestern portion of the area.

ACCESSIBILITY

In general the area is readily accessible by vehicle. Its eastern side may be reached from Mason or Fredericksburg via U. S. Highway 87. It may be approached on the western side by Farm to Market Road 648 which branches off U. S. Highway 87 north of the area. From this road a graded county road passes through the central part of the area and connects with U. S. Highway 87 approximately 1 3/4 miles north of the Mason-Gillespie County line (see fig. I). There are numerous ranch trails scattered over the area but most of these require a jeep or pick-up for use.

Figure I



Reproduced from Highway Map
of Mason County, Texas,
prepared by Texas State
Highway Department, 1956

LOCATION OF THE SQUAW CREEK-MARSHALL CREEK AREA,
MASON COUNTY, TEXAS

METHODS OF INVESTIGATION

Following a review of the literature the actual geologic field work was performed during the period from July 15, 1957 to September 13, 1957. The field work consisted primarily of locating accurately the contacts between various geologic units, determining the strike and dip of these strata, locating and recording the attitude of faults, and collecting lithologic and paleontologic samples for determining the age of and describing the geologic units. Field observations were recorded on acetate-covered prints of vertical aerial photographs prepared by the U. S. Department of Agriculture. The mapped area is covered by photographs 127 through 129 of series DFZ-3P dated November 17, 1955 and by photographs 219 through 221 of series DFZ-2P dated January 2, 1956. The approximate photograph scale is 1:20,000 or one inch equals 1667 feet. These photographs were used as base maps and served as an aid in locating general formation outcrop patterns as well as fault traces. The Brunton compass was used to measure the dip and strike of the outcropping bedded rocks. This compass, a measuring rod, and a hand level were used to measure the thickness of beds and to prepare a measured stratigraphic section. The information gathered in the field and the information plotted on the base map were used to construct the final geologic map of the area (Pl. I). Enlarged maps with a scale of approximately one inch equal to 660 feet were made for two localities in the area. Plate II is an enlarged geologic map of a southeastern portion of the area and plate III is an enlarged geologic map of a northwestern portion of the area. Structural cross sections are included with the final geologic maps to give a more complete illustration of the structural problems. In the construction of the cross sections, horizontal distances were scaled from the photographs, and the topographic relief was estimated by the use of a stereoscope.

PREVIOUS INVESTIGATIONS

Some detailed geologic work has been done in the Llano region of Central Texas, but none has previously been conducted in the thesis area.

A letter written by Ferdinand Roemer in 1846 to the editors of The American Journal of Science and Arts, seems to be the first published geologic reference to the Llano region (Roemer, 1846). This publication concerns primarily the Cretaceous rocks and fossils from bordering areas. Roemer briefly mentions specimens of coarse-grained granite obtained from outcrops approximately 20 miles north of Fredericksburg. It was believed by Roemer that the plutonic rocks of the Central Mineral region were part of the crystalline mass of the Rocky Mountains, and that the boundary where the stratified rocks of the east side of the continent come in contact with the crystalline masses of the Rocky Mountains is found in this area. In 1848, a second publication by Roemer, based on observations made while accompanying an exploring party of German colonists to the San Saba River, referred to the existence in this region of Lower Silurian and Carboniferous rocks. This publication also gave a description of the characteristic fossils of these strata. Later studies by Roemer (1849) gave a more thorough account of the stratigraphy and paleontology of the Paleozoic rocks in the Central Mineral region of Texas. The first geologic map of Texas was prepared in connection with this report. Roemer (1852) gave a detailed description of the Cretaceous rocks and fossils of Texas, accompanied by a description of the Paleozoic strata and fossils of the Llano region in the appendix.

The notes of Dr. G. G. Shumard (1886) made while passing through the Llano region in 1855 and 1856, gave a brief description of the geology along a route through the San Saba River Valley to Fort Mason and Fredericksburg.

B. F. Shumard (1861) presented a review of the fossil descriptions by Roemer and gave additional descriptions of the fossils found in the Llano region. In this paper Shumard describes the rocks and fossils in the Llano region as equivalent to the Potsdam group of the New York System.

C. D. Walcott (1884) made a hurried reconnaissance of a portion of the Paleozoic area of central Texas, and established the Upper Cambrian age of the Potsdam group. He found an unconformity at the base of all Potsdam sections studied in central Texas and proposed the local name Llano group for the series of pre-Potsdam strata whose best exposures occur in the county of Llano.

R. T. Hill (1887) gave a brief discussion of the geology of the Llano region and mentioned the importance of the work of Roemer and Walcott. Two years later Hill (1889) named and established the age of the Carboniferous rocks cropping out in the vicinity of Marble Falls. The erosion of the Cretaceous rocks from the Llano uplift was discussed by Hill (1890) in a paper concerning the major geographic features of Texas.

The organization of the Texas Geological Survey in 1889 brought about the first actual comprehensive geological examination of the Llano region. T. B. Comstock (1889) published a preliminary report of the geology of the Central Mineral region in which he gave a description of the geology with particular emphasis on the rocks of pre-Carboniferous age. In this report the names Valley Springs and Packsaddle were applied to the Precambrian gneisses and schists and the terms Hickory series, Riley series, and Katemcy series were applied to the Cambrian rocks exposed in the uplift.

R. S. Tarr (1890) described the general history of the drainage system of central Texas and concluded that the major streams of the region were developed originally on the Cretaceous strata in Tertiary times, and after removing this cover they were superimposed upon the underlying Paleozoic rocks.

Paige (1911) in a report on the mineral resources of the Llano-Burnet region of Texas, named and briefly described the Cap Mountain, Wilberns, Ellenburger, and Smithwick formations. In addition Paige applied the name Hickory sandstone to the strata which had been designated the Hickory series by Comstock and redefined the Valley Springs gneiss and the Packsaddle schist. Paige (1912) published a detailed geologic map of the Llano and Burnet quadrangles. A detailed description of the geology, including measured sections, accompanied this map.

A geologic map of Texas is presented by Udden, Baker, and Bose (1916), in a publication by the Bureau of Economic Geology. This map shows Cretaceous, Pennsylvanian, Undivided Paleozoic, Cambrian-Ordovician, and Precambrian rocks outcropping in the Llano region.

Plummer and Moore (1922) presented a map of the Carboniferous formations and introduced the name Barnett for the lower Bend shale, differentiating it as a separate formation.

Girty and Moore (1919) presented a discussion on the age of the Bend series. Girty maintained that the correct age of the Barnett shale was Mississippian, whereas Moore believed it to be Pennsylvanian. The crinoidal limestone beds beneath the Barnett shale have been established as of Early Mississippian age by Girty (Roundy, Girty, and Goldman, 1926). Sellards (1932) applied the name Chappel to this new formation.

Deen (1931) presented a discussion of the algal reefs in the Wilberns formation in Mason County.

The Ellenburger limestone in the Camp San Saba area was correlated with strata of the Ozark region in Missouri through the use of fauna by Dake and Bridge (1932). No formational boundaries were proposed for the Ellenburger although a lithologic sequence was recognized within the unit.

A thorough review of the stratigraphy of the pre-Paleozoic and Paleozoic systems in Texas has been presented by Sellards (1932).

Stenzel (1932) reinvestigated and redefined the Valley Springs gneiss and the Packsaddle schist of the Llano region.

Sellards (1934) discussed the Paleozoic deformation of the Llano region and indicated that the Llano uplift originated as a positive element as early as mid-Mississippian time. The Precambrian structural conditions in the Llano region are discussed by H. B. Stenzel in this report. A report was presented by Stenzel (1935) on Precambrian unconformities in Llano County.

A state geologic map (Darton et al, 1937) issued by the U. S. Geological Survey shows the Paleozoic rocks of the Llano region to be divided into the Canyon group, the Strawn group, the Smithwick shale, the

Marble Falls limestone, the Ellenburger limestone, the Wilberns and Cap Mountain limestones, and the Hickory sandstone.

In a study of the Lower Paleozoic rocks of the western side of the Llano uplift, Bridge (1937), named the Lion Mountain sandstone member of the Cap Mountain formation and redescribed many of Roemer's type localities. Bridge and Girty (1937) redescribed Paleozoic fossils of the Llano region that were described earlier by Roemer.

Barnes and Parkinson (1939) were first to report the occurrence of dreikanters in the basal Hickory sandstone. A map of Hickory sandstone outcrops in central Texas, showing dreikanter localities, was presented by them.

Keppel (1940) published a paper concerning the structure and texture of the coarse-grained granites of the Llano-Burnet area.

Cheney (1940) attempted to identify the subdivisions of the Ellenburger group by insoluble residues and the general character of well cuttings. He also proposed rearrangement of certain formations and groups of the Pennsylvanian and Lower Permian strata.

Barnes (1941) described the overlap of Lower Cretaceous sediments on the south side of the Llano uplift in a paper read before the Geological Society of America.

Papers by Plummer (1939, 1944, and 1945) concerning the origin of travertine deposits in the Llano region have been published in abstract form.

Barnes (1944), in a paper dealing primarily with the occurrence of gypsum in the Edwards limestone of central Texas, gave a brief discussion of the Precambrian, Paleozoic, and Cretaceous rocks of the Llano region.

Cloud, Barnes, and Bridge (1945) divided the Ellenburger group into the following formations: The Tanyard formation at the base, containing the Threadgill and Staendebach members; the Gorman formation in the middle; and the Honeycut formation at the top. These three formations were correlated with the Gasconade, Roubidoux, and Jefferson City formations of Missouri. In addition, the authors proposed the name Riley formation to include the Hickory sandstone, the Cap Mountain limestone, and Lion Mountain sandstone members.

Barnes, Cloud, and Warren (1945) published a description of the Devonian rocks found in central Texas. Two years later Barnes, Cloud, and Warren (1947) described two new formations of Devonian rocks occurring in the Llano region. In upward succession the Devonian units are the Pillar Bluff limestone and the Stribling, Bear Spring, and Zesch formations.

Plummer (1946), in a report on Texas water resources, discussed the importance of the Hickory sandstone and Ellenburger limestone as aquifers in central Texas. Plummer (1950) published a detailed description of the Carboniferous rocks of the Llano region. This paper contains fossil descriptions, measured sections from various localities, and a geologic map showing the Carboniferous rocks.

The Upper Cambrian units in the Llano uplift in central Texas were described or redefined by Bridge, Barnes, and Cloud (1947). This paper was published for the purpose of providing a standard reference for the Upper Cambrian stratigraphic units in central Texas.

Cloud and Barnes (1948) published a detailed report on the Ellenburger group of central Texas.

Blank (1951 a and b) discussed the exfoliation and weathering on granite domes in the Llano region. The existence of "rock doughnuts" or the doughnut-shaped weathering pits is one of the features discussed by the author.

Hendricks (1952) published a paper on the correlation between surface and subsurface sections of the Ellenburger group. The author emphasized the importance of insoluble residues as a method of dividing the Ellenburger.

Alexander (1952), McGrath (1952), Polk (1952), Duval (1953), Parke (1953), Fritz (1954), Grote (1954), Dannemiller (1957), Fuller (1957), Mounce (1957), Scaife (1957), Sliger (1957), Sweet (1957), and Wilson (1957) have presented detailed geologic work on small areas in the Llano region. Rogers (1954) presented a detailed report on an arkosic conglomerate found cropping out in Mason, Menard, and Kimble Counties, Texas. Goolsby (1957) presented a detailed report on the Hickory sandstone of the Llano region.

Barnes and Bell (1954) presented a review of the rocks of the Llano region from Precambrian up through Pennsylvanian time. Several measured and described sections are included in this report.

Flawn (1954), through a study of cores and cuttings of subsurface Precambrian rocks, made a subdivision of the basement in Texas and southeast New Mexico. In this subdivision, the Texas craton is proposed to be the fundamental basement element in this area and it apparently came into existence in "Middle Precambrian" time. Flawn (1956) presented a more complete report on the basement rocks of Texas and southeast New Mexico which included a general discussion of the basement rocks of the Llano region.

The lead and zinc deposits in the Upper Cambrian rocks of central Texas are reviewed by Barnes (1956). Several measured sections of the Cambrian rocks are included in the appendix of this report.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr. Horace R. Blank and Dr. Melvin C. Schroeder, of the Agricultural and Mechanical College of Texas, for their aid in selecting the thesis area and for their many helpful criticisms in the pursuance of this problem and its final solution.

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Special appreciation is expressed to Joan B. Woolsey for her assistance in preparing this paper. The equipment used in the field work belongs to the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas.

G E O G R A P H Y

CLIMATE

The Squaw Creek-Marshall Creek area is located within the semi-arid belt of central Texas. According to the Texas Almanac (1958-1959) published by The Dallas Morning News, the annual rainfall is 22.50 inches for Mason County. This may vary from a few inches up to about 45 inches. A serious drouth condition has existed in Mason County for several years but was somewhat relieved in 1957. Although more rainfall occurred in 1957 much of it was lost by runoff, since the rains came in heavy showers during the winter and early spring months. For example, in the early spring of 1957 approximately 16 inches of rainfall occurred within a two week period.

The average annual temperature in Mason County is 64° F. (Texas Almanac, 1958-1959). It may vary from 110° F. in the summer to -5° F. in the winter.

VEGETATION

The vegetation found in the thesis area is that which is adapted to the semi-arid climate, wide temperature ranges, and rocky and rugged slopes. Cedar, mesquite, Mexican persimmon, and oak trees are found primarily on the areas of higher elevation while pecan and cottonwood are found in the valleys and along the streams. Several species of cacti are indigenous to the thesis area and some of them have served the ranchers as cattle feed during the drouth years. Numerous species of grasses occur in the region but overgrazing and drouth have seriously depleted the natural grass cover. Tharp (1952) presented a discussion and a list of the various species of grasses occurring in the region.

The following is a list of the predominant vegetation found in the thesis area.

Common Name	Scientific Name
<u>Trees</u>	
Mesquite	Prosopis juliflora
White brush (bee brush)	Aloysia ligustrina
Mexican persimmon	Brayodendron texanum
Cedar	Juniperus mexicana
Catsclaw	Acacia greggii
Cottonwood	Populus deltoides
Pecan	Hicoria pecan
Live oak	Quercus virginiana
Post oak	Q. stellata
Blackjack oak	Q. marilandica
Shin oak	Q. mohriana
<u>Cacti</u>	
Prickly pear	Opuntia phaeacantha
<u>Yucca</u>	
Spanish dagger	Yucca treculeana
<u>Grasses</u>	
Hairy grama	Bouteloua hirsuta
Sideoats grama	B. curtipendula
Buffalo	Buchloe dactyloides
Curly mesquite	Hilaria belangeria
Texas needle grass	Stipa leucotricha

The local variation and distribution of vegetation are due primarily to the nature of the bed rock, and as a result of this, the contacts between the various stratigraphic units may be marked by a change in vegetation. The significant differences in the vegetation for each separate rock unit are discussed later under the stratigraphy of each unit.

INDUSTRY

Most of the thesis area's surface lies in ranches and stock farms devoted to cattle, sheep, Angora goats, and hogs. There are very few cultivated fields, and of these the primary use is for growing feed for the livestock. Cotton and peanuts are the principal commercial crops grown in the region, but very little of either is grown in the thesis area.

Large production of beef cattle was originally the most important phase of the ranching, but overgrazing and a long drouth period have caused beef production to be supplemented by the raising of other stock.

There is no irrigation in the thesis area at the present time, but some of the ranchers have indicated plans for irrigating on a small scale in the future.

A few of the owners in the area live in the nearby city of Mason, and have other sources of income. The hunting season provides the ranchers with a small income, since about 10 percent of the state's annual deer crop is killed in Mason County. Turkey, quail, and dove also produce an attractive hunting season.

PHYSIOGRAPHY

GEOMORPHOLOGY

The Squaw Creek-Marshall Creek area is located on the southwestern flank of the Llano uplift. The Llano region is structurally a great dome, but topographically a broad basin. Precambrian and Paleozoic rocks have been exposed by erosion within the basin and are surrounded by a high flat rim composed of undisturbed Cretaceous rocks.

According to Plummer (1950) the highest elevations in the Llano region, which are over 2,200 feet, are located on the plateau between Fredericksburg and Mason. The lowest elevation, about 650 feet, is located where the Colorado River flows out of the region southeast of Marble Falls. This indicates a maximum relief of approximately 1,550 feet.

The Cretaceous hills in the southeastern portion of the thesis area are estimated to be 1,980 feet above sea level. The elevation at the bottom of Cold Spring Creek located just north of the area is estimated to be 1,590 feet. This allows a maximum relief of about 390 feet.

Along the eastern edge of the thesis area, and extending far beyond it toward the east, is a rugged lowland developed on the Precambrian rocks and on the Hickory sandstone. This lowland is separated by the Loyal Valley fault from the higher and more resistant Paleozoic limestones to the west. Within the thesis area the northern part of the lowland is underlain by the Precambrian rocks, and several granite and gneiss knobs rise above the gently rolling topography. In contrast the southern part, underlain by the Hickory sandstone, is rather flat and contains only a few exposures of the bedrock. An exceptional feature in the northern part is a northeast-southwest trending hill of caliche conglomerate overlying the Precambrian rocks (location 5, Pl. I). Likewise, in the southern part one exceptional sandstone hill about 100 feet high is located 0.5 miles north of the Mason-Gillespie County line and 0.2 miles west of U. S. Highway 87.

West of the lowland, beginning at the fault-line scarp on the west side of the Loyal Valley fault and extending throughout most of the thesis area, the gently dipping Paleozoic rocks form a plateau of somewhat higher elevation. This plateau indicates a condition of peneplanation must have existed before the deposition of the Cretaceous strata. Within this plateau a rather obscure drainage divide trends north-south through the central part of the area. The plateau is dissected into rocky hills by a dendritic drainage system both eastward and westward from the divide.

A narrow valley, parallel to and on the southeast side of the Squaw Creek fault, crosses the plateau in the northwestern portion of the area. It is underlain by the Hickory sandstone and bounded on the northwest side by a fault-line scarp composed of the Paleozoic limestones. It is bounded on the southeast side by the harder, more resistant Cap Mountain limestone. The valley becomes extremely narrow to the north due to less displacement on the Squaw Creek fault and exposure of only the upper part of the Hickory sandstone.

The highest elevations are formed by nearly horizontal beds of Cretaceous age in the southeastern part of the area. These rocks form a nearly flat-topped plateau overlying the plateau formed by the Paleozoic rocks. Thick accumulations of wash from the Cretaceous hills support some cultivated fields.

EROSIONAL AGENCIES

The most effective agent of erosion on the thesis area is running water. Although the area is in a semi-arid climate, the rainfall tends to come in heavy showers resulting in a great deal of runoff. The vegetation has decreased because of the long drouth period and has little effect in retarding the runoff.

Minor erosional effect is caused by strong winds in areas of little vegetation and loose material.

DRAINAGE

Plummer (1950, p. 8) pointed out that four principal streams drain the Llano region. These are the Colorado River on the east, the San Saba River on the north, the Llano River in the central part, and the Pedernales River on the south.

Tarr (1890), in a study of the drainage patterns of the Llano region, provided abundant proof that these major streams originated upon the Cretaceous strata during Tertiary time. After removal of the Cretaceous rocks they became superimposed upon the harder Precambrian and Paleozoic rocks now exposed.

Squaw Creek and Beaver Creek are the largest streams in the thesis area. Squaw Creek, cutting across the southwestern portion, joins Threadgill Creek just off the western edge of the area to form Beaver Creek. Beaver Creek meanders into and out of the northwestern portion of the area. These creeks are tributaries to the Llano River and are superimposed upon the Precambrian and Paleozoic rocks. Several of the larger tributaries to Beaver and Squaw Creeks are also of the superimposed type, but a few of the smaller ones follow the existing structure and are subsequent. An example of the subsequent type is the small stream in the Hickory valley in the northwestern portion of the area. At approximately 1/4 mile northeast of R. Evers' ranch house this stream empties into a stream that flows southeast-northwest, cutting across the Hickory valley and the hard resistant limestones northwest of it in a distinct water gap. This latter stream, despite its small size, must be superimposed and older than the subsequent stream following the Hickory valley.

As mentioned previously, a local drainage divide extends through the central portion of the area from north to south. The largest streams east of this divide form tributaries to Cold Spring Creek to the north and Marshall Creek to the east of the area. In contrast to the streams west of the divide, these streams are in agreement with the present regional dip and appear to be of the consequent type. However, they also may have originated upon the Cretaceous strata and may be superimposed.

With the exception of Beaver and Squaw Creeks, all of the streams in the thesis area are intermittent.

STRATIGRAPHY

GENERAL STATEMENT

The stratigraphic column for the thesis area is as follows:

Cenozoic Era

- Quaternary System
  - Recent Alluvium
- Tertiary System (?)
  - Caliche conglomerate

Mesozoic Era

- Cretaceous System
  - Lower Cretaceous (Comanchean) Series
    - Limestone and conglomeratic sandstone
    - Arkosic conglomerate

Paleozoic Era

- Ordovician System
  - Lower Ordovician Series
    - Ellenburger limestone
- Cambrian System
  - Upper Cambrian Series
    - Wilberns formation
      - San Saba limestone member
      - Point Peak shale member
      - Morgan Creek limestone member
      - Welge sandstone member
    - Riley formation

Lion Mountain sandstone member

Cap Mountain limestone member

Hickory sandstone member

Precambrian System

Igneous rocks

Granite

Metamorphic rocks

Gneiss and schist units

Only one small section was measured and described by the author (see appendix), primarily for obtaining the thicknesses of the members. However, the type section of the Welge sandstone member of the Riley formation is located in the southwest corner of the area. A detailed description of this type section has not been published. Through correspondence with Dr. Virgil E. Barnes, who named the member, it was learned that the Squaw Creek section, which includes the type Welge sandstone, was measured and described several years ago and will appear in a volume on the Cambrian of Texas by Dr. Virgil E. Barnes and Dr. W. C. Bell. The measured and described section includes not only the Welge sandstone, but also the Lion Mountain sandstone, 14 feet of Cap Mountain limestone, and three feet of Morgan Creek limestone. The top of the section is about 1,700 feet northeast of mile marker 29 on the Gillespie-Mason County line, about 1,200 feet slightly south of west from Lehman's hunting cabin, and on the south side of Squaw Creek. The base of the section is about 2,100 feet due north of mile marker 29, about 2,000 feet slightly north of west from Lehman's hunting cabin, and on the west bank of Squaw Creek. Along with the Squaw Creek section, another section, the Threadgill Creek section will be described by Dr. Barnes and Dr. Bell. The Threadgill Creek section actually begins at the granite outcrop along Squaw Creek and extends up Threadgill Creek. It is painted in five foot intervals with yellow paint. Although there is no detailed description of the Threadgill Creek section in print, fossils have been collected and described from this section by Palmer (1954).

PRECAMBRIAN ROCKS

Precambrian igneous and metamorphic rocks form the northern part of the lowland along the eastern boundary of the area. Granite and gneiss predominate, with schist cropping out at one locality and pegmatite veins found in various parts of the Precambrian rocks. One exposure of a coarse-grained granite is found in the western part of the area.

Metamorphic Rocks

The term Llano series was first applied to the metamorphosed rocks of the Llano region by Walcott (1844, p. 43). Comstock (1889) made the first division of the rocks into two units, the Packsaddle schist and the Valley Spring gneiss. The type localities for both units are in Llano County, at Packsaddle Mountain and Valley Spring respectively. Paige (1911, p. 14, and 1912, p. 25) redefined and applied these names to the metamorphic rocks which he mapped in the Llano-Burnet area. He believed the Valley Spring gneiss to be the older of the two units and that possibly some of the metamorphic material in it may have been originally igneous. Paige regarded these rocks as probably of Algonkian (Proterozoic) age. Sellards (1932, p. 32) presented a description of the two units and restated Paige's belief concerning their age. Stenzel (1932,

p. 143, and 1934, p. 74) stated that the Valley Spring gneiss was igneous in origin and intruded, with conformable contacts, into the Packsaddle schist. Under this interpretation, the Packsaddle schist is the only Precambrian sedimentary formation.

Paige (1912, p. 33) discussed another Precambrian unit, the Red Mountain gneiss and believed it to be formed by metamorphism of an intrusive granite. Barnes (1945, p. 56) reviewed the divisions of the Precambrian rocks made by Paige and in addition defined still another metamorphic unit, the Big Branch gneiss. This gneiss is of igneous origin and is the predominant rock of the Precambrian of northeastern Gillespie County and northwestern Blanco County. It has intruded the Packsaddle schist and Valley Spring gneiss, but has been intruded by the granites, pegmatites, and aplites of the area. Barnes, Romberg, and Anderson (1954, p. 79) gave a brief discussion of the Precambrian rocks in the Llano region and agreed with Paige on the relative age of the units, the oldest unit being the light-colored, highly feldspathic Valley Spring gneiss, followed by the dark-colored Packsaddle schist. These rocks were highly folded, and during the folding igneous rocks were intruded which were metamorphosed into the Red Mountain gneiss and the more important Big Branch gneiss.

Paige (1912) prepared an areal geologic map of the Llano quadrangle that extends almost to the eastern edge of the thesis area. This map indicates that the Packsaddle schist should extend into the thesis area. Barnes, Romberg, and Anderson (1954, p. 80), on a generalized geologic map of the Llano region, showing Precambrian rocks, also indicate the presence of the Packsaddle schist unit in the thesis area.

Two main groups of metamorphic rocks are found in the thesis area, a gneiss unit which is predominant and a schist unit which is found cropping out at one locality. The contact between these two units is not exposed; therefore the units were not mapped separately, but the location of the schist unit is shown on the accompanying geologic map (Pl. I).

Gneiss Unit

Occurrence and relationships

The gneiss unit forms a narrow strip in the eastern part of the thesis area. The best exposures are found in the road cut along U. S. Highway 87 and in small knob hills formed by the unit on the east side of the highway (Pl. IV, fig. 1, 2). The foliation planes of the gneiss are distinct in only a few localities, but these show the general strike of the unit to be in a northeast-southwest direction. The average strike is about 20 degrees east of north, and the dip ranges from 40 to 60 degrees southeast.

The gneiss unit is bounded on the west by the Loyal Valley fault separating it from Upper Cambrian units. The fault is parallel to and just west of Highway 87. A rather high escarpment is formed by the more resistant Upper Cambrian limestones. The actual contact between the gneiss and Upper Cambrian units cannot be seen because of soil cover. To the south, the gneiss is unconformably overlain by the Hickory sandstone. To the east, with the exception of the schist outcrop, a transition zone is present between the gneiss and granite. This zone is not distinct throughout the area, but no actual contact of the gneiss with the granite was found in the area.

PLATE IV

Exposures of Precambrian Gneiss

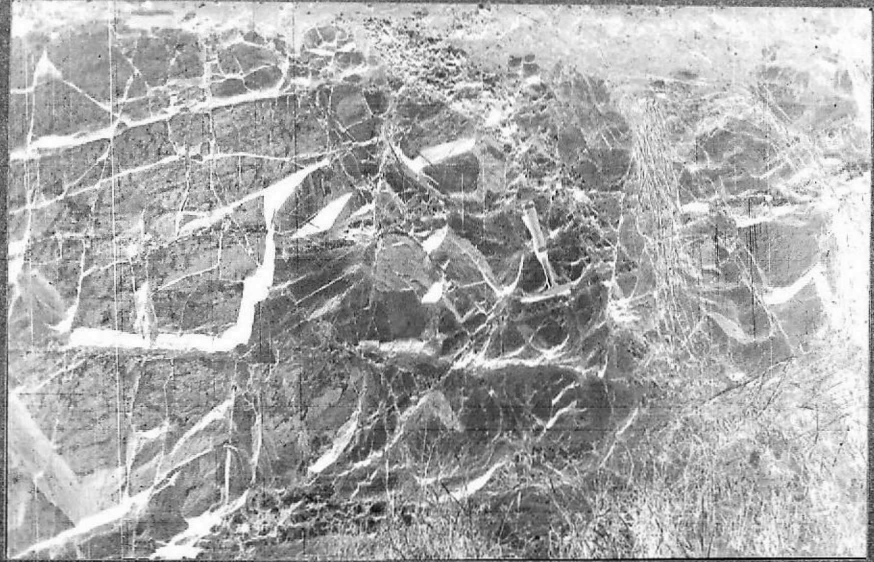

Figure 1.—Road cut exposure of gneiss unit along U. S. Highway 87 about 0.2 miles north of entrance to the Henry Keyser, Jr. residence.

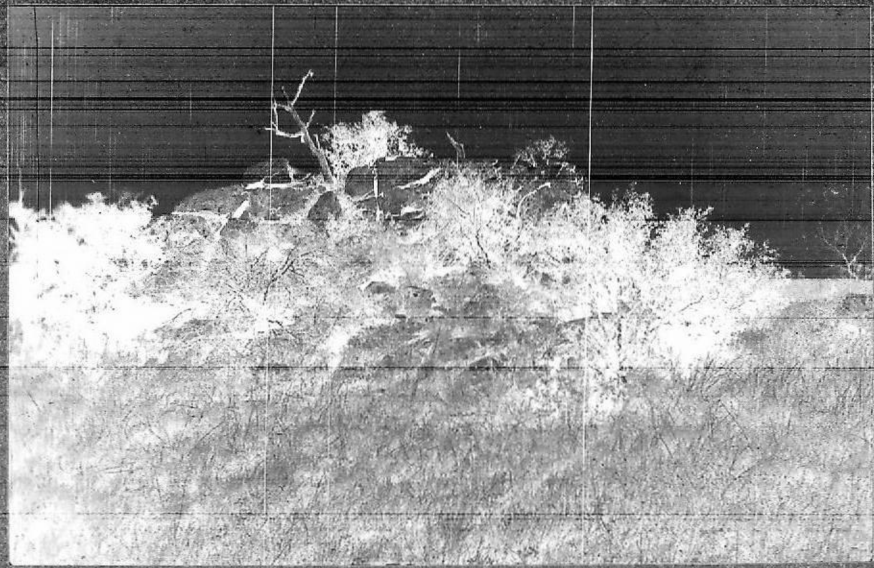

Figure 2.—Small knob or hill exposure of gneiss unit on east side of U. S. Highway 87 about 0.1 miles north of entrance to the Kelley Keller residence.

Megascopic description

The texture and composition of the gneiss unit vary in different parts of the area. At several localities near the granite rocks, the gneiss is pink, medium-grained, hard, and generally massive. It weathers easily to a light reddish-brown color. The most abundant mineral is pink feldspar which gives the gneiss its characteristic color. Colorless quartz and black biotite are present in about equal amounts.

A much finer grained, lighter colored, loosely consolidated gneiss is found farther away from the granite. This gneiss is highly weathered and good fresh samples could not be obtained. It is tan to light brown in color with a reddish-brown weathered surface. Colorless to cloudy quartz is the principal mineral, with some light-colored feldspar and specks of a darker mineral making up the remainder of the unit. The darker mineral, possibly biotite, has been altered in places and occurs only in specks scattered throughout the rock. A good exposure of this gneiss is found in the road cut three-fourths mile south of Kelley Keller's residence along U. S. Highway 87 (Pl. V, fig. 1).

Numerous pegmatite dikes are found in the gneiss unit (Pl. V, fig. 1). They are composed principally of large grains of colorless to milky quartz with various amounts of feldspar. There are some darker minerals present; usually biotite can be identified, but it appears in small amounts.

Aplite dikes occur in the unit, but are not as numerous as the pegmatite dikes. The constituents are essentially the same as those appearing in the pegmatite dikes (Pl. V, fig. 2).

Several fragments of quartzite were found along the fault-line at the western edge of the gneiss belt. These are composed of materials

PLATE V

Pegmatite and Aplite Dikes

Figure 1.--Fine-grained, loosely consolidated gneiss, intruded by pegmatite dikes exposed along U. S. Highway 87 about one mile south of entrance to Kelley Keller's residence.

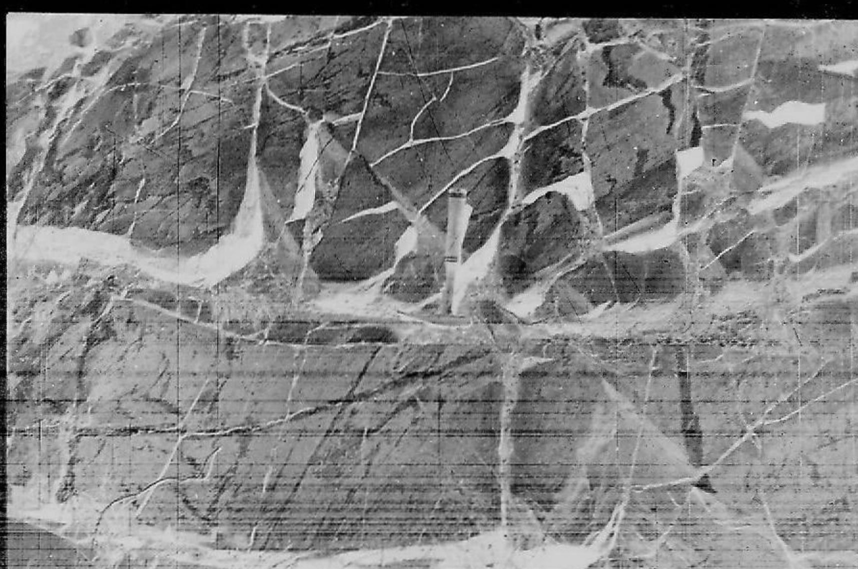

Figure 2.--Massive, highly weathered gneiss intruded by aplite dikes of different ages exposed in road cut along U. S. Highway 87 about 0.2 miles north of entrance to the Henry Keyser, Jr. residence.

resembling Lower Hickory sandstone. A megascopic examination suggests that the quartzite is composed entirely of fine to medium-grained, colorless quartz. The evidence indicates that the quartzite was originally part of the Hickory sandstone and was left as fragments along the fault plane.

Topography and vegetation

In general, the gneiss unit forms a flat lowland covered with a light brown to reddish-brown soil. A few small hills or knobs are found protruding above this flat lowland. Scattered on the surface are large fragments of colorless to milky quartz with some smaller fragments of pink feldspar. These fragments are the remains of the more resistant pegmatites that have intruded the gneiss (Pl. VI, fig. 1).

The vegetation is generally sparse, mainly due to drouth conditions, but mesquite, scrub oak, and various grasses seem to be predominant (Pl. VI, fig. 2).

Schist Unit

Occurrence and relationships

The schist unit is found at what is considered and mapped as one locality by the author; however, two different schist types are exposed at this locality. One exposure, of biotite schist, is found in the bed of a small creek about 0.3 miles directly south of the Kelley Keller residence. The other exposure, of hornblende schist, is located approximately 30 yards south of the biotite schist exposure. Both exposures are isolated due to the soil cover. No contact between these two exposures or between either exposure and the surrounding igneous or gneiss units could be found. The biotite and hornblende schists appear to be located

PLATE VI

Surface Expressions of Precambrian Gneiss

Figure 1.--Large milky quartz and smaller feldspar fragments scattered on the surface about 0.1 miles south of the Kelley Keller ranch house.

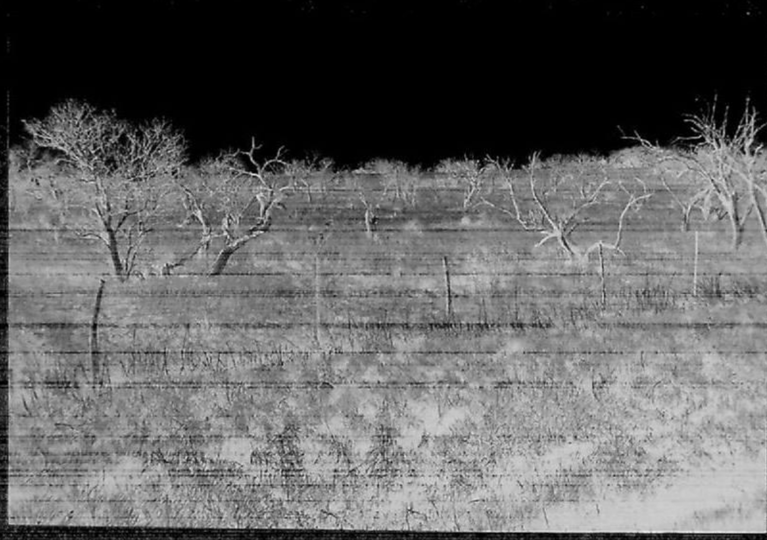

Figure 2.--Typical topography and vegetation on Precambrian gneiss, looking east from a point one-half mile south of Keller's store on U. S. Highway 87.

within the transition zone between the gneiss and granite.

Megascopic description

Megascopically, the biotite schist is composed chiefly of biotite with a considerable amount of milky quartz. The quartz occurs in thin layers in some parts of the schist but more commonly occurs scattered throughout the rock. The flakes of the biotite are arranged in such a manner as to show distinct foliation in parts of this schist. The average strike of the foliation is N. 20° W. and its dip about 60 degrees to the northeast. The schist is loosely consolidated and highly weathered throughout the exposed area (Pl. VII, fig. 1).

The hornblende schist, in contrast to the loosely consolidated biotite schist, is very hard, dark black, and fairly resistant to weathering. This schist is composed principally of black slender prisms of hornblende having their long direction in a parallel arrangement and showing a fibrous, silky luster. Very small quartz grains are scattered throughout the rock (Pl. VII, fig. 2).

Topography and vegetation

The biotite schist crops out in a small valley with a thick cover of soil and has more vegetation than the hornblende schist located just out of the valley. The type of vegetation found on the soils of both schists is essentially the same as that found on the soils derived from the gneiss unit.

Igneous Rocks

General Statement

The metamorphic rocks of the Llano region have been intruded by a variety of igneous rocks, all of which are assigned to Precambrian

PLATE VII

Exposures of Precambrian Schist

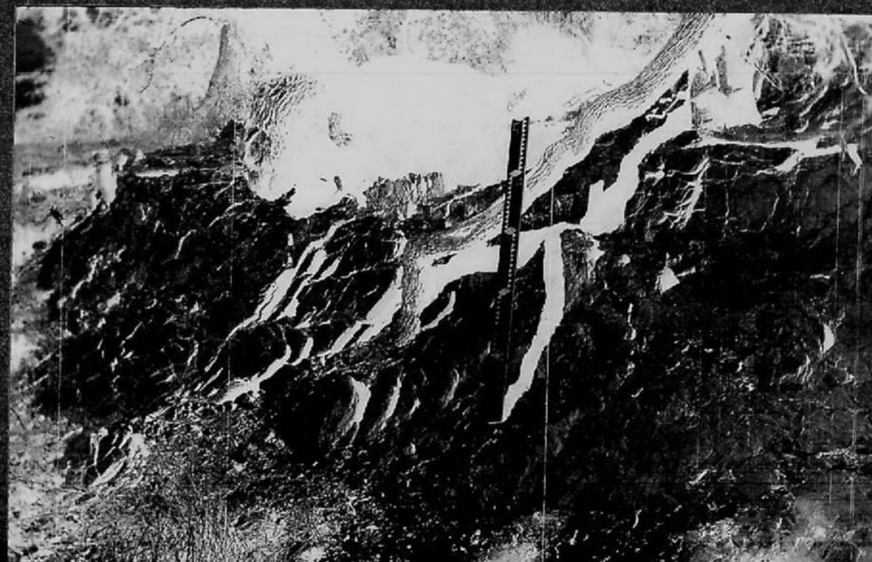

Figure 1.—Loosely consolidated schist exposed in small creek about 0.3 miles due south of the Kelley Keller residence.

Figure 2.—Hornblende schist exposed approximately 0.4 miles due south of the Kelley Keller residence.

age, even though several periods of igneous activity are represented. Roemer (1846), Schumard (1861), Walcott (1884), and Comstock (1889-1890) are some of the early geologists who mentioned and described the igneous rocks of the region. For a comprehensive account of the igneous rocks exposed in the Llano uplift, the reader should refer to Paige (1911, 1912), Stenzel (1932, 1935), Keppel (1940), Goldich (1941), Barnes (1945), and Barnes et al (1950).

Stenzel (1932, p. 114) divided the batholithic intrusions (from oldest to youngest) into: (1) the pink, coarse-grained, Town Mountain granite, (2) the grey to pink, medium-grained, Oatman granite, and (3) the grey, fine-grained, Six-mile granite.

Flawn (1956, p. 27) stated that the batholithic granite exposed in the Llano uplift has an age of about 1,000 million years.

Two granites of different texture are found in the thesis area, a coarse-grained, pink granite in the western part and a medium-grained, pink granite in the eastern part.

Coarse-Grained Granite

Occurrence and relationships

The coarse-grained granite is exposed in Squaw Creek about 200 yards north of the graded county road. Squaw Creek cuts across a northeast-southwest trending horst which forms a hill with Lower Hickory sandstone overlying the granite. Good exposures are located on both sides of the creek. These exposures are an excellent illustration of the pre-Hickory relief and of the superposition of Squaw Creek (Pls. VIII and IX). In plate VIII, figure 1, the ruled five foot board and hammer are lying upon the granite. The head of the hammer is just below the contact between

PLATE VIII

Figure 1.

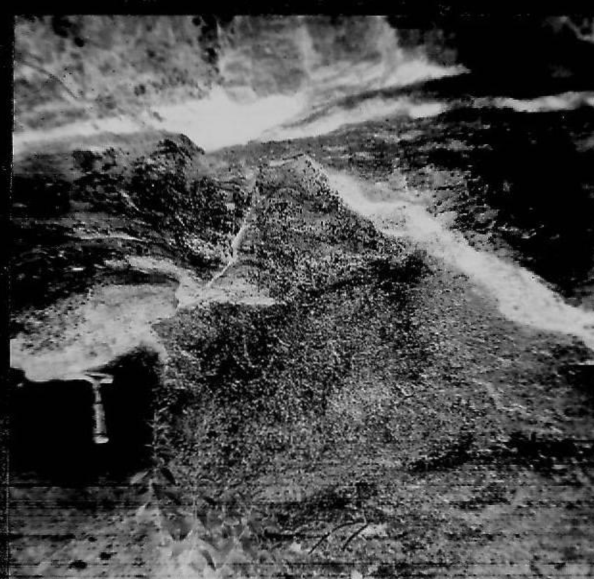

Figure 2.

Coarse-grained Precambrian granite and Lower Hickory sandstone contact exposed in Squaw Creek about 200 yards north of the graded county road.

PLATE IX

Figure 1.

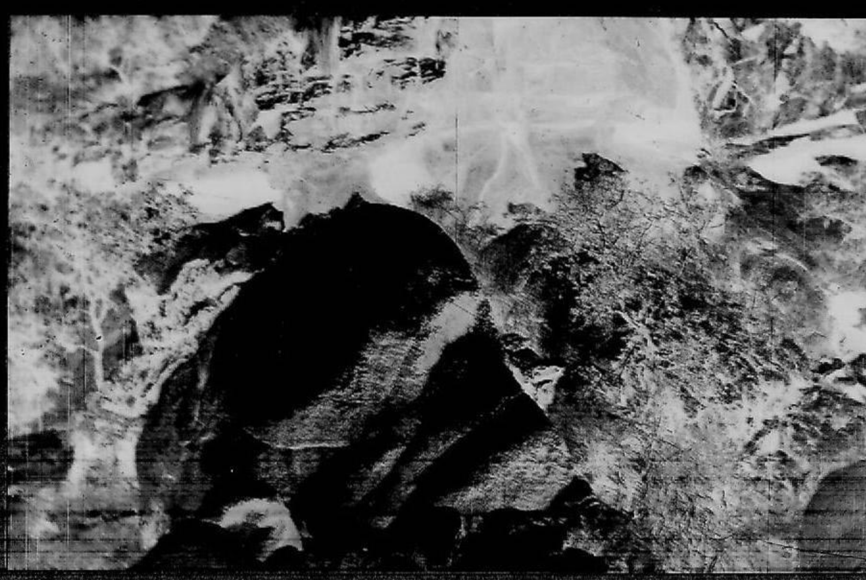

Figure 2.

Small holes or caves representing a weathered zone between coarse-grained granite and Lower Hickory sandstone exposed in Squaw Creek about 200 yards north of the graded county road.

the granite and the overlying Hickory sandstone. Approximately 20 feet of Hickory sandstone overlie the granite. At the contact with the Hickory unit, about two feet of the upper part of the granite is highly weathered. In plate IX, figures one and two, this weathered zone is represented by the small holes or caves just below the Hickory unit. These holes or caves are caused by erosion and by the burrowing of small animals in the loose, highly weathered material. The weathered zone probably developed during pre-Hickory time and deposition of the Hickory sandstone followed without removal of the zone. However, it is possible that the weathering is due to water descending through the sandstone and accumulating on the granite.

Barnes, Romberg, and Anderson (1954, p. 80), on a generalized geologic map of the Precambrian rocks of the Llano region, show an outcrop of Town Mountain granite that coincides with the location of the above coarse-grained granite. These authors do not include a description of this outcrop.

Megascopic description

This granite is coarse-grained and in general has a pink to reddish appearance due to the large crystals of microcline feldspar. Between these large feldspar crystals and making up the remainder of the rock are quartz, biotite, and possibly some plagioclase and hornblende. The large feldspar crystals make up approximately 40 to 50 percent of the rock, while quartz is the next most abundant mineral, comprising about 20 to 30 percent.

The grain size of the granite ranges from very small to over 20 mm., but averages about five to eight mm. The microcline grains are generally above the average while the quartz and biotite grains are usually close to average in size. The remaining minerals occur in very small grains.

The weathered surface of the granite is reddish-brown in color, and the granite is easily broken up after being weathered.

The weathered zone beneath the Hickory sandstone is white to purple in color and rather friable. The feldspars have weathered to a white and purple clay. The quartz grains have remained much the same, being very resistant to weathering. There are no traces of the darker minerals left in this weathered rock.

Pegmatite and aplite dikes are not found at this exposure.

Medium-Grained Granite

Occurrence and relationships

Paige (1912) indicates on his areal geologic map of the Llano quadrangle that a fine to medium-grained granite extends into the north-eastern part of the thesis area.

This granite, referred to as medium-grained by the present author, is exposed in the extreme northern and eastern parts of the low flatland of the thesis area. As previously mentioned, it has transitional contact with the gneiss unit.

Wilson (1957), in the Big Bend of the Llano River area, observed and described a similar transition zone between a medium-grained granite and a gneiss unit. He suggested that perhaps the term migmatitic would describe the nature of the rocks contained in the transition zone. According to Turner (1948, p. 306) migmatites may evolve in three general ways: (1) development by injection of magma, (2) development by magmatic soaking, and (3) development by differential fusion. Wilson favored the idea that the zone resulted from invasion of the original rock by magma or by solutions or gases from the magma. This idea was favored because a xenolith with sharp boundaries was found in the transition zone.

A microscopic examination was not made of the granite in the thesis area, but a megascopic examination indicates it to be similar to the medium-grained granite found by Wilson. Also, in the thesis area xenoliths are found in the form of long stringers at the edge of the granite or possibly within the transition zone (Pl. X, fig. 1).

The idea favored by Wilson, that the transition zone resulted from invasion of the original rock by magma or by solutions or gases from the magma, seems reasonable and applicable to the thesis area. The medium-grained granite represents the intrusive body, the gneiss and schist units represent the intruded rocks, and the transition zone represents a zone penetrated by the gases and solutions from the intrusive magma. A fact indicative of this relationship is the decreasing grain size of the gneiss with increasing distance from the granite. The larger grain sizes were formed closer to the hot intrusive body and the smaller grains under cooler conditions farther away.

Megascopic description

The medium-grained granite is equigranular with most grains under five mm. in diameter. Pink microcline and milky quartz are the most abundant minerals and they occur in about equal amounts. The granite has a characteristic pink color due to the pink microcline. Some dark minerals are present, but biotite is the only one recognizable megascopically. Several samples of the medium-grained granite contain small hollow spaces or cavities exhibiting a miarolitic structure.

PLATE X

Exposure of Medium-Grained Granite

Figure 1.--Stringers of xenoliths found in medium-grained granite close to transition zone. Exposed about 0.2 miles due south of Kelley Keller's residence.

Figure 2.--Weather pits found on the outcrops of medium-grained granite about 0.2 miles south of the Kelley Keller residence.

The weathered surface of the granite is dull reddish-brown in color. Several small, shallow, round or elliptical depressions are found on top and on the gently dipping sides of the small hills or knobs of medium-grained granite (Pl. X, fig. 2; page 37). These depressions have been referred to as "weather pits" by Blank (1951). However, none of the weather pits found in the thesis area are surrounded by the raised annular rims described by Blank. The weather pits found in the thesis area are usually small, from one to two feet in diameter and two to three inches in depth. The bottom of the pit may be covered with either soil or particles of disintegrated granite.

Numerous pegmatite dikes cut the granite in the area. Megascopically, the dikes contain essentially the same minerals as the granite but the mineral grains are somewhat larger. Most of the dikes are less than three inches in width, but a few are much larger.

Topography and vegetation

The topography of the granite is about the same as that shown by the gneiss unit; however, the small knob hills are more numerous in the granite. The granite is very easily weathered, as can be seen in the quarry just north of the Raymond Keyser residence. In the quarry the granite is so highly weathered and loosely consolidated that it can be scraped out by a bulldozer and used for road material by the local ranchers.

The most abundant type of vegetation is blackjack oak and post oak. Shin oak, mesquite, cacti, and various grasses are found, but are less common.

CAMBRIAN SYSTEM

Evidence indicates that Paleozoic sedimentation began in the Llano region in early Late Cambrian time. Upper Cambrian rocks form extensive outcrops throughout the region and rest unconformably upon the irregular surface of the Precambrian rocks. Rocks of Upper Cambrian age comprise two formations: a lower one, the Riley formation, divided into three members; and an upper one, the Wilberns formation, currently divided into four members. All members of the Upper Cambrian rocks are found cropping out in the Squaw Creek-Marshall Creek area.

Riley Formation

The Riley formation, as defined by Cloud, Barnes, and Bridge (1945, p. 154), includes all known Cambrian strata in central Texas beneath the Wilberns formation. It is composed, from bottom to top, of the Hickory sandstone, the Cap Mountain Limestone, and the Lion Mountain sandstone members. The contacts of those three members intergrade both laterally and vertically. In its type area, in the Riley Mountains of southeastern Llano County, the formation is approximately 780 feet thick, and it normally averages about 695 feet in thickness (Barnes and Bell, 1954, p. 36).

The thickness of the Riley formation could not be measured in the thesis area due to an incomplete section of the lowest member, but it is estimated to be close to the average for the region.

Hickory Sandstone Member

Definition and thickness

The name Hickory was first used as a series name by Comstock (1890) for the sandstone series occurring along Hickory Creek in Llano

County. The series classification was dropped by Paige (1912, p. 42) and the Hickory sandstone was classified as a formation. Cloud, Barnes, and Bridge (1945, p. 154) redefined the Hickory sandstone as the basal member of the Riley formation and established the Hickory sandstone-Cap Mountain limestone contact at the top of the non-calcareous sandstone beds below the limestone.

Goolsby (1957) presented a detailed report on the Hickory sandstone. He proposed a formation status for the Hickory sandstone because it consists of three mappable units that represent distinct types of genetic environment.

Bridge, Barnes, and Cloud (1945, p. 112) reported 360 feet as an average thickness for the Hickory sandstone with a range from about 415 feet to a feather edge. The variations in thickness are attributed to topography of the invaded area, irregularities in deposition, and to more rapid gradation into limestones in some areas.

A complete section of the unit is not present within the Squaw Creek-Marshall Creek area. Lower Hickory beds unconformably overlie the Precambrian rocks in the southeastern portion of the area. Although their horizontal extent is considerable in this locality, no great thickness is indicated because of flat or nearly flat-lying beds. Lower, Middle, and Upper Hickory beds are exposed in the northwestern portion of the thesis area but do not represent a complete section. Small patches of the Upper Hickory beds extend into the area in its northern part close to U. S. Highway 87. The extensive faulting and soil cover prevent an accurate estimate of the thickness, but the exposures of the Upper, Middle, and Lower Hickory beds indicate their total thickness in the thesis area to be at least as much as the average for the region.

Lithology

The Hickory sandstone is a light tan to deep red, fine to coarse-grained, non-calcareous, essentially non-glauconitic, partially feldspathic, sandstone and conglomerate. The member, at the lower contact, occurs as a coarse-grained, tan to light brown, conglomeratic sandstone with subrounded pebbles ranging from one mm. to 15 mm. in diameter. Ventifacts are found in the base of the member at several localities. Although none are found in the thesis area, Barnes and Parkinson (1940) report their occurrence at a locality due east of the thesis area just across the Mason-Llano County line. Cross-bedding has been reported to occur throughout the member but occurs only in the lower beds in the thesis area.

In its middle part, the Hickory sandstone is a tan to greenish-brown, fine to medium-grained, thinly bedded sandstone with thin beds of silty and shaly material. Symmetrical ripple marks are found in this part of the member at one locality in the area. Intraformational conglomerates and phosphatic brachiopods (mostly Lingula) are reported to occur in the middle and upper-middle parts of the member at several localities in the region but none are found in the area.

The upper part of the Hickory member is a dark brown to dull red, medium to coarse-grained sandstone. The quartz grains are well rounded and cemented with ferruginous cement which causes the characteristic dull red color. This part of the member also contains many small spherical balls or bean shaped bodies of hematite which according to Fuller (1957, p. 57), may represent oxidized glauconite. A distinctive characteristic of this part of the unit is its susceptibility to weathering, which results in a deep red soil often cultivated by the ranchers.

The Hickory sandstone forms the southern portion of the lowland along the eastern edge of the area. Only the basal, tan to light brown, coarse-grained part of the member is exposed in this portion. The contact between the Precambrian rocks and the Hickory sandstone can be seen along the northern edge of this exposure. The Hickory unit is bounded to the west by a fault separating it from different members of the Wilberns formation. To the south, it is covered by the Cretaceous hills and wash from the Cretaceous, while to the east it extends out of the area. In the extreme eastern portion the outcrops of the Hickory sandstone are characterized by networks of raised ridges of more firmly cemented sandstone. These ridges, according to Barnes and Parkinson (1940, p. 669), indicate fracture planes and that a fault should be found nearby.

The lower part of the Hickory member, as previously mentioned, is found unconformably overlying the coarse-grained granite on Squaw Creek in the western part of the thesis area. Bridge, Barnes, and Cloud (1947, p. 113) estimated as much as 800 feet of relief in some portions of the Llano region at the time of deposition of the Hickory member, but only 20 to perhaps 50 feet of relief is shown at this locality. The basal quartz grains here do not seem to be as large as those found in the eastern part of the area. On the surface of the granite-Hickory sandstone hill (Pl. IX, figs. 1, 2, page 33), the Hickory unit is very hard, almost quartzitic, while an exposure a little farther to the north in the bed of Squaw Creek exhibits a soft to friable, cross-bedded sandstone (Pl. XI, fig. 1).

One exposure of the middle part of the Hickory sandstone is found about 1/4 mile northwest of Ruben Evers' residence (location 2,

PLATE XI

Cross-bedding and Vegetation of Hickory Sandstone

Figure 1.—Cross-bedding in Lower Hickory sandstone exposed in the bed of Squaw Creek about 0.5 miles north of graded county road.

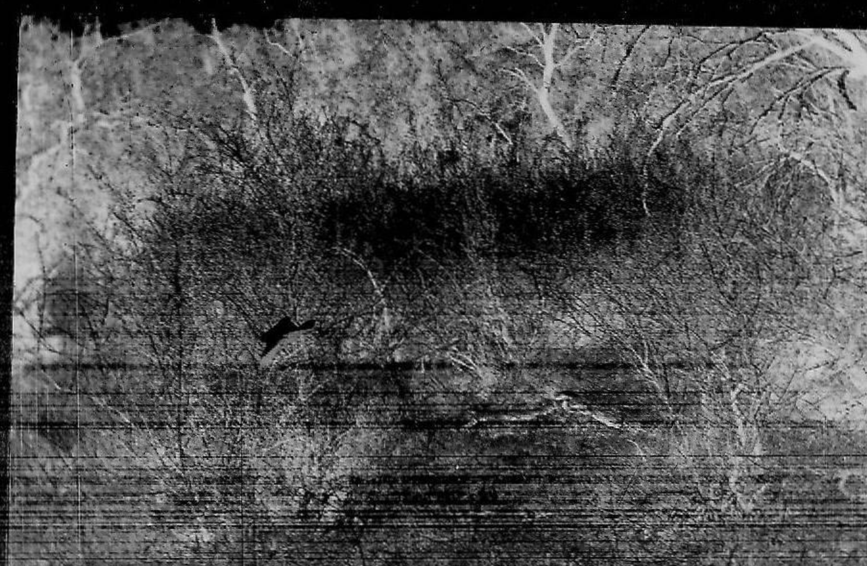

Figure 2.—White brush or bee brush growing on the soil formed by the Hickory sandstone about 0.1 miles north of the Squaw Creek-county road crossing.

Pl. I). This outcrop is found in a small creek with only a few feet of the member exposed. Symmetrical ripple marks are exposed in a thin sandstone bed in the bottom of the creek (Pl. XII, fig. 1, 2), while thinly bedded, green to purple, silty and shaly beds are exposed in the bank. Actually two sets of ripple marks are present in this exposure. The larger ripple marks (Pl. XII, fig. 1) strike in a direction 20 degrees west of north, measure 18 inches from crest to crest, and have an amplitude of about 2 1/2 inches. Their crests seem to have worn down, leaving flat tops which have a set of smaller ripple marks developed on them. Both sets can be seen in figure two of plate XII. The fountain pen in this figure is lying across the crests of three of these small ripple marks. They strike in a direction 5° west of north, measure 1 1/2 inches from crest to crest, and have an amplitude of about 1/2 inch. Several small faults with a general strike of N. 65° E. cut the sandstone beds containing the ripple marks. These faults show horizontal movement by the offsetting of the still-level ripple mark crests.

The upper part of the Hickory sandstone crops out in a narrow belt across the northwestern portion of the area and in small patches extending into the northern part close to U. S. Highway 87. Only a few exposures of the bedrock are found due to a thick cover of red soil.

Topography and vegetation

The Hickory sandstone has very little relief in the thesis area with the exception of the northeast-southwest-trending horst which forms a hill in the western part, and the Lower Hickory hill with about 100 feet of relief in the southeastern part.

The Hickory sandstone which overlies the coarse-grained granite on the horst hill is very hard and highly resistant to weathering.

PLATE XII

Ripple Marks in Hickory Sandstone Member

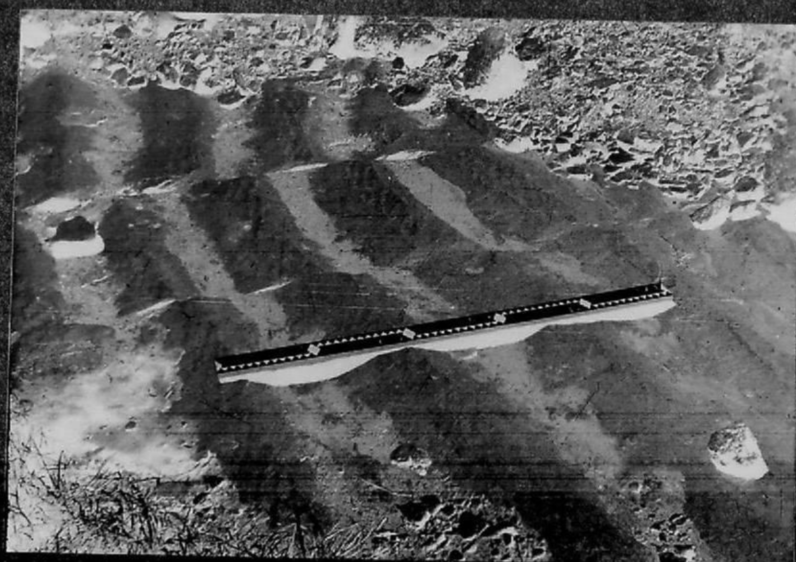

Figure 1.--Symmetrical ripple marks in Middle Hickory sandstone with small faults cutting the bed. Exposure is 1/4 mile northwest of Ruben Evers' residence.

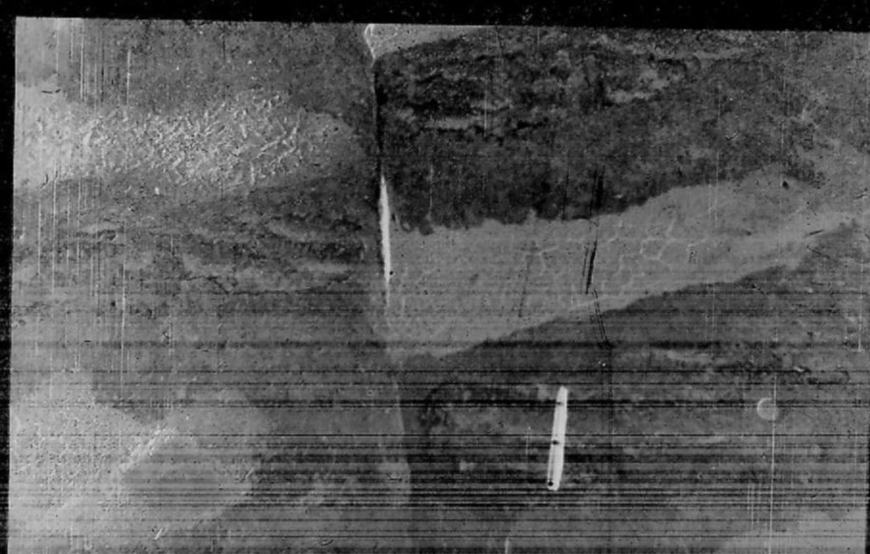

Figure 2.--Small symmetrical ripple marks on top of large ones. The location is the same as above.

Vegetation is sparse on this hill with blackjack oak, post oak, and white brush representing the dominant types. In the rest of the area the Hickory unit generally has more vegetation with post oak and white brush being more abundant.

Cap Mountain Limestone Member

Definition and thickness

The currently accepted definition of the Cap Mountain limestone is that of Cloud, Barnes, and Bridge (1945, p. 154) which gave it a member status and designated it as the middle member of the Riley formation. The type locality is at Cap Mountain in Llano County. Under this definition, the upper boundary of the member is below the Lion Mountain sandstone and the lower boundary is placed below the calcareous sandstone beds. The upper and lower boundaries are gradational. Field contacts for the upper boundary are based on the appearance of sand and a flat or gentle slope which characterizes the Lion Mountain outcrop. Bridge, Barnes, and Cloud (1947, p. 113) placed the lower boundary at the distinct topographic and vegetational change which is easily seen on aerial photographs. They also gave a range in thickness of 135 to 455 feet, with an average thickness of about 280 feet for the member.

The thickness of the Cap Mountain limestone was not measured in the thesis area, but is estimated to be close to or greater than the average.

Lithology

The Cap Mountain member consists of dark brown to reddish-brown, calcareous sandstones and silty limestones at the base. The limestones become coarser, thicker bedded, glauconitic, and lighter in color in the upper part. Limonite stains and fossiliferous limestones appear in the middle and upper parts of the member.

The Cap Mountain limestone crops out in a wide belt trending northeast-southwest and covers a large part of the thesis area. The bedding shows a general strike of N. 40° E. and a very gentle dip to the southeast. Although considerable area is covered by the unit, a great thickness is not indicated due to the nearly flat-lying beds.

The lower part of the member is exposed along the northwestern side of its belt of outcrop, and exhibits the sharp topographic and vegetational break at the contact mentioned by Bridge, Barnes, and Cloud (1947, p. 113). The contact was picked at this break by the present author due to the difficulty in determining the first predominantly calcareous beds. This part of the member is composed of alternating layers of medium-grained, dull brown, calcareous sandstone and fine to medium-grained, reddish-brown, arenaceous limestone.

In the middle part of the member the sandstones decrease and the limestones increase. The beds are usually less than one foot in thickness, very hard, and form ledges protruding out of the hill sides. Fossiliferous limestones and glauconite appear in this part of the member.

The limestone beds become thicker in the upper part of the member with some beds having a thickness of over three feet. The limestone is fine to medium-grained, light tan to gray, glauconitic, and fossiliferous. Thin beds of sandstone and fossiliferous limestone are found in this part of the member. The limestones show the honeycombed weathering in the thick beds and the mottled fragments scattered over the surface that have been recorded by previous authors.

A cave (location 1, Pl. I) located in the Cap Mountain limestone in the central part of the area may have formed as a result of a complex jointing system. No evidence of faulting is found at the cave. Hudson (1955) explored the cave and reported carbon dioxide gas blowing from it in a steady stream. The entrance (Pl. XIII, fig. 1) is vertical, 60 feet long, six feet wide, and 50 feet deep. The cave completely traps a small intermittent stream and during heavy rains takes in a considerable amount of water. Hudson and his party entered the cave and explored a passage to the east for a distance of 1/4 to 1/2 mile, but were unable to find the source of the carbon dioxide or what happened to the water that flows into the cave. The cave was not entered by the present author; however, no trace of the escaping carbon dioxide was found.

Topography and vegetation

The Cap Mountain limestone is more resistant to weathering than the underlying Hickory sandstone and forms hills or cuestas where it crops out. The eastern part of the large Cap Mountain limestone outcrop forms a fault-line scarp running parallel to and on the western side of U. S. Highway 87 (Pl. XIII, fig. 2).

Live oak and Mexican persimmon represent the dominant types of vegetation on the Cap Mountain limestone. Mesquite, cacti, cedar, and various grasses occur in smaller amounts.

Lion Mountain Sandstone Member

Definition and thickness

The Lion Mountain sandstone is currently defined as the uppermost member of the Riley formation (Cloud, Barnes, and Bridge, 1945, p. 154). The type locality is at Lion Mountain in the northwest portion of the Burnet Quadrangle in Burnet County, Texas.

PLATE XIII

Cave and Fault-Line Scarp of Cap Mountain Limestone

Figure 1.--Cave entrance in Cap Mountain limestone located in central part of area about 0.6 miles south of county road on the Henry Keyser, Sr. ranch (location 1, Pl. I).

Figure 2.--Fault-line scarp formed by Cap Mountain limestone on west side of U. S. Highway 87. The location is about one mile north of the county road-Highway 87 intersection.

The Lion Mountain sandstone is 20 feet thick at the type locality but is considerably thicker in the thesis area. In the Squaw Creek section, previously mentioned (see page 20), the Lion Mountain unit is approximately 60 feet thick. A section located about 1/4 mile due west of E. W. Henke's residence (see appendix) was measured and described by the author and included 59 feet of Lion Mountain sandstone.

Lithology

The Lion Mountain member consists of fine to coarse-grained, dark green, glauconitic sandstone, tan to purple sandy limestone, and calcareous trilobite and brachiopod coquina lenses. It is highly glauconitic, and the green color characterizes well-exposed sections, such as the one exposed in the Squaw Creek section (Pl. XIV, fig. 1). The lower boundary is usually based on the appearance of sand and a flat or gentle slope which characterizes the Lion Mountain sandstone. Numerous, subrounded, dull to shiny, reddish-black "pebbles" composed of hematite and sand are found scattered over the surface of the member (Pl. XIV, fig. 2). These nodules of hematite are believed to be weathering products of the glauconite and are used in recognizing the member. Along with these nodules, slabs of trilobite "hash" are found protruding through the soil cover.

Alternating fine-grained sandstone, shale, and fine- to medium-grained limestone beds occur in the bottom part of the member. The limestones are rusty to greenish-brown, well bedded, glauconitic, and contain small calcite grains showing good cleavage. Some of the limestone beds are very silty and slightly fossiliferous, containing trilobite fragments and brachiopod shells. Tangential lenses of trilobite "hash" make their appearance toward the middle of the member and continue

PLATE XIV

Bedrock and Surface Exposure of Lion Mountain Sandstone

Figure 1.—Dark green sandstone with "trilobite hash" lenses of the Lion Mountain sandstone exposed in Squaw Creek in the southwestern corner of the area.

Figure 2.—Hematite nodules scattered on surface of Lion Mountain sandstone on the south side of the county road about 1/4 mile west of U. S. Highway 87.

throughout the remainder. The sandstone becomes coarse and extremely glauconitic in the middle and upper parts of the member. Silty and shaly beds decrease in the middle and upper parts.

The Lion Mountain member crops out in a narrow belt trending northeast-southwest across the southern part of the thesis area. It also crops out at several places in the faulted zone in the northwestern portion. The Squaw Creek section is the only good exposure of the Lion Mountain bedrock in the area. The member was recognized elsewhere by the gently sloping bench, hematite nodules, slabs of trilobite "hash", and reddish to brown soil. At one locality just east of E. W. Henke's residence large blocks of limestone over two feet thick occur in the Lion Mountain member. The limestone is coarse-grained, tan to light gray, and slightly glauconitic. Hematite nodules and slabs of trilobite "hash" are common at this locality, with some coarse-grained, dark green sandstone exposed in the road ditch. The shape of the large blocks of limestone indicates a lens type limestone.

The trilobite "hash" lenses are composed of trilobite fragments, some brachiopod shells, glauconite, and some calcite grains. Where these lenses or hematite nodules are scarce the reddish-brown soil of the member may be confused with the upper part of the Hickory sandstone member.

The Lion Mountain member is bounded at the top by a disconformity which also represents the boundary between the Riley and Wilberns formations.

Topography and vegetation

Topographically, the Lion Mountain member forms a gently sloping bench that is covered by a reddish-brown soil. In the thesis area it is easily distinguished from the hills and ledges of the underlying Cap Mountain member and the ledge formed by the overlying Welge sandstone member.

The vegetation is generally sparse with scrub oak and Mexican persimmon being predominant. Mesquite, catsclaw, cacti, and needle grass are present in smaller amounts.

Wilberns Formation

The term Wilberns was first suggested by Paige (1911, p. 6) for exposures at Wilberns Glen in Llano County. Under the currently accepted definition by Barnes and Bell (1954, p. 36), the Wilberns formation is divided into four members (from oldest to youngest): Welge sandstone, Morgan Creek limestone, Point Peak shale, and San Saba limestone and dolomite.

According to Bridge, Barnes, and Cloud (1947, p. 114), the Wilberns formation has an average thickness of 580 feet and varies from 540 to 610 feet. Only the lowest member of the formation was measured in the thesis area. All members of the Wilberns formation are found in the thesis area but they do not all exhibit complete sections.

Welge Sandstone Member

Definition and thickness

The Welge sandstone was named and described by Barnes from exposures found in Squaw Creek in the southwestern part of the area (Pl. XV, figs. 1, 2). The exact location of the section is given on page 20 of this report. The unit is 27 feet thick at the type locality, averages 18 feet and ranges from nine to 35 feet in thickness throughout the Llano

PLATE XV

Type Locality of Welge Sandstone

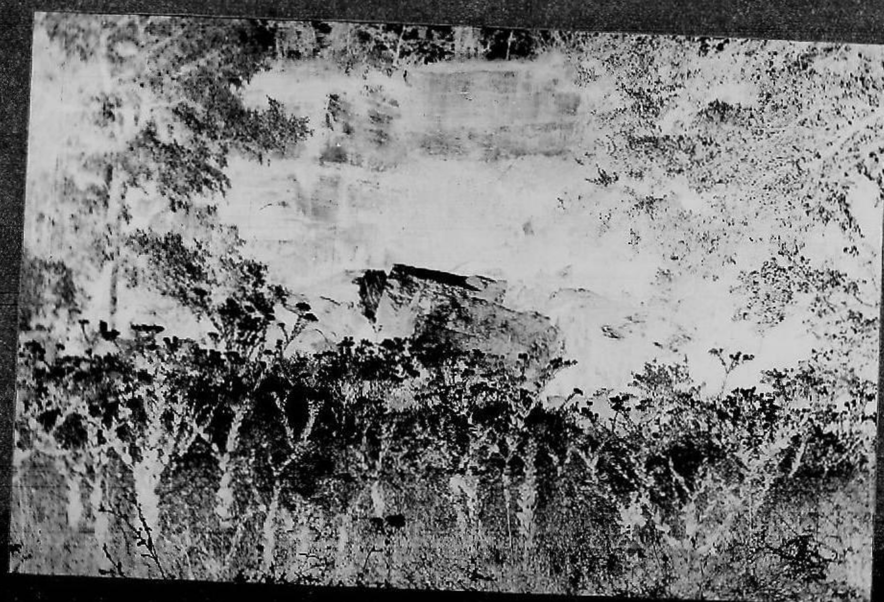

Figure 1.—Type locality of the Welge sandstone exposed in Squaw Creek. The exact location is given on page 20 of this report.

Figure 2.—Massive thick beds of Welge sandstone member at type locality (same locality as figure 1).

region (Bridge, Barnes, and Cloud, 1947, p. 114). A section located about 1/4 mile due west of E. W. Henke's residence (see appendix) was measured and described by the author and included approximately 30 feet of the Welge sandstone.

Lithology

The Welge sandstone is a tan to reddish-brown, fine to coarse-grained, typically non-glauconitic, sparsely fossiliferous, non-calcareous, well sorted marine sand.

At the base of the Welge sandstone there is a thin bed or zone of earthy, poorly sorted, slightly glauconitic, calcareous sandstone that is believed to be the reworked Lion Mountain sandstone that marks the surface of disconformity on which the Welge member was deposited. This bed or zone also contains fragments of unrecognizable fossils and small calcite grains. Overlying this zone is a massive sandstone bed over ten feet thick that is greenish-yellow, fine-grained, non-calcareous, and slightly glauconitic. Above this sandstone bed there is a gradational change into thickly bedded, medium to coarse-grained, reddish-brown, non-calcareous, non-glauconitic sandstone beds. There is an abrupt change above these beds to a thick bed of tan to light brown, coarse-grained, non-calcareous, non-glauconitic sandstone. Above this bed is the reddish-purple, coarse-grained, transition zone, slightly over one foot thick, between the Welge sandstone and overlying Morgan Creek limestone.

As can be seen by the above description, the Welge member is composed primarily of thick beds of fine to coarse-grained sandstone (Pl. XV, fig. 2). Some of the sandstone has quartz grains with recomposed faces which glitter in the sunlight, but these occur only in scanty amounts. Most of the quartz grains in the Welge are rounded.

Excellent exposures of the Welge member are found at several localities in the area.

Topography and vegetation

The Welge sandstone, being more resistant to weathering than the underlying Lion Mountain sandstone, generally forms a distinct scarp between the gently sloping bench of the Lion Mountain unit and the overlying Morgan Creek limestone.

The Welge sandstone has a dense vegetation that sometimes appears as a dark band on aerial photographs. Post oak, catsclaw, and white brush are the dominant types of vegetation.

Morgan Creek Limestone Member

Definition and thickness

Bridge (Bridge, Barnes, and Cloud, 1947, p. 114) defined the Morgan Creek limestone from exposures on both the north and south forks of Morgan Creek in Burnet County. It is 110 feet thick at the type section and averages about 120 feet throughout the region. The thickness was not measured in the thesis area.

Lithology

The Morgan Creek unit is essentially a light gray, fine to coarse-grained, fossiliferous, glauconitic limestone with alternating thin marly beds. It is sandy in the lower part.

The lower contact is gradational, but generally easily determined and picked at the first appearance of the lower, purple, arenaceous limestones of the Morgan Creek unit.

The upper contact is also gradational and is generally picked at the first appearance of thin layers of calcareous shale and siltstone.

The Morgan Creek limestone crops out in a northeast-southwest trending belt in the southern portion of the thesis area and in the faulted zones in the southeastern and northwestern parts of the area.

The lower beds are dull red to purple, coarse-grained, arenaceous, slightly glauconitic, fossiliferous, and average about one foot in thickness.

There is a gradational change above these basal beds into fine to medium-grained, greenish-gray, glauconitic, and slightly fossiliferous limestone beds which alternate with thin, soft marly beds. The latter are easily weathered and generally covered by soil. These limestone beds vary from a few inches to about two feet in thickness, with the thicker beds making their appearance in the middle part of the member. Only slight variations in this lithology occur in the remaining limestone beds of the member.

The _Eoorthis texana_ zone that usually occurs from 40 to 60 feet above the base of the member is not recognized in the thesis area.

Near the top of the member, small bioherms of gray micro-granular limestone are commonly found. At one locality in the area (location 3, Pl. I), the bioherms are found about three feet beneath the contact with the overlying Point Peak shale member. These bioherms (Pl. XVI, figs. 1, 2) range from a few inches to over three feet in diameter. Thin shaly layers are deposited between and over the spheroidal to ellipsoidal shaped bioherms (Pl. XVI, fig. 2). The bioherms are composed of one or more "cabbage head" structures that are believed to represent individual algal colonies.

Above these bioherms, as can be seen in the top left hand corner of figure one, plate XVI, is a limestone bed about 1.5 feet thick.

PLATE XVI

Small Bioherms in Morgan Creek Limestone

Figure 1.—Small bioherms near top of Morgan Creek limestone, located in Beaver Creek about 1.2 miles northwest of the R. Evers ranch house (location 3, Pl. I).

Figure 2.—Thin shale layers deposited between and over bioherms (close up view of figure 1).

This limestone bed has two sets of symmetrical ripple marks exposed on its surface. These ripple marks are of different sizes and intersect at an acute angle across the surface of the bed. The larger set (Pl. XVII, fig. 1) has a strike of N. 37° E., measures four feet from crest to crest, and has an amplitude of about 5 inches. The smaller set (Pl. XVII, fig. 2) has a strike of N. 20° E., measures 2 1/2 feet from crest to crest, and has an amplitude of about 3 1/2 inches. This limestone bed is just below the Point Peak member. It is a medium-grained, gray, slightly glauconitic limestone, and is overlain by thin, tan to green siltstone beds. The small bioherms and the ripple marks in the overlying limestone bed seem indicative of shallow water deposition.

Topography and vegetation

A steep slope that exhibits distinct and traceable limestone beds is generally formed by the Morgan Creek limestone.

The lower part of the member has a fairly dense cover of vegetation that becomes noticeably thinner in the upper part. Live oak and Mexican persimmon are predominant, but Spanish dagger and prickly pear are common throughout the member.

Point Peak Shale Member

Definition and thickness

Bridge, Barnes, and Cloud (1947, p. 115) named the Point Peak shale member from exposures at Point Peak near Lone Grove, Llano County. It is 270 feet thick at the type section and averages about 160 feet throughout the region.

In the thesis area, the Point Peak member is mapped and discussed as two separate units, a lower shale unit and an upper unit of stromatolitic

PLATE XVII

Ripple Marks in Morgan Creek Limestone

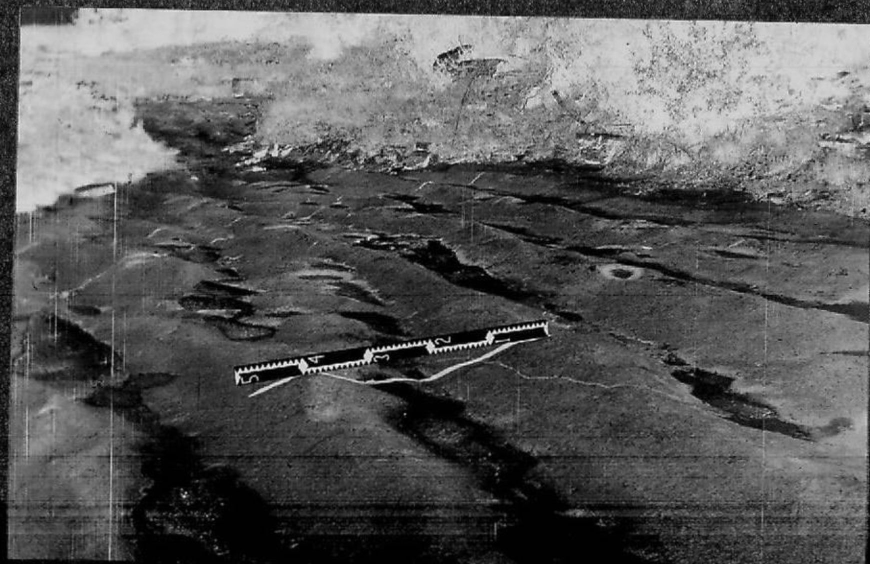

Figure 1.—Large symmetrical ripple marks in Upper Morgan Creek limestone, exposed in bed of Beaver Creek about 1.2 miles northwest of the R. Evers ranch house (location 3, Pl. I).

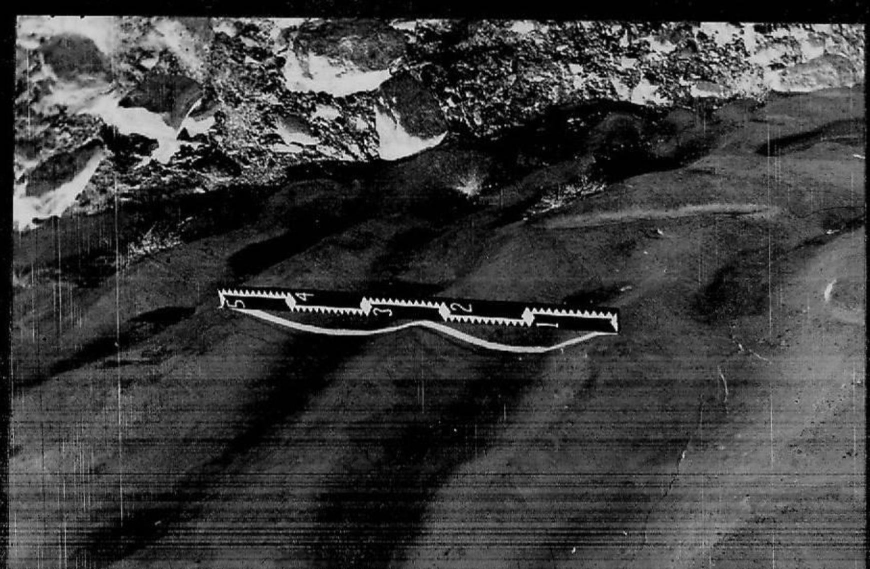

Figure 2.—Small symmetrical ripple marks in Upper Morgan Creek limestone (same location as figure 1).

bioherms. However, the shale unit also contains a thin bioherm zone in its middle portion in the northwestern part of the area. The shale and upper bioherm units were not measured, but the shale unit is known to be over 100 feet thick and the upper bioherm zone is believed to be at least 150 feet thick in the northwestern part of the area.

The best outcrops of the Point Peak member are found east of Beaver Creek in the northwestern portion and east of Squaw Creek in the southern portion of the area.

Shale Unit

Lithology

The lower contact between the Point Peak member and the Morgan Creek limestone is gradational and picked at the first appearance of typical calcareous, Point Peak shale and siltstone.

The shale portion of the Point Peak member consists of a sequence of calcareous siltstones, shales, silty limestones, intraformational conglomerates, and the thin bioherm zone previously mentioned.

Alternating siltstone, shale, and limestone beds occur in the basal part of the member. The siltstone and shale beds are olive green and gray, calcareous, glauconitic, laminated, and finely micaceous. The limestones are fine to medium-grained, gray, silty, glauconitic, and well bedded. The limestones occur as thin beds throughout the member. The shales are non-resistant to weathering and commonly produce gentle to fairly steep, soil-covered slopes. Intraformational conglomerates appear in the middle and possibly lower parts of the member and form rough ledges protruding out of the covered slopes (Pl. XVIII, fig. 1). The conglomerates are composed of a gray to greenish-tan matrix of fine-grained

PLATE XVIII

Exposures of Point Peak Shale

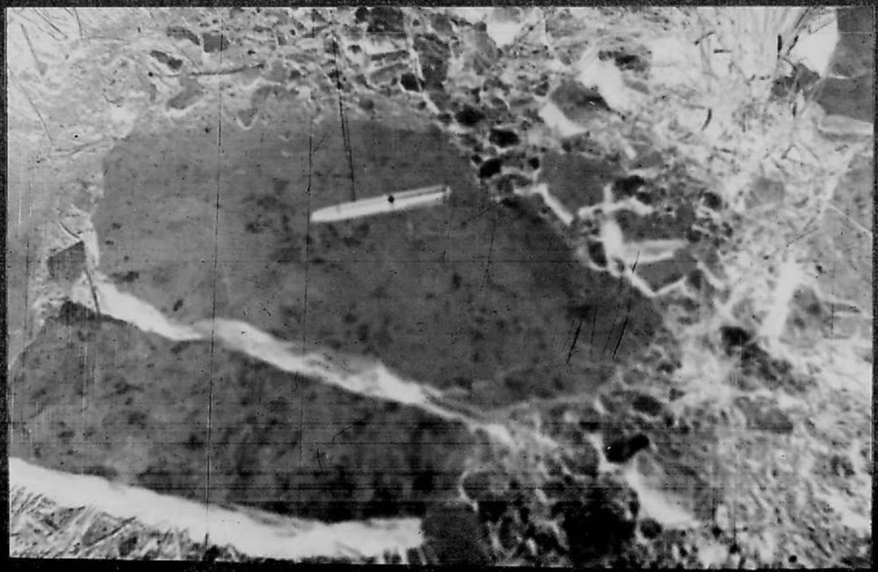

Figure 1.--Intraformational conglomerate ledge protruding out of cover formed by Point Peak shale member about 3/4 mile northwest of Ruben Evers' residence.

Figure 2.--The Point Peak shale forming a high bluff on the east side of Beaver Creek in the extreme northwestern corner of the area.

limestone containing silty limestone fragments or pebbles. The fragments or pebbles are flat, yellowish-green, subrounded, sometimes laminated, and tend to be parallel to the planes of bedding.

No indications of fossils were found in the shale unit.

High, almost vertical walls or bluffs are formed by the Point Peak member along Beaver Creek (Pl. XVIII, fig. 2). In this part of the area, a thin bioherm zone occurs near the middle of the shale unit. This zone is from three to four feet thick and is underlain and overlain by shale beds. It is a light gray, very dense, sublithographic limestone.

Topography and vegetation

The lower shaly and silty part of the member may form either gentle or steep soil-covered slopes. These slopes are characterized by sparse vegetation, a poor caliche soil, and the presence of mesquite trees.

Upper Bioherm Zone

General statement

According to Cloud (1952, p. 2146), the bioherms of the Upper Cambrian in the Llano region are masses of stromatolitic limestone that locally shows filamentous structure strongly suggestive of the calcium-precipitating and sediment-binding blue-green algae. This suggests that the development of the bioherms was controlled by certain environmental factors. Previous investigations and studies show that the growth of algal reefs depends on light and is favored by clear, warm, quiet, and shallow water conditions. However, the occurrence of the bioherm zone within the Point Peak shale at some localities in the Llano region and entirely within the San Saba limestone at other localities show adaptability of the algae to varying environmental conditions.

The bioherm zone occurs throughout most of the Llano region and usually near the Point Peak shale and San Saba limestone boundary. The zone is not continuous throughout the region, but has abrupt lateral gradation into shale and granular limestone. Most of the previous investigations indicate the bioherm zone to be within the Point Peak shale in the southern and eastern parts of the uplift and in the San Saba limestone in the northern and western parts. According to Mounce (1957, p. 51), the bioherm zone transgresses from the upper part of the Point Peak member in the area south of Mason to the lower portion of the San Saba member north of Mason. This change in position of the bioherm zone is believed to be caused by an adjustment to change in environment. Thus, the bioherm zone is restricted as a good time marker.

If the bioherm zone is not present, the upper boundary of the Point Peak member is picked at the highest significant shale bed. Where reefs transgress the Point Peak-San Saba boundary, placing of the contact is arbitrary. To add to the difficulty of determining the position of the bioherm zone, Bridge, Barnes, and Cloud (1947, p. 117) reported a bioherm zone exposed in Squaw Creek in Gillespie County that is definitely believed to be within the San Saba limestone.

Good exposures of the bioherm zone are found in the northwestern and southern parts of the Squaw Creek-Marshall Creek area. A very large and thick zone of the bioherms is found cropping out east of Beaver Creek, in the northwestern portion. This zone was not measured but is at least 150 feet, and possibly 200 feet thick. The zone seems to have an unusually great stratigraphic extent, as in this portion of the area the bioherms are believed to extend from the upper part of the Point Peak shale to at least the upper San Saba limestone and possibly all the way to the Ellenburger limestone. In the southern portion of the area the bioherm zone is much thinner and occurs between the Point Peak shale and San Saba limestone.

Lithology

The thick bioherm zone in the northwestern portion of the area is composed of a tan to light gray, thinly laminated, microgranular to sublithographic limestone with "cabbage-head" structure being evident throughout. It has been cut by several fairly deep gullies that form tributaries to Beaver Creek. Very large individual bioherms are revealed in the walls of the gullies and capping the tops of the hills. Large subcircular resistant boulders or hummocks are found along the edges and tops of the gullies and scattered throughout the outcrop (Pl. XIX, fig. 1). Their weathered surface is honeycombed or reticulated and shows a layering or sheeting effect similar to the exfoliation of granite domes (Pl. XIX, figs. 1, 2). The raised honeycombed or reticulated surface of the bioherms is composed principally of yellowish-brown dolomite. The zone becomes highly dolomitic above the basal part. This high dolomite content and the great thickness of the zone suggests a high stratigraphic extent. Previous investigations in the region show a fairly high dolomite content within the San Saba and Ellenburger limestones with small amounts occurring occasionally in the Point Peak member.

The bioherm zone found east of Squaw Creek in the southern portion of the area is composed of a compact, gray to light-blue, sublithographic limestone. The individual bioherms are much smaller and have less tendency to coalesce in this part of the area. The zone shows

PLATE XIX

Surface Exposures of Thick Bioherm Zone

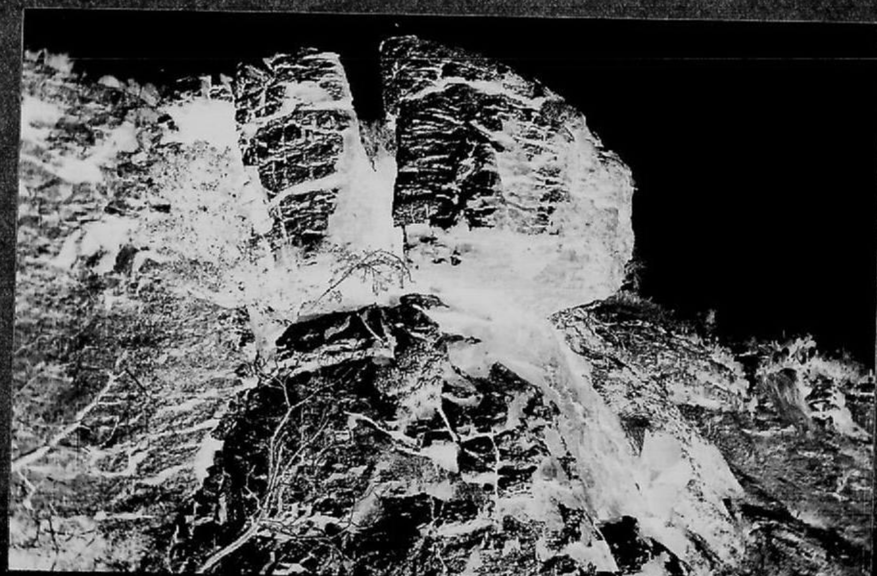

Figure 1.--Hummock formed by the weathering of the bioherm zone along the edge of a tributary to Beaver Creek in the northwestern portion of the area.

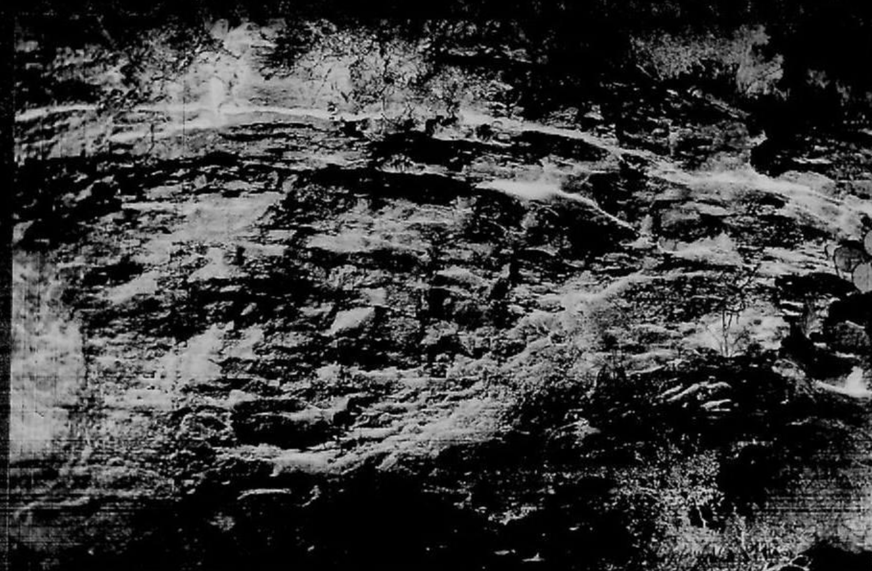

Figure 2.--Layering or sheeting effect shown by bioherm zone (same location as above).

very little dolomite content, which agrees with the bioherm zone placed in the Upper Point Peak member by other authors. These bioherms also form large resistant boulders on the weathered surface that show the "cabbage-head" structure.

Topography and vegetation

The bioherm zone at the top of the Point Peak member forms a rugged terrain capping the hills and creek bluffs.

The vegetation of the bioherm zone is thicker than the vegetation of the shale unit. Live oak, Mexican persimmon, and cacti represent the dominant types.

San Saba Limestone Member

Definition and thickness

The name San Saba was first used by Comstock (1890, p. 566) as a series term applied to exposures of limestone along the San Saba River near Camp San Saba in McCulloch County. Bridge (Bridge, Barnes, and Cloud, 1947, p. 117) revised the San Saba to its present member status, to include the glauconitic limestones overlying the Point Peak shale member and underlying the Tanyard formation of the Ellenburger group.

At the type section, the San Saba member is 280 feet thick. The thickness was not measured in the thesis area. Although both lower and upper beds of the member are found in the area, it is doubtful that a full section exists, due to the extensive faulting.

Lithology

The San Saba limestone is generally composed of a calcitic facies and a dolomitic facies throughout most of the Llano region. The calcitic facies is usually overlain by the dolomitic facies, but the reverse or only one of the facies has been found in some parts of the region.

The lowermost beds, just above the bioherm zone of the Point Peak member, are typically composed of tan to yellow, medium to coarse-grained, and glauconitic limestone. These beds grade into gray to greenish-gray, fine to coarse-grained, glauconitic, fossiliferous limestones in the middle part of the member. The upper part is usually composed of thin-bedded, slightly glauconitic, sublithographic limestones. In the eastern and northern parts of the uplift small round limestone spheres known as girvanellas are abundant in the basal beds, while in the extreme western part intervals of sandstone appear in the calcitic facies.

The best exposures of the San Saba member are found in the northwestern and southern portions of the thesis area.

The lower contact is picked at the last occurrence of the bioherms and the first appearance of tan to yellow, glauconitic, and granular limestone beds. A few hard and resistant ledges resembling intraformational conglomerates occur in the lower beds. These ledges are composed of a fine-grained, pink to gray, slightly glauconitic limestone matrix with fine-grained, tan to green, subrounded, flat pebbles that are dispersed at angles to the bedding planes.

Neither the girvanella limestones nor the sandstone beds reported within the member in other parts of the region are found in the thesis area.

Thin fossiliferous beds resembling "hash" beds are found in the middle part of the member. These beds are tan to greenish-yellow, coarse-grained, glauconitic, and contain trilobite fragments. The weathered surface is very rough and tan to brown in color.

The upper part of the member consists of thin to medium-bedded, hard, gray, sublithographic, slightly glauconitic limestones. Symmetrical ripple marks are found in the hard, resistant ledges of this part of the member. The ripple marks strike N. 25° W., measure eight inches from crest to crest, and have an amplitude of about one inch. The ripple marks have the same direction of strike as the beds upon which they occur. The coiled form of the gastropod, Lytospira gyrocera is also present in the upper part of the member.

The boundary with the overlying Ellenburger group is gradational. The contact is usually picked at the first occurrence of the uncoiled form of the Lytospira gyrocera and the disappearance of glauconite.

Topography and vegetation

The San Saba member forms steep slopes at the top of the hills and caps the hills in the thesis area. The hard, resistant limestones form thick rough ledges protruding from the soil cover.

Vegetation consists principally of scattered Mexican persimmon, live oak, and prickly pear.

ORDOVICIAN SYSTEM

Ellenburger Group

Definition and thickness

Paige (1912, p. 52) named the Ellenburger limestone formation for exposures in the Ellenburger Hills in southeastern San Saba County. The Ellenburger formation was raised to a group status by Cloud, Barnes, and Bridge (1945, p. 133) and divided, from bottom to top, into the Tanyard, Gorman, and Honeycut formations. The Ellenburger group is reported to have a maximum thickness of about 1,820 feet in the southeast corner of the Llano region.

The thickness is unknown in the thesis area and only the basal limestone beds of the group are believed to be present. The type section for the Threadgill member of the Tanyard formation extends along Threadgill and Mormon Creeks south of Lange's Mill in Gillespie County. The Ordovician rocks found in the thesis area are believed to be of the same type as those found at the type section of the Threadgill member.

Lithology

The Ellenburger group is essentially composed of pure, light gray to tan, thin to thick-bedded, sublithographic limestones and gray to dark gray, fine to coarse-grained dolomites. Intraformational conglomerates and ripple marks occur locally in the lower part of the group.

The Ellenburger group is mapped and discussed as a group in the Squaw Creek-Marshall Creek area. The lower beds are exposed in the northwestern corner of the area and are composed predominantly of sublithographic, pearl-gray to ivory, non-glauconitic, fossiliferous limestone. A few large rectangular blocks of extremely micro-granular, mottled limestone with corrugated or hackly weathered surfaces are found on the ground surface. A little higher in the member, weathered blocks of micro-granular limestone, over one foot in thickness, closely resemble some of the smaller bioherms found in the Point Peak member of the Wilberns formation. These are found in other parts of the region and are believed to represent localized algal reef developments.

In the south and southeastern parts of the area the dolomitic facies is exposed and bounded by faulting. The dolomite is fine to medium-grained, tan to yellowish-brown, and massive. The outcrops of bedrock resemble the shape of outcropping bioherms but have different and distinct textural character. White to light gray chert fragments up to several inches in diameter are found within the dolomite facies.

A thin bed of oölitic limestone is found just below the massive dolomite in the southern part of the area. This limestone bed is light gray and contains abundant small, white, spherical or egg shaped bodies, that give the rock an oölitic texture.

At its lower boundary the Ellenburger group is in gradational contact with the San Saba member of the Wilberns formation, except in the eastern part of the Llano region where it overlies the San Saba member disconformably. Devonian, Carboniferous, and Cretaceous rocks unconformably overlie the Ellenburger group.

Topography and vegetation

The Ellenburger rocks usually cap the low, rolling hills in the thesis area and support a distinct type of vegetation consisting chiefly of grasses with scattered clumps of small trees. Live oak represents the predominant type of tree, and the grasses are represented principally by the gramas.

CRETACEOUS SYSTEM

Comanchean Series

General Statement

The Llano region is bordered on all sides, except the northwest, by Lower Cretaceous strata that lie unconformably upon the older formations. The Cretaceous strata dip gently toward the southeast and rest upon every older formation in the region. Erosion has removed much of the Cretaceous strata that once covered the Llano region, but a few scattered outliers and topographic extensions of Cretaceous rocks remain in the uplift area. These outliers and extensions often interfere with the tracing of structural and lithological features of older age. The thinning of Cretaceous formations which overlap high topographic features in the region indicates that the Paleozoic and Precambrian surface was irregular when the Cretaceous sea transgressed the region. Barnes (1941) believed the Edwards limestone was the first Lower Cretaceous stratigraphic unit to completely cover the region. According to Plummer (1950, p. 101), the Cretaceous beds in the Llano region become progressively younger from southeast to northwest.

High hills composed of the nearly horizontal Lower Cretaceous strata extend from the south into the southeastern part of the Squaw Creek-Marshall Creek area. Plummer (1950, Pl. I) shows this extension on his map and places its Cretaceous rocks in the Travis Peak formation of the Trinity group. However, in this report, the Cretaceous strata are mapped and discussed only as sandstones and limestones of Early Cretaceous age.

Fragments and a few outcrops of an arkose conglomerate that has previously been designated as Lower Cretaceous in age are found around the base of the Cretaceous rocks. Although its age is not conclusive the conglomerate will be discussed with the Lower Cretaceous strata in this report.

Arkose Conglomerate

Rogers (1955), in a detailed report on the arkosic conglomerate beds in Mason, Menard, and Kimble Counties, stated that the arkosic conglomerate bodies were terrestrial stream deposits existing in two terrace levels. Rogers considered the conglomerate to be of Lower Cretaceous age throughout.

The conglomerate is found cropping out at the western edge of the Cretaceous hills in the Squaw Creek-Marshall Creek area (location 4, Pl. I). The outcrop is surrounded by the Recent alluvium at the base of the Cretaceous hills and its exact stratigraphic position is undeterminable; however, physically it seems to lie directly upon the truncated Paleozoic rocks. Throughout the rest of the area the conglomerate is found only as fragments located near the base of the Cretaceous hills.

The conglomerate is yellow to reddish-brown, non-calcareous, and composed predominantly of sub-rounded, colorless to milky quartz pebbles ranging from very small to over one inch in diameter. Feldspar grains (possibly microcline and plagioclase) are fairly common, ranging from very small to over four mm. in diameter. It is cemented by yellowish-brown clayey limonite, dark reddish-brown hematite, and silica. The limonite and hematite give it the characteristic color. The weathered surface is dark brown, extremely rough and irregular, with large milky quartz pebbles being more resistant and contrasting to the darker matrix. The unit is indicated to be only a few feet thick in the thesis area.

Sandstone and Limestone

The lower basal conglomerate reported on the east side of the region by Damon (1940) is not found in the Squaw Creek-Marshall Creek area. The thickness of Lower Cretaceous sandstone and limestone in the thesis area is estimated to be about 190 feet, including approximately 130 feet of sandstone that grades upward into about 60 feet of limestone.

The lowermost beds of the continuous Cretaceous sequence consist of a fine to medium-grained, calcareous, tan to rusty, silty sandstone. This sandstone does contain a few quartz grains up to three mm. in diameter, but is predominantly very fine-grained. It forms a steep soil-covered slope at the base of the Cretaceous hills.

The fine-grained sandstone strata grade upward into a coarse-grained, tan to yellowish-brown, calcareous, conglomeratic sandstone. This sandstone is composed of sub-rounded quartz pebbles ranging from very small to over 15 mm. in diameter that are cemented together by a fine, silty, calcareous material. The conglomeratic sandstone contains beds up to three feet in thickness that form ledges in a stair-step arrangement that can be traced on aerial photographs.

The conglomeratic sandstone grades into alternating thick beds of fine-grained, silty, slightly calcareous to very calcareous, yellowish-tan, white, and gray limestones. The limestones become predominantly gray and fine-grained to micro-granular in the top part of the Cretaceous strata. Several of the thick, micro-granular limestone beds contain numerous chert nodules. These chert nodules average about five inches in diameter and are pink to light grayish-brown in color. The beds of the limestone also form the stair-step arrangement and appear as wavy closed lines on aerial photographs.

Fossils were not found in the Cretaceous strata.

A thick growth of cedar caps the flat Cretaceous hills and the stair-step ledges surrounding them.

TERTIARY (?) SYSTEM

Caliche Conglomerate

Location and description

In the northeastern part of the area (location 5, Pl. I), a small hill composed of a caliche conglomerate trends northeast-southwest and unconformably overlies Precambrian granite. The conglomerate is only 20 feet thick, but it covers a fairly large area. The top of the hill has been scraped off and part of the conglomerate has been removed and used by the local ranchers as road material. The quarried hill shows as a narrow white belt on aerial photographs.

At the eastern end of the hill the conglomerate is a loosely consolidated, fluffy, fine-grained, white caliche containing a few scattered grains of pink feldspar and colorless quartz derived from the underlying Precambrian granite. It also contains a small amount of clayey material. At the western end the material becomes very coarse and well indurated. Near the contact with the underlying granite (Pl. XX, fig. 1), the conglomerate is composed chiefly of quartz and pink feldspar pebbles, ranging from very small to over 10 mm. in diameter, that are tightly cemented with a sugar-textured calcareous cement. Just above the contact, numerous sub-rounded pebbles, cobbles, and boulders of limestone and chert are scattered throughout the material. Limestone and sandstone pebbles and boulders are found that resemble each type of the Lower Paleozoic rocks found in the thesis area. The pebbles average about one inch in diameter, but a few boulders over three feet in diameter are found (Pl. XX, fig. 2).

PLATE XX

Exposures of Caliche Conglomerate

Figure 1.--Contact between caliche conglomerate and underlying Precambrian granite exposed due north of Kelley Keller's residence (contact above hammer head).

Figure 2.--Large, sub-rounded, Cap Mountain type limestone boulder found on caliche conglomerate hill due north of the Kelley Keller residence.

These large boulders suggest that extreme turbulence was involved in the deposition of the conglomerate. The pebbles also seem to be separated throughout the deposit, possibly indicating some swelling during or after deposition. According to Pettijohn (1956, p. 254), gravels collected by ordinary water currents have a closed framework; gravels deposited by sub-aqueous turbidity flows and slides, and by glacial ice or other modes of mass transport have a disrupted or open framework. The latter is notable for the greater excess of matrix over gravel-sized fragments. The separated pebbles in the caliche conglomerate might correspond to Pettijohn's open framework classification. This characteristic, the large boulders of limestone, and the immature nature of the pebbles and boulders suggest a turbulent stream deposit possibly in the form of an alluvial fan.

The chert fragments found in the caliche conglomerate resemble those found in the Cretaceous strata more than the chert found in the Ellenburger group. Several fragments of an arkose conglomerate, of the type found at the base of the Cretaceous hills, are found lying loose on top of the caliche hill. These fragments are believed to have been originally incorporated within the caliche conglomerate as they show well-worn, smooth surfaces.

<u>Origin and age</u>

The caliche conglomerate could be an outlier of the apparently marine Lower Cretaceous conglomeratic sandstones occurring in the hills to the south, or it could have been deposited by a Cretaceous stream before the Cretaceous sea actually invaded the area. However, two lines of evidence oppose these conclusions. One is the resemblance of the chert fragments in the caliche conglomerate to the chert in the Cretaceous limestones. The other is the fact that barometric elevations show the top of the caliche hill to be over 100 feet lower than the lowest Cretaceous beds found in the thesis area, together with the existence of strong evidence throughout the Llano region that a condition of peneplanation existed before the Cretaceous strata were deposited.

The caliche conglomerate now lies upon a divide between the tributaries of Cold Spring Creek and Marshall Creek. If it is a stream deposit, as suggested by its nature, it must be older than the present imperfect peneplane developing on the granite, gneiss, and schist. These relations suggest that it is of Tertiary age. However, two possibilities are suggested: (1) the conglomerate could be a remnant of a terrace deposited by the ancient Llano River, the rest of the terrace having been removed by the present creeks, or (2) the conglomerate could represent an alluvial fan deposit formed by a stream descending from a former spur of the Cretaceous hills, now eroded away. The latter explanation seems more reasonable. Under the first possibility, other deposits of caliche conglomerate might be expected in the vicinity on other interstream divides.

Thus, most of the evidence in the area suggests that the caliche conglomerate is a stream deposit of Tertiary age. This age would account for the Cretaceous-type chert, the fragments of arkose conglomerate, the pebbles and boulders of Paleozoic-type limestones and sandstones, and the Precambrian material found within the conglomerate. Additional evidence for Tertiary or later age is the nature of the caliche itself, since this fluffy calcium carbonate seems to form more readily from the Cretaceous limestones than from the Paleozoic limestones.

The conglomerate needs to be studied in more detail before a definite age can be established. It is mapped as a stream deposit of Tertiary age in this report.

QUATERNARY SYSTEM

Recent Alluvium

Thick accumulations of Recent alluvium derived from Cretaceous bedrock are spread out around the edge of the Cretaceous hills. These deposits were mapped where the identity of the underlying bedrock could not be determined.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The folded and metamorphosed Precambrian sediments with igneous masses intruded into them are the results of the first known period of deformation occurring in the Llano region. According to Stenzel (1934), the regional structure of the Precambrian rocks in the Llano uplift consists of several broad, open folds which have a northwest-southeast trend and a pitch of 16 degrees southeast. Stenzel also stated that the bedding and schistosity are parallel, and that the grain in the schists and gneisses is parallel to the axes of the open folds. More recent investigations show folds in the region that do not follow the northwest-southeast trend. All these folds were truncated by erosion previous to Paleozoic deposition and were not reflected in the Paleozoic or later rocks.

Uplift of the Llano region in late Mississippian time is suggested by the thinning of the Barnett shale as it approaches the region. The principal uplift is believed to have occurred during the Pennsylvanian period and has been dated by Sellards (1934, p. 97) as post-Bend and pre-Canyon in age. During or following this uplift, the region was affected by normal faults which, although varying in direction, have a prevailing northeast-southwest trend. According to Cloud and Barnes (1948, p. 118), the dips of the faults range from 60° to 90° with the steeper dips predominating.

For a more complete picture of the structural geology of the Llano region the reader should refer to Barnes (1956), Cheney and Goss (1952), Cloud and Barnes (1948), Plummer (1950), Sellards (1932, 1934), and Stenzel (1934).

STRUCTURE OF THE SQUAW CREEK-MARSHALL CREEK AREA

General Statement

The controlling structural feature of the area is the extensive cutting of the Precambrian and Paleozoic rocks by a series of normal faults. These faults have a prevailing northeast-southwest trend, a steep dip, and a varying throw. The Paleozoic rocks exposed in the area have an average strike of N. 40° E. and a dip of 2°-5° SE. This southeast dip coincides with the dip found in several other areas in this part of the Llano region. The Cretaceous rocks exposed in the southeastern part of the area are essentially flat-lying and are unaffected by faulting.

Faulting

Description of Faulting

The geologic structure in the Squaw Creek-Marshall Creek area is dominated by three highly faulted zones, two of which are located in the southeastern part of the area and the third in the northwestern part. However, if the Cretaceous rocks were removed the first two zones would probably be connected. An enlarged map of the faulted zone in the extreme southeastern portion is shown in plate II, and an enlarged map of the zone in the northwestern portion in plate III.

Two major faults seem to control the faulted zones in the area. That is, these two major faults branch out into numerous minor faults. The names Loyal Valley and Squaw Creek will be used by the author in discussing the major faults.

The Loyal Valley fault is located in the eastern part of the area and strikes almost due north and south. The fault brings the Precambrian rocks and Cap Mountain limestone into contact at the northern edge of the area, requiring a minimum throw of about 350 feet. The throw increases to the south, bringing the Lower Hickory sandstone into contact with the Ellenburger limestone, indicating a minimum throw of about 1,200 feet. The dip of the fault is estimated to be nearly vertical with the downthrown side to the west. A fault-line scarp is formed by the more resistant Paleozoic limestones on the downthrown side of the fault.

The Loyal Valley fault extends out of the area to the north and extends beneath the Cretaceous strata to the south. In the southern part of the area it branches out into numerous minor faults that strike slightly east of north. These in turn, branch into other minor faults that strike nearly parallel to the strike of the beds. All of the above faults are accompanied by what could be termed sliver faults and cross faults. The sliver faults branch off and connect back to the same fault. The cross faults strike northwest and connect the minor faults. The major, minor, sliver, and cross faults form a highly faulted zone. The minor, sliver, and cross faults vary in throw from less than 50 feet to about 300 feet. No set pattern is established for the downthrown sides of these smaller faults; consequently, a series of horsts and graben are formed between them. Repetition and omission of strata are caused by the smaller faults and the strata tend to become older toward the southeast. The overall pattern revealed by the strata and structure shows the strike of the rocks progressively changing from northeast-southwest (approximate regional strike) to north-south as the Loyal Valley fault is approached. There is some uncertainty as to the meaning of this change in direction of strike and the overall pattern of the faulted zone. Dr. Horace R. Blank (personal communication) suggested that the pattern of the minor faults in this zone marks the Loyal Valley fault as a major break whose movement possibly had an appreciable horizontal component with the east side appearing to have moved northward. Although no direct evidence for horizontal movement was found by the present author the possibility certainly should not be overlooked.

The faulted zone west of the Cretaceous hills is similar to and believed to be a continuation of the zone discussed above. The throw of the faults in this zone varies from a few feet to almost 300 feet, causing the repetition and omission of strata and the formation of horsts and graben.

The Squaw Creek fault cuts across the northwestern portion of the area, striking approximately N. 40° E. Paige (1912, Llano quadrangle) shows a fault striking northeast in the southwest portion of the Llano quadrangle that is believed to be part of this fault. The throw of the Squaw Creek fault varies from a few feet at the north border of the thesis area to over 600 feet at the south border. The downthrown side is to the northwest and a dip of 83° NW. was measured at one locality. The southwest end of the fault shows as a distinct vegetation alignment on aerial photographs. The Squaw Creek fault is accompanied by many of the minor, sliver, and cross faults previously discussed. The strata in this part of the area have been throughly sliced by the faulting. In some parts of the zone the faulting has caused a change in the direction of strike and a complete reversal of the dip. No set pattern is established by the faulting that can be used in determining the relative ages of the faults. The downthrown side occurs in different directions, thus forming horsts and graben in different parts of the zone. The throw of the smaller faults varies from a few feet to about 400 feet in this zone.

Although no faulting could be detected within the wide Cap Mountain belt in the central portion of the area, it is highly probable that faulting does occur. The narrow southwest portion and wide northeast portion of the belt are strong evidence of faulting. The extensive faulting on both sides of the belt also suggests that faulting should be present within the belt. Indications of a complex jointing system are found here and there throughout the Cap Mountain unit. On aerial photographs numerous vegetation alignments appear throughout the Cap Mountain belt. Several of these were closely checked, but in the absence of lithologic contrast within the Cap Mountain member no evidence of faulting could be found. It is highly probable that many of these alignments, if not all of them, represent faulting.

Detection of Faulting

Because of the complexity of the fault and joint patterns in the area, vegetation patterns were of little help in the delineation of individual faults. The detection and tracing of the minor, sliver, and cross faults required a thorough field study. The field indications that were used to detect faulting were repetition and omission of strata, erratic strikes and dips, the abrupt termination of beds, and the actual observation of the fault surface where it has been exposed by erosion.

In the faulted zone in the southeast portion of the area, many of the smaller faults are strikingly similar due to their exposure of a thin sliver of very hard, quartzitic, Welge sandstone (Pl. XXI).

PLATE XXI

Thin sliver of hard, quartzitic Welge sandstone exposed by minor fault along south side of graded county road about 0.2 miles west of U. S. Highway 87.

Age of Faulting

The Ellenburger limestone is the youngest rock unit cut by faulting in the area, indicating that the faulting is at least no older.

Cloud and Barnes (1948, p. 120) found evidence indicating that the faulting of the region occurred in either Strawn or post-Strawn and pre-Canyon time.

Cause of Faulting

There have been several theories presented for the origin of faulting in the Llano region. One of the first theories (Paige, 1912, p. 74) stated that the faults were the direct result of compressive forces. In contrast to this theory, Cloud and Barnes (1948, p. 118) attributed the faulting to tensional rather than compressive forces. Sliger (1957, p. 55) listed the following possible explanations for the origin of the faulting: (1) Doming of the region, (2) tectonic folding of the Paleozoic strata followed by relaxation of the compressive forces, (3) uplift of the basement complex with northeast-trending zones of more positive uplift, and (4) down-warping of beds on the southeast flank of the region into the Llanoria geosyncline. None of the above theories is believed to fully explain the faulting of the Llano region.

With the exception of the Loyal Valley fault and a few smaller faults, the strike of the faults in the thesis area coincides with the northeast trend of the major faults of the region.

Folding

In the Squaw Creek-Marshall Creek area folding is restricted to the bioherm zones. This folding is the result of differential compaction of the sediments above and between the bioherms. Several of these small folds can be seen in the tributaries to Beaver Creek in the north-western portion of the area.

GEOLOGIC HISTORY

Paige (1911), Sellards (1932), Cloud and Barnes (1948), and Barnes (1956) have presented detailed discussions on the geologic history of the Llano region. The following geologic sequence is based primarily upon evidence found in the thesis area, but some of the history is supplemented by evidence from other parts of the Llano region.

The gneisses and schists found in the thesis area are of metasedimentary and possibly meta-igneous origin and represent the oldest rocks of the Llano region. It appears that great thicknesses of sedimentary rocks, including sandstones, limestones, and shales with possibly some early emplacement of igneous intrusives were formed in the region during Precambrian time. This great thickness of rocks was folded, metamorphosed, and extensively intruded by igneous rocks. The coarse-grained texture of the granitic intrusions over the whole region indicates deep seated crystallization of the magmas. After the intrusions of the magmas the region was subjected to uplift and prolonged erosion, exposing the granites at the surface.

This prolonged erosion began in Late Precambrian time and lasted until Late Cambrian time, when the sea transgressed over the irregular Precambrian surface. The first Cambrian sea deposited the Hickory sandstone. The Hickory unit contains ventifacts and other reworked material of the erosion surface. Shallow water conditions seem to have prevailed throughout the deposition of the Hickory sandstone as can be seen by cross-bedding in the lower strata, symmetrical ripple marks and intraformational conglomerates in the middle portion, and phosphatic brachiopods in the middle and upper parts.

A continued slow subsidence of the land area is evidenced by the gradational contact between the Hickory sandstone and overlying Cap Mountain limestone. This slow subsidence is also seen by the appearance of calcareous material in the Cap Mountain member, but a shallow water deposition is still indicated by the deposition of arenaceous and glauconitic material.

The clastic and glauconitic nature of the Lion Mountain sandstone member suggests small-scale uplift and a slight regression of the sea.

The abrupt contact between the highly glauconitic Lion Mountain sandstone and the non-glauconitic Welge sandstone may represent an interruption in deposition and a renewed transgression of the sea. Scaife (1957) suggested that the abrupt contact may indicate a rapid change from non-deposition or slow deposition under reducing conditions to rapid deposition under oxidizing conditions.

A continued transgression of the sea is suggested by the decrease in detrital sediments and the increase in calcareous material of the Morgan Creek limestone. The glauconite, abundance of fossils, symmetrical ripple marks, and bioherms contained in the Morgan Creek limestone indicate deposition in a warm sea of moderate depth.

The gradation into the fine-grained argillaceous material of the Point Peak member suggests shallowing of the sea and a quiet marine environment. Intraformational conglomerates occurring very frequently within the member indicate intermittent shallowing of the seas, and mud cracks occurring locally indicate shallowing to the extent that the sediments were exposed on tidal flats. The small algal bioherms occurring within the member and the large bioherms at the top also suggest a shallow, relatively warm, quiet sea condition.

The gradational contact into the glauconitic, sublithographic San Saba limestone suggests slight subsidence but still shallow sea. Ripple marks and intraformational conglomerates are found in the middle and upper portions of the member. Shallow warm seas probably prevailed throughout the deposition of the San Saba limestone member and continued into Lower Ordovician time. The Cambrian-Ordovician boundary is gradational in the thesis area, occurring in a sublithographic, fossiliferous limestone. Cloud and Barnes (1948, p. 100) described the sedimentary environment of the Lower Ordovician sediments as being similar to that on the Bahama Banks today. An oölitic-type limestone is found in the Ordovician sediments in the thesis area.

There are no Late Ordovician and Silurian deposits in the region and it has not been determined whether sediments of this age were deposited and eroded or never deposited. It is generally believed that this interval represents a period during which the Ellenburger group was eroded and truncated.

Devonian, Mississippian, and Pennsylvanian rocks are not found in the thesis area but do occur in other parts of the region. The Devonian rocks occur only as isolated sinks and collapse fillings. The thinning of the Mississippian strata as they approach the region suggests the first domal uplift of the region. The abundant marine fossil content of the Devonian and Mississippian strata indicates a warm sea environment.

The Pennsylvanian strata exposed in the region generally unconformably overlie the Mississippian rocks, but in some places they are in contact with the Ellenburger limestone. Although knowledge of the conditions during Pennsylvanian time is limited, it is believed that the disturbance that caused the extensive faulting in the Llano region was probably related to the Ouachita orogeny and occurred in post-Bend and pre-Canyon time.

Subsequent to Canyon deposition, the Llano region was uplifted and subjected to extensive erosion that exposed the Precambrian rocks in the central part of the area. This interval is believed to have extended throughout the remainder of the Paleozoic time and to have continued until early Cretaceous time.

Prior to the transgression of the first Cretaceous sea, the region was reduced to a broad surface with little relief. The arkosic conglomerate is believed to represent a terrestrial stream deposit that was deposited during pre-Cretaceous or early Cretaceous time. The early Cretaceous sea deposited nearly flat-lying beds upon the truncated Paleozoic rocks and exposed Precambrian basement. The Cretaceous deposition was closed by a widespread uplift and followed by a prolonged period of erosion. There is no evidence of an invasion of the sea after the deposition of the Cretaceous rocks. Since the withdrawal of the Cretaceous sea, erosion has formed a topographic basin in which the Paleozoic and Precambrian rocks are exposed.

The major streams in the thesis area and most of their larger tributaries are believed to have originated upon the Cretaceous strata, possibly during Tertiary time. After removal of the Cretaceous rocks they became superimposed upon the harder Precambrian and Paleozoic rocks now exposed.

Cenozoic rocks occur only as stream and alluvial deposits in the region. A caliche conglomerate is exposed in the thesis area that is believed to be a stream deposit of Tertiary age. Recent alluvium composed of detrital material derived from the Cretaceous rocks covers the bedrock around the edge of the Cretaceous hills.

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

The most important resource of the Squaw Creek-Marshall Creek area is the grazing land. A small amount of land is cultivated primarily for growing feed for the livestock. The soils used for farming are those derived from the Hickory sandstone in the northwestern and southeastern parts of the area and the Recent alluvium in the south-central part of the area.

A granite quarry in the northeastern corner of the area and a caliche conglomerate quarry northeast of Kelley Keller's ranch house furnish road material for the local ranchers.

An attempt has been made to quarry a stromatolitic limestone of the Wilberns formation located about one mile north of the Mason-Gillespie County line and about one-third of a mile west of U. S. Highway 87. This limestone is highly faulted and saw blocks of sound stone could not be produced.

No ore deposits or petroleum have been found in the area.

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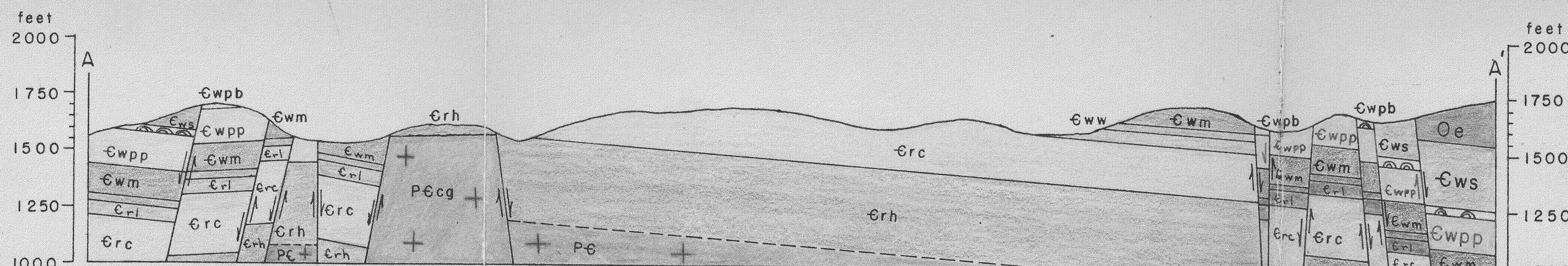
A P P E N D I X

Section of Lion Mountain sandstone and Welge sandstone exposed on the Henry Keyser Sr. ranch about 0.25 miles southwest of the graded county road and 1.9 miles west of U. S. Highway 87 (location 6, Pl. I). The base of the section is at the north edge of the flat bench and it continues southward to the top of the escarpment formed by the Welge sandstone and Morgan Creek limestone.

	Thickness in feet
Wilberns formation	
Morgan Creek limestone member	
6. Limestone; reddish-purple, coarse-grained, slightly glauconitic, and sandy. Weathers to a reddish-brown.	2.0
Total Morgan Creek member measured	2.0
Welge sandstone member	
5. Sandstone; thickly bedded, tan to light brown, coarse-grained, non-calcareous, non-glauconitic sandstone. These beds are covered in places by a thin soil cover.	19.7
4. Sandstone; tan to reddish-brown, fine to medium-grained, non-fossiliferous, non-calcareous, non-glauconitic sandstone. The actual contact between this unit and the underlying unit is covered.	10.0
Total Welge member measured.	29.7

	Thickness in feet
Riley formation	
Lion Mountain sandstone member	
3. Partly covered slope; This is a rather steep slope that has a few exposures of bedrock. The exposed bedrock consists of a medium to coarse-grained, light to dark green sandstone and a bluish-purple siltstone. These beds contain dark gray to purple lenses of "trilobite hash". Where the bedrock is covered, slabs of the "trilobite hash" and dark red to black hematite nodules are scattered over the surface	49.0
2. Covered bench; This is a flat bench completely covered with bright red soil, with slabs of "trilobite hash" and hematite nodules scattered on the surface	10.3
Total Lion Mountain member	59.3
Cap Mountain limestone member	
1. Limestone; thickly bedded, fine to medium-grained, fossiliferous, glauconitic, and contains calcite grains and hematite stains. Thin layers of light tan to gray siltstone and very fossiliferous limestone are found between these thick limestone beds.	4.8
Total Cap Mountain member.	4.8
Total thickness measured	95.8

Geology by I. W. Woolsey, 1958



(Topography and dips of faults estimated)

GEOLOGIC MAP AND SECTION OF THE SQUAW CREEK–MARSHALL CREEK AREA, MASON COUNTY, TEXAS

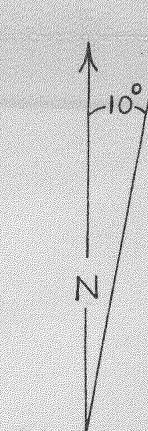
EXPLANATION

GEOLOGIC COLUMN

- QUATERNARY — RECENT
  - Qal — Alluvium
- UNCONFORMITY
- TERTIARY (?)
  - Tc — Caliche conglomerate
- UNCONFORMITY
- CRETACEOUS — LOWER CRETACEOUS
  - Kls / Kss — Limestone with underlying sandstone
  - Kac — Arkosic conglomerate
- UNCONFORMITY
- ORDOVICIAN — LOWER ORDOVICIAN — ELLENBURGER GROUP
  - Oe — Ellenburger limestone and dolomite
- CAMBRIAN — UPPER CAMBRIAN
  - WILBERNS FORMATION
    - Ꞓws — San Saba limestone member
    - Ꞓwpb / Ꞓwpp — 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
  - PꞒcg PꞒmg — Medium-grained and Coarse-grained granites
  - PꞒgn PꞒs — Gneiss and Schist

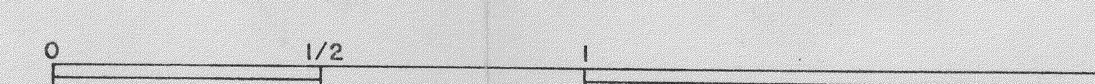
SYMBOLS

- U / D — Normal fault; U, upthrown side; D, downthrown side
- U / D — Inferred normal fault
- Observed and inferred contacts
- 3, 60 — Strike and dip of strata and foliation
- Flowing stream
- Intermittent stream
- A———A' — Structure section line
- Property line fence
- County line
- Oil pipeline
- Paved road
- County road
- Ranch road
- Stock tank
- Ranch building
- 6 — Location described in text



Approximate mean declination, 1958

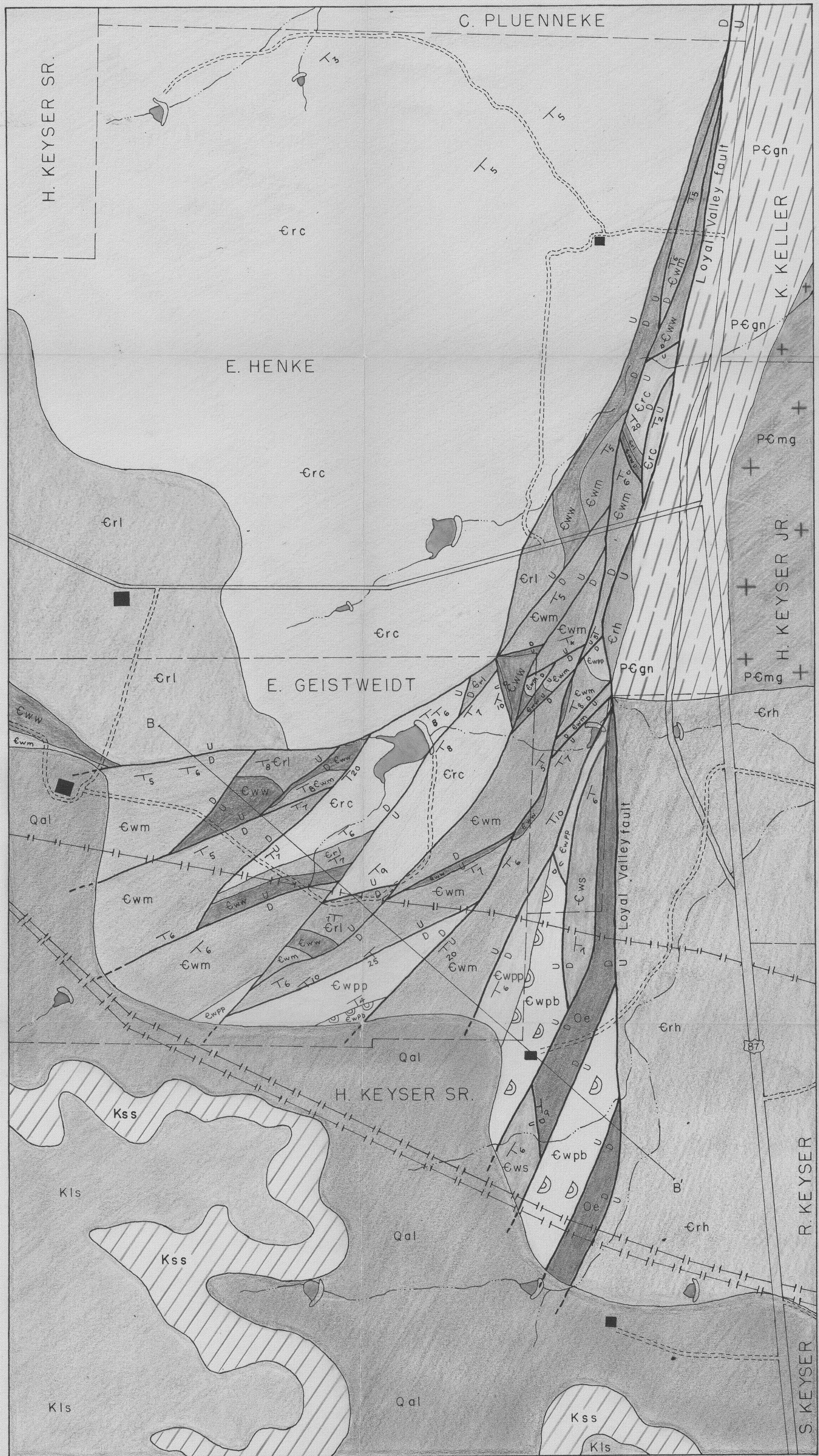
Horizontal Scale 1:20,000



Vertical Scale { 3.3 X Horizontal Scale; Datum = approximate sea level

Base from U. S. Department of Agriculture, Soil Conservation Service, Aerial photographs, 1955–1956.

DETAILED GEOLOGIC MAP AND SECTION OF A SOUTHEASTERN PORTION OF THE SQUAW CREEK-MARSHALL CREEK AREA, MASON COUNTY, TEXAS



EXPLANATION

GEOLOGIC COLUMN

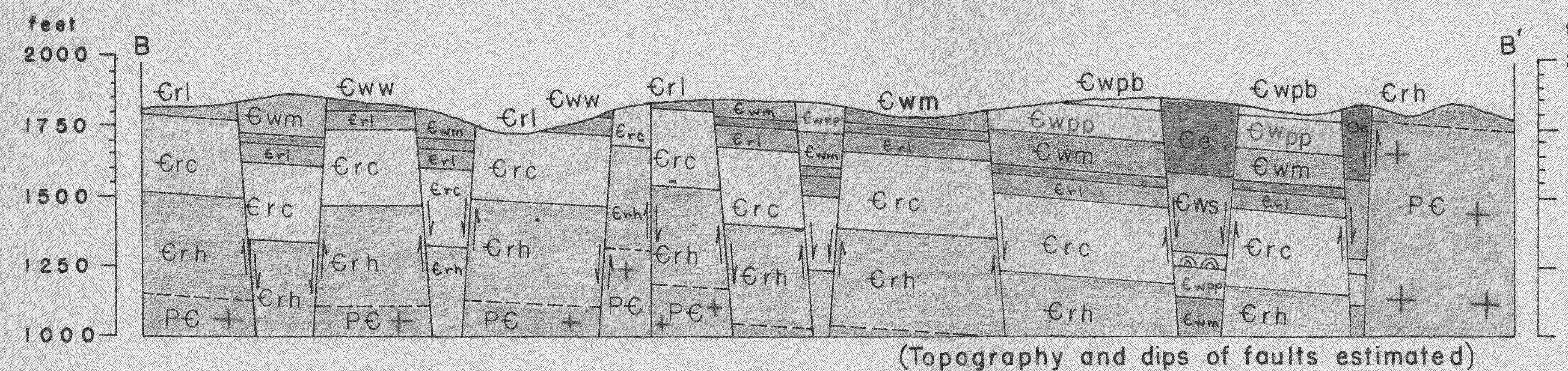
RECENT		Qal	Alluvium	QUATERNARY
			UNCONFORMITY	
LOWER CRETACEOUS		Kls / Kss	Limestone with underlying sandstone	CRETACEOUS
			UNCONFORMITY	
LOWER ORDOVICIAN	ELLENBURGER GROUP	Oe	Ellenburger limestone and dolomite	ORDOVICIAN
UPPER CAMBRIAN	WILBERNS FORMATION	€ws	San Saba limestone member	CAMBRIAN
		€wpb / €wpp	Point Peak shale member (Bioherms at top)	
		€wm	Morgan Creek limestone member	
		€ww	Welge sandstone member	
	RILEY FORMATION	€rl	Lion Mountain sandstone member	
		€rc	Cap Mountain limestone member	
		€rh	Hickory sandstone member	
			UNCONFORMITY	
		P€mg	Medium-grained granite	PRECAMBRIAN
		P€gn	Gneiss	

SYMBOLS

- U / D — Normal fault. U, upthrown side; D, downthrown side
- Inferred normal fault
- Observed and inferred contacts
- 3 — Strike and dip of strata
- Ranch building
- Intermittent stream
- B—B' — Structure section line
- Property line fence
- Oil pipeline
- Stock tank
- Paved road
- County road
- Ranch road

N — 10° — Approximate mean declination, 1958

Base from U. S. Department of Agriculture, Soil Conservation Service, Aerial photographs 1955-1956.



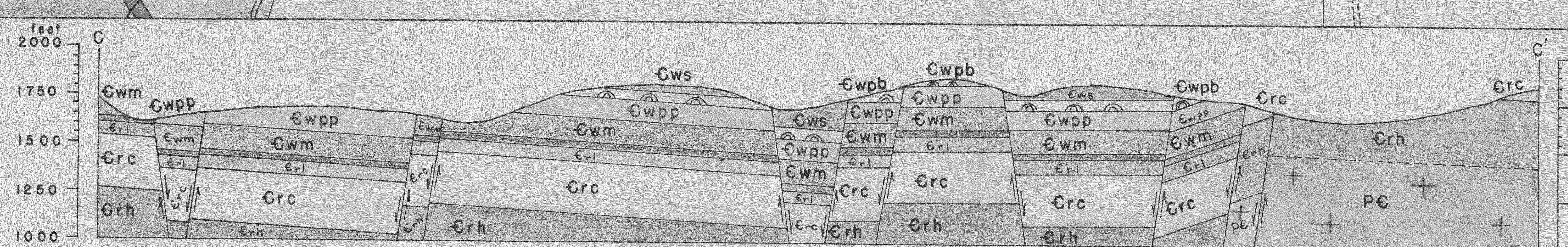
Horizontal scale 1:7,920

0 — 1/4 — 1/2 — 1 mile

Vertical scale { 1.3 X Horizontal scale; Datum = approximate sea level

Geology by I. W. Woolsey, 1958

1958
Thesis
W916



(Topography and dips of faults estimated)

EXPLANATION

GEOLOGIC COLUMN

LOWER ORDOVICIAN — ELLENBURGER GROUP — ORDOVICIAN
- Oe — Ellenburger limestone and dolomite

UPPER CAMBRIAN — CAMBRIAN

WILBERNS FORMATION
- Ꞓws — San Saba limestone member
- Ꞓwpb / Ꞓwpp — Point Peck 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
- PꞒcg — Coarse-grained granite

SYMBOLS

- Normal fault; U, upthrown side; D, downthrown side
- Inferred normal fault
- Observed and inferred contacts
- Strike and dip
- Flowing stream
- Intermittent stream
- Structure section line (C — C')
- Property line fence
- Ranch building
- Stock tank
- Location described in text
- County road
- Ranch road

Horizontal scale 1:7,920

0 — 1/4 — 1/2 — 1 mile

Vertical scale { 1.3 x Horizontal scale; Datum = approximate sea level

Base from U. S. Department of Agriculture, Soil Conservation Service, Aerial Photographs 1955-1956.

Geology by I. W. Woolsey, 1958

Approximate mean declination, 1958 (N, 10°)

DETAILED GEOLOGIC MAP AND SECTION OF A NORTHWESTERN PORTION OF THE SQUAW CREEK-MARSHALL CREEK AREA, MASON COUNTY, TEXAS