GEOLOGY OF THE PONTOTOC NORTHWEST AREA,

SAN SABA AND MASON COUNTIES, TEXAS

A Thesis

By

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(Chairman of Committee)

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A B S T R A C T

This study of the Pontotoc Northwest area was done to prepare a geologic map of the area showing the structural and stratigraphic relationships of the lithologic units in order to determine the geologic history of the area and the environmental conditions that existed at the time the rock units were deposited.

The Pontotoc Northwest area is situated on the northwestern flank of the Llano uplift and is located in the southwest corner of San Saba County and in northeastern Mason County. The area is one of low relief, and part of the area drains northward into the San Saba River and part drains southward into the Llano River.

Strata within the Pontotoc Northwest area are of Precambrian, Late Cambrian, Early Ordovician, and Quaternary ages. Rocks of Precambrian age are represented by a fine-grained, pink granite and by a gneiss-schist unit that is probably equivalent to the Valley Spring gneiss. The Riley and Wilberns formations comprise the strata of Late Cambrian age, and rocks of Early Ordovician age are represented by the Ellenburger group. Rocks of Quaternary age are limited to very small deposits of alluvium and conglomerate that occur along the major streams.

Relief of the Precambrian depositional surface within the area at the time of Late Cambrian deposition was about 500 feet, and the area was somewhat rugged. Buried Precambrian hills exist in the area with the highest extending upward almost to the top of the Cap Mountain limestone member of the Wilberns formation.

The Llano uplift is a portion of an ancient structural feature called the Concho arch. The main structural features of the Llano region

are northeast trending grabens and horsts. The Pontotoc Northwest area is located on the Pontotoc axis which is an upthrown block between two downthrown blocks.

The main structural feature of the Pontotoc Northwest area is the Fredonia fault which extends from the James River, Mason County, almost to the San Saba River in San Saba County. It is one of the longest faults in the Llano region.

Several smaller faults branch from the Fredonia fault within the Pontotoc Northwest area. Most of the smaller faults do not extend beyond the limits of the area, and displacement of the faults is small. The only folds observed in the area were small folds within the Point Peak shale and a small structural basin that has been disrupted by several faults.

Uplift of the Llano region, which deformed rocks of Paleozoic and Precambrian ages, began in Mississippian time and terminated in Pennsylvanian time.

Underground water is the most important resource of the area with usage being primarily for domestic and ranch needs. Recent interest in the lower Hickory sandstone as a source of sand for "sand fracturing" strata in wells promises to add to the economy of the area.

INTRODUCTION

LOCATION

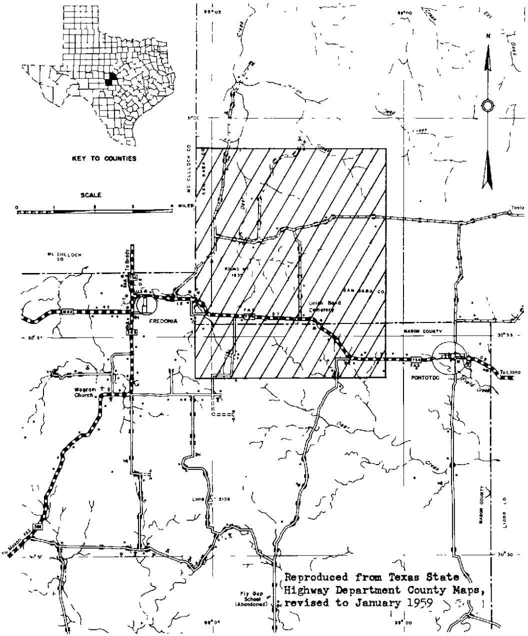
The Pontotoc Northwest area is about thirty square miles in extent and is located mainly in the southwest corner of San Saba County, Texas. A small part of the area is in Mason County (Figure 1). The Pontotoc Northwest area is situated on the northwestern flank of the Llano uplift.

The area is rectangular in shape and is approximately six miles long, north to south, and five miles wide, east to west. In San Saba County the western boundary of the area coincides with the west boundary of the county, and in Mason County the western boundary is a projection of this line southward. The southern boundary is a line 1.4 miles south of and parallel to the San Saba-Mason county line. The eastern boundary is approximately two miles west of the town of Pontotoc, Mason County, Texas. Both the eastern and northern boundaries of the area are marked by fence lines that extend the length and width of the area.

ACCFSSIBILITY

From the towns of Pontotoc and Fredonia, Mason County, the Pontotoc Northwest area is easily reached by Ranch Road 734. A network of unpaved but well maintained county roads intersects Ranch Road 734 and affords accessibility to most of the area. Numerous ranch trails lead from the major roads to windmills, stock feeding areas, and to the creeks. Some of the ranch trails are passable only in dry periods and then only in pickups or jeeps.

Figure 1



LOCATION MAP OF THE PONTOTOC NORTHWEST AREA,
SAN SABA AND MASON COUNTIES, TEXAS

METHODS OF FIELD WORK

Most of the field work was done between July 22, 1959, and September 17, 1959, and was completed on weekend trips to the area during the fall of 1959.

Geologic mapping was done on acetate overlays of U. S. Department of Agriculture aerial photographs dated November 25, 1948. The scale of these photographs is 1:20,000 or one inch equals approximately 1,667 feet. The photographs are of series BRH-6E and are numbers 3-9, 77-82, and 88-94. New photographs of series BRH-4W were used as an aid in mapping. These photographs are dated November 6, 1958, and were used to prepare the base map for the geologic map (Plate 1).

Geologic contacts and faults were traced in the field and their locations were plotted on acetate overlays. Stereoscopic examination of the photographs aided in locating some faults and contacts that were somewhat obscure and difficult to find by field work alone.

Dips and strikes of the beds were taken with a Brunton compass. Elevation readings to aid in drawing the cross sections were taken with a Keuffel and Esser Company aneroid altimeter between the hours of 6 and 7:30 A.M. November 7 and 8, 1959. The altimeter was set at the U. S. Geological bench mark located one-half block south of the junction of Ranch Roads 501 and 734 in the town of Pontotoc.

FIELD CONDITIONS

Low relief exists in the Pontotoc Northwest area, and dense growths of grasses in low areas complicated the tracing of geologic contacts. Suitable localities for measuring and describing stratigraphic sections do not occur, and the thicknesses of the units within the area were estimated from widths of exposures and dips. At all times an attempt was made to do objective geologic mapping, but in many places obscure geologic contacts necessitated their representation by dotted lines on the geologic map.

REVIEW OF LITERATURE

The first published description of the rocks and fossils of the Llano region was by Ferdinand Roemer. Roemer (1846, 1848) briefly described the rocks of Paleozoic and Mesozoic ages and remarked on the similarity between the rocks of Cretaceous age of the area and those around the Mediterranean Sea of Europe. He erroneously considered the coarse-grained granite of Enchanted Rock, Llano County, to be part of the crystalline mass of the Rocky Mountains. This work was followed by numerous other reports on the Llano region of which those of importance to this study are mentioned.

B. F. Shumard (1861) described the rocks of the "primordial zone" of Texas and divided them into the Calciferous sand group and the Potsdam sandstone which he considered to be Late Cambrian in age. He also described new species of fossils of Late Cambrian age from the Llano region.

G. G. Shumard (1886) briefly described the rocks of the Llano region. His observations of the geology of the region were made in 1885 and 1886 while accompanying an expedition of army engineers.

The name Llano group was proposed by Walcott (1884) for the pre-Potsdam strata. On the basis of lithologic character and stratigraphic relation to the overlying Potsdam group he correlated the Llano group with the Grand Canyon group and referred it to the Lower Cambrian Series. Walcott also assigned a pre-Potsdam age to the granites that are intruded into the Llano group, and on the basis of paleontology he confirmed the age of the Potsdam group of Texas as being Late Cambrian.

Hill (1887) in reviewing the geology of Texas noted the importance of the work done by Walcott in definitely establishing the Potsdam group of Texas as being Cambrian in age. Hill (1889) correctly established by paleontological criteria that the rocks at Marble Falls are of Carboniferous age. They had previously been considered as being Devonian in age.

As a portion of the investigations undertaken by the Texas Geological Survey, Comstock (1890) reported on the minerals and ores of the Llano region. In subdividing the Precambrian System he introduced the terms Valley Spring series and Packsaddle series. For subdivisions of the rocks of Paleozoic age he proposed the terms; Hickory series (Lower Cambrian); Riley series (Middle Cambrian); Katemcy series (Upper Cambrian); and the San Saba series (Silurian). The term Katemcy series has been dropped from usage, and the other series names have been modified and redefined.

Tarr (1890) recognized that the larger streams in the Llano region cut through the rocks of Paleozoic age without regard to structural features. He concluded that the present drainage system originated during Tertiary time on the rocks of Cretaceous age and is now superimposed on the older rocks.

The metamorphic rock units, Packsaddle schist and Valley Spring gneiss, were redefined by Paige (1911). Paige also changed the use of the term Hickory (Comstock, 1890) to refer to the Hickory sandstone. Under Paige's classification the Upper Cambrian strata were divided into the Hickory sandstone, Cap Mountain formation, and the Wilberns formation. Paige also named and defined the Ellenburger limestone and the Smithwick shale. Paige (1912) described and discussed the geology of the Llano and Burnet quadrangles. The report included geologic maps, structural sections, and topographic maps.

Udden, Baker, and Bose (1916) reviewed the geology of Texas and published the first comprehensive geologic map of the state. The rocks of Paleozoic age in the Llano region were shown on the map as Pennsylvanian, Paleozoic undivided, and Cambrian-Ordovician.

Plummer and Moore (1921) published a geologic map showing the Carboniferous formations of central Texas. The shale underlying the Marble Falls limestone was designated as the Barnett. Girty (Girty and Moore, 1919) correlated the Barnett shale with the Caney shale of Oklahoma and the Moorefield shale of Arkansas and concluded that it was of Mississippian age. A crinoidal limestone of Early Mississippian age, underlying the Barnett shale, was reported by Roundy, Girty, and Goldman (1926). Sellards (1932) assigned the name Chappel to the unit.

Jones (1929) described the stratigraphic units along the Pedernales River in Gillespie and Blanco counties. He stated that the granites along the river are not intruded into the rocks of Paleozoic age and that they are of Precambrian age.

Deen (1931) discussed the occurrence of algal limestones in the shaley upper portion of the Wilberns formation. He also noted that the algal limestones capped hills at many localities.

A correlation of faunal zones of the Ellenburger limestone was made with similar zones in rocks of Ordovician age in other states (Dake and Bridge, 1932).

Sellards, Adkins, and Plummer (1932) reviewed the systems of the Llano region and included a discussion of the regional structure and geologic history. The suggestion that the thinning of the Barnett shale over the Llano region indicated that the first uplift of the area began in Mississippian time was made by Sellards and Baker (1934).

Stenzel (1934) proposed a three-fold division for the granites of the Llano region on the basis of the lithology and internal structure of the granite masses. He also redefined the Packsaddle schist and the Valley Spring gneiss.

Stenzel (1935) reported that apparently no stratigraphic breaks occur in the metamorphic rocks of sedimentary origin within the Llano region.

Bridge and Girty (1937) reviewed the descriptions of the rocks of Paleozoic age originally given by Roemer. Some of the fossils described by Roemer were redescribed and their definite localities and stratigraphic ranges were determined.

Darton visited the Llano region in 1933 while employed by the U. S. Geological Survey. Geologic data were collected from geologists of Texas, certain areas and contacts were checked in the field, and with the help of Stephenson and Gardner, Darton prepared a new geologic map of the State of Texas (1937). The map showed the rocks of Paleozoic age divided into the Hickory sandstone, Wilberns and Cap Mountain limestones, Ellenburger limestone, Marble Falls limestone, Smithwick shale, Strawn group, and Canyon group.

Bridge (1937) concluded that the Upper Cambrian section of the Llano region is nearly as complete as the section of the upper Mississippi valley. The Texas section was correlated with the Missouri and Mississippi valley sections. At the same time Bridge named the Lion Mountain sandstone and designated it a member of the Cap Mountain formation.

Dreikanters from the Hickory sandstone were described by Barnes and Parkinson (1939). They stated that dreikanters continued to form after deposition of the Hickory sandstone began and that parts of the lower Hickory sandstone represent wind blown sediments.

Using subsurface data Cheney (1940) presented a new classification of the Pennsylvanian strata of north-central Texas. He also suggested a structural relationship between the Concho arch and the Llano uplift.

Keppel (1940) studied the large bodies of granite in the Llano-Burnet region and suggested that they were forcibly injected into the country rock.

A four-fold division of the Wilberns formation was suggested by Bridge and Barnes (1941). The four members were not named but were described as a basal sandstone, a glauconitic limestone, a calcareous shale, and a limestone at the top. The members were later named by Barnes (1944).

Goldich (1941) studied the granite masses of the Llano region and concluded that they evolved by differentiation.

The rocks of the Llano region suitable for use as building stones were studied by Barnes, Dawson, and Parkinson (1942). A review of the stratigraphy of the region and comprehensive descriptions of the building stones were given.

Plummer (1943a) recognized the importance of the Hickory sandstone and the Ellenburger limestone as aquifers. He also discussed the water resources of the State of Texas.

Small occurrences of rocks of Devonian age were discovered and described by Barnes, Cloud, and Warren (1945). The age determination was based on fossils contained in the rocks.

Decker (1945) studied the graptolites of the Wilberns formation and correlated the Wilberns with units of similar age in other areas in the United States. He reported that the graptolites of the Wilberns formation occurred relatively low in the Upper Cambrian Series.

The use of the term Ellenburger was revised to apply to the Ellenburger group of Early Ordovician age (Cloud, Barnes, and Bridge, 1945). The Ellenburger group was divided into three formations: the Tanyard at the base and containing the Threadgill and Standebach members, the Gorman, and the Honeycut at the top. The formations were correlated with strata in Missouri. The authors also revised the nomenclature of the pre-Wilberns strata, named the new unit the Riley formation, and divided it into the Hickory sandstone, Cap Mountain limestone, and the Lion Mountain sandstone.

The two formations and eight members of the Upper Cambrian of the Llano region were described and redefined by Bridge, Barnes, and

Cloud (1947). The work was intended to be a standard reference for the section.

Cloud and Barnes (1948) reported on the Ellenburger group of Central Texas. A brief discussion of the pre-Ellenburger strata was included in the report.

The trilobite fauna of the basal Wilberns formation was described by Wilson (1949).

Blank (1951) discussed the weathering and exfoliation of the granite domes of central Texas and determined that the erosional surfaces of the granites are due to both granular disintegration and exfoliation. He concluded that the release of stresses within the granitic masses was responsible for the exfoliation.

Cheney and Goss (1952) discussed the Llano uplift from a tectonic viewpoint.

Upper Ordovician rocks were reported in a collapse structure in southern Burnet County by Barnes, Cloud, and Duncan (1953). The name Burnam limestone was applied to these rocks.

An age determination of 1,000 million years for the batholithic granites of the Llano uplift was made by Flawn (1956) using the magnetite-helium and the zircon methods of age determination. An age of Middle Precambrian was assigned to the Texas craton.

Barnes (1956) reported on the lead deposits of the Llano region and described the occurrence of igneous rocks of Carboniferous or later age that consist of diabase dikes and are intruded along the Marble Falls fault.

Goolsby (1957) proposed that the Hickory sandstone be raised to formational status as it could be divided into three distinct members.

Several detailed studies have been made of areas in the vicinity of the Pontotoc Northwest area. Mounce (1957) made a detailed study of the Camp San Saba-West area. Mosteller (1957) studied the North Fredonia area in detail. The North Fredonia area borders the Pontotoc Northwest area for a short distance on the western side. McGrath (1952) made a detailed geologic study of the Fredonia area which adjoins the Pontotoc Northwest area along the greater portion of the western boundary.

GEOGRAPHY

CLIMATE

The Llano region is located in a semi-arid climatic zone where the average annual precipitation approximates 25 inches. The precipitation is greatest during the fall and spring months. Run-off is high as the rains are often of short duration and of a torrential nature.

The mean annual temperature of the Llano region is approximately 70° F., and the temperature ranges from over 100° F. in the summer to slightly below 0° F. in the winter. In San Saba County the average temperature is 49° F. for the month of January and 82° F. for the month of July. The mean annual temperature in San Saba County is 66° F.

VEGETATION

Vegetation is limited to those types having affinities for semi-arid climatic conditions and thin, rocky soils. Mesquite, persimmon, and scrub oak are in general the principal trees of the Pontotoc Northwest area. A few pecan trees occur along the valleys of the creeks and larger draws.

The portions of the area where the soils are derived from limestone are generally characterized by the growth of scrub oak, cacti, persimmon, occasional mesquite, and grasses. Mesquite, grassburrs, beebrush, grasses, and scrub oak grow on the sandy soils derived from the weathering of the sandstones.

The differences in vegetation between the exposures of sandstones and limestones result in differences in patterns on the aerial photographs that are extremely useful in determining contacts between the different lithologic units.

LAND USE

Farming and ranching are the chief sources of income in the Pontotoc Northwest area with the raising of cattle, sheep, and goats predominating. Hog raising exists on a limited scale. Farming is almost wholly confined to those areas occupied by lower and upper Hickory sandstone. Nearly all of the fields occurring on Lion Mountain and Welge sandstones are now fallow. A marked exception is the irrigated farm of about forty acres on the Charlie Hoover property. Cotton, peanuts, watermelons, and grain are the principal crops. All of the fields are small and have sandy soils.

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

TOPOGRAPHY

Structurally a dome, the Llano uplift is topographically expressed as a basin and is one of Texas' major physiographic features. Younger rocks have been eroded from the center of the region, exposing rocks of Precambrian age and leaving a surrounding rim of rocks of Paleozoic and Cretaceous ages.

One of the most outstanding physiographic features in the Pontotoc Northwest area is Round Mountain (locally called Dick Mountain) which has an elevation of 1,835 feet and is the highest point in the area. Round Mountain is a rather small, isolated hill on the western side of the Charlie Hoover property and is formed of Point Peak shale capped by bioherms. The Hill probably owes its existence to local geologic structure as it is the center of a small faulted basin from which erosion has stripped sediments leaving the top of Round Mountain about 185 feet above the low area immediately northeast of the hill.

On the eastern side of the area where the general dip of the beds is in a direction a few degrees east of north the Cap Mountain and Morgan Creek limestones form cuestas. The escarpment formed by the Cap Mountain limestone can be traced with ease on aerial photographs. A few outliers of Cap Mountain limestone are located near the escarpment.

The exposures of San Saba and Ellenburger limestones form rather low rolling hills. In the major portion of its area of exposure the Hickory sandstone forms relatively flat land, but in the southeastern part of the area it forms an escarpment.

A broad, low valley occupies the northwestern portion of the area and has been formed by Deer Creek and its tributaries flowing over the highly faulted strata.

In the southern portion of the area the metamorphic rocks form an east-west trending hill that has a local relief of about 125 feet.

Probably the second most outstanding physiographic feature of the area is the escarpment formed by the Point Peak shale capped by bioherms. The escarpment occurs within the downthrown block of a graben on the eastern side of the Wallace Wever property. The upthrown block to the northwest of the graben has been reduced to a level lower than the graben.

The area of lowest elevation within the Pontotoc Northwest area is in the southeastern corner and has an elevation of approximately 1,575 feet. The maximum relief of the area is 260 feet, and the points of lowest and highest elevations are separated by a distance of about four and one-half miles.

DRAINAGE

The Colorado River system, with three major tributaries flowing eastward, affords drainage for the Llano region. The tributaries are the San Saba River on the northern flank of the uplift, the Llano River in the central portion, and the Pedernales River on the southern flank.

The drainage is dendritic, and the major streams were formed as consequent streams on the old Cretaceous surface. Tertiary uplift of the region caused the streams to become incised, and they are now superimposed on the rocks of Paleozoic and Precambrian ages.

A portion of the drainage divide between the San Saba and Llano rivers is within the Pontotoc Northwest area. The southeast corner of the area is drained by several unnamed draws and creeks that are tributaries of San Fernando Creek which drains into the Llano River. One of these small creeks heads in the Hickory sandstone and flows through the S. S. Capps estate where it cuts through a hill of metamorphic rocks of Precambrian age. Diminutive waterfalls a few feet in height and related potholes have developed in the metamorphic rocks of the creek bed (Plate II, Fig. 1).

Three major creeks occur in the Pontotoc Northwest area. Deer Creek drains the larger portion of the area and occupies a broad valley in the northeastern part of the area and flows northward to join the San Saba River. One tributary extends southward almost to Ranch Road 734. Deer Creek flows across several faults and has complete disregard for the attitudes of the beds.

Lost Creek flows through a small portion of the western side of the area, and its tributaries drain the southwest part. To the west of the Pontotoc Northwest area Lost Creek turns northward and drains into the San Saba River.

The northeastern part of the area is drained by Hinton Creek which flows northwest out of the area to join Deer Creek before entering the San Saba River.

All of the streams are intermittent, but some of them carry considerable amounts of water for short periods immediately following heavy rains.

PLATE II

EXPOSURES OF GNEISS

Fig. 1. Waterfall in massive gneiss on S. S. Capps estate.

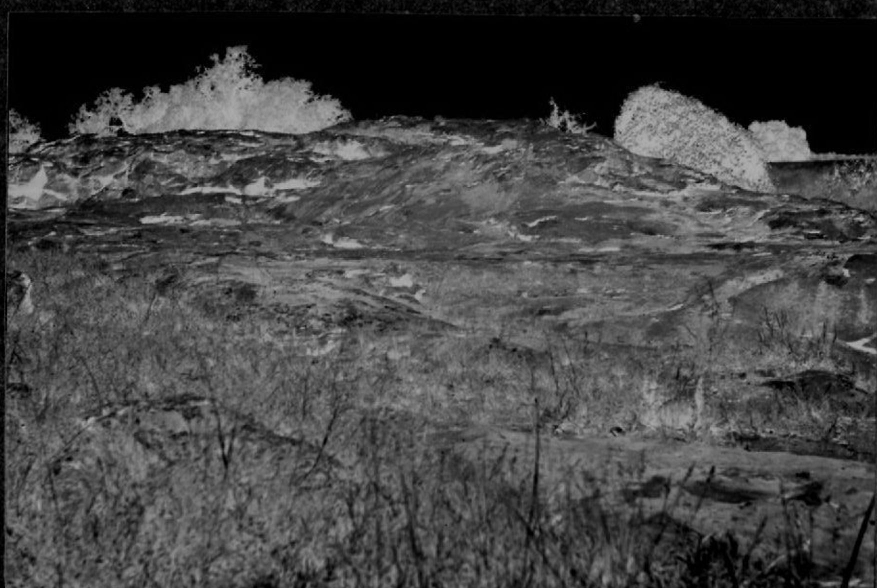


Fig. 2. Exposure of massive gneiss on Stacy Miller farm.

STRATIGRAPHY

GENERAL STATEMENT

Rocks of Precambrian, Cambrian, Ordovician, and Quaternary ages occur within the Pontotoc Northwest area. Rocks of Quaternary age are limited to very small exposures of conglomerate and alluvium along the major streams and are not represented on the geologic map because of their diminutive size.

The stratigraphic column for the Pontotoc Northwest area is given:

- Quaternary System
  - Conglomerate and alluvium
- Ordovician System
  - Ellenburger group
- Cambrian System
  - 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 Rocks
  - Igneous rocks
    - Fine-grained granite
    - Aplite and pegmatite dikes
  - Metamorphic rocks
    - Gneiss-schist unit

PRECAMBRIAN ROCKS

Rocks of Precambrian age in the Pontotoc Northwest area are of igneous and metamorphic origin and are represented by granite, aplite and pegmatite dikes, and by a gneiss-schist unit.

METAMORPHIC ROCKS

The metamorphic rocks of the Llano region were named the Llano group by Walcott (1884, p. 431). Walcott concluded that varying degrees of metamorphism are evident in the rocks with the section at Packsaddle Mountain, Llano County, exhibiting but little evidence of metamorphism whereas near Honey Creek, four miles west of Packsaddle Mountain, the Llano group has been more highly metamorphosed.

The terms Valley Spring gneiss and Packsaddle schist were first used by Comstock (1890) in dividing the Precambrian Systems. They were later redefined and restricted by Paige (1912) and Stenzel (1934). In the Llano-Burnet area (Paige, 1912, p. 29) the schist overlies the gneiss and is exposed along the flanks of anticlines and in synclines. The gneiss is exposed primarily along the crests of the anticlines.

Valley Spring Gneiss

The Valley Spring gneiss as defined by Sellards (1932, p. 32) is light in color and consists predominantly of quartz and feldspathic minerals. Sellards stated that the gneiss grades into schist and contains schist, and that in many places a separation of the two is impossible. Where it is possible, the separation is made on the basis of the gneiss having a higher content of acidic materials and being more massive in character. The type locality is Valley Spring, Llano County.

Packsaddle Schist

The Packsaddle schist consists of several thousand feet of metamorphosed sediments that according to Sellards (1932, p. 33) were originally shales, sandstones, and limestones. Basic and acidic igneous rocks have intruded the metamorphosed sediments. Various schists, including hornblende, mica, amphibole, and graphite schists, are represented in the unit. Cleavage is well developed in the schists and generally coincides with the original bedding planes of the sediments. The type locality is Packsaddle Mountain, Llano County.

Gneiss-Schist Unit

The gneiss and schist could not be differentiated with any accurracy within the Pontotoc Northwest area and were mapped as one unit. In general, throughout the area, there is more gneiss than schist in the unit. In certain outcrops the schist occurs only in limited amounts and gives the overall appearance of being included within the gneiss.

Geologic contacts between the gneiss-schist unit and other stratigraphic units vary greatly in nature. At places the contacts are well defined, but where the gneiss-schist unit has undergone extensive weathering the contact is usually obscured to a certain degree but can still be mapped with reasonable accuracy. Pegmatite, aplite, and quartz dikes have intruded the unit at several localities.

Outcrops of the gneiss-schist unit occur in several general localities within the Pontotoc Northwest area. Because of variations in nature of contacts, character of the unit, and relationship to other stratigraphic units the discussion of the unit is presented by individual locality.

Southwest Corner Stacy Miller Property

The exposure at this locality is a light pink, massive gneiss. A large portion of the outcrop is weathered gneissic soil containing an abundance of quartz and gneiss fragments with a lesser number of fragments of biotite schist. However, in two places outcrops of massive gneiss stand a few feet above the gneissic soil.

Foliation in the gneiss is generally poorly developed, but where the small creek has cut through the mass, the foliation is in an east-west direction. Quartz and aplite dikes with random orientations are intruded into the gneiss.

The smaller of the two masses of gneiss (Plate II, Fig. 2) contains several small, dark inclusions that apparently have an east-west lineation. The inclusions range in size from minute specks to masses an inch and a half in length on the exposed surface (Plate III). A small aplite dike cuts through one of the inclusions (Plate III, Fig. 2) clearly indicating that the inclusion preceeded the injection of the dike.

The geologic contacts at this locality are mostly obscurred by soil formed by the weathering of the gneiss, and the relation of the gneiss-schist unit to the small outcrop of granite on the eastern side of the locality could not be determined. A portion of the exposure has been under cultivation in the past, and location of the contact was determined by the presence of quartz boulders, and gneiss and schist fragments in the soil formed from the weathering of the unit.

PLATE III

INCLUSIONS IN MASSIVE GNEISS

Fig. 1. Inclusions in massive gneiss on Stacy Miller farm shown in Plate II, Fig. 2.

Fig. 2. Aplite dike cutting inclusion in massive gneiss at same locality as Fig. 1.

C. C. Pluenneke Property

The exposures in the extreme southern part of the locality are small masses of pink gneiss that stand only a few feet above the surrounding soil.

The unconformable contact between the gneiss-schist unit and the overlying Hickory sandstone is exposed in the creek bed just south of the bend in Ranch Road 734 (Plate IV, Fig. 1). The foliation in the gneiss-schist unit resembles bedding planes and is N. 40° W. and apparently dips about 15° toward the northeast. The color of the gneiss varies from light pink to dark gray.

Most of the gneiss-schist unit at this locality has weathered to soil, and the contact between the unit and the overlying Hickory sandstone was located by the rocky nature of the soil derived from the weathering of the gneiss-schist unit.

S. S. Capps Estate, Hoy-Bush, and C. W. Capps Properties

At this locality the gneiss-schist unit forms an east-west trending hill rising about 125 feet above the valley on the north. At the west end of the hilltop middle Hickory sandstone is in contact with the unit. At the eastern end of the hill the unit has weathered to a rocky soil which is under cultivation on the C. W. Capps and Hoy-Bush farms.

The surface of the hill is littered with large boulders of gneiss that appear to have random orientations (Plate V). Most of the boulders are probably erosional remnants that have been moved from their original positions. Between the boulders the unit has weathered to a

PLATE IV

CONTACTS OF HICKORY SANDSTONE
AND GNEISS-SCHIST UNIT

Fig. 1. Contact between Hickory sandstone and gneiss-schist unit exposed in creek bed on C. C. Pluenneke property.

Fig. 2. Contact between Hickory sandstone and gneiss-schist unit exposed in creek bed in southwest corner of Stacy Miller property.

PLATE V

EXPOSURES OF GNEISS-SCHIST UNIT

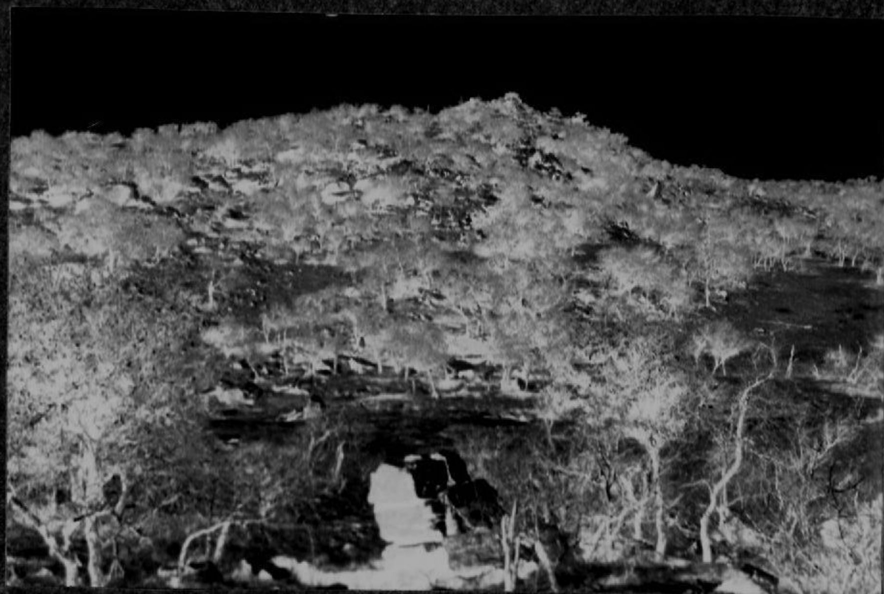


Fig. 1. Hill formed of gneiss-schist unit on S. S. Capps estate.

Fig. 2. Boulders of gneiss on hill shown in Fig. 1.

rocky soil which supports a fairly thick growth of grass. Fragments and boulders of muscovite schist, biotite schist, quartz, gneiss, and pegmatite litter the slopes.

Some of the large boulders exhibit excellent foliation, and minerals recognized in hand specimen are pink feldspar, biotite, and quartz. Other boulders closely resemble pink granite and have very poorly defined foliation. Megascopically they appear to be composed of quartz, biotite, and pink feldspar. Aplite dikes, pegmatite dikes, and quartz vein intrusions occur within the gneiss-schist unit.

The direction of the trend of foliation could not be determined with much accuracy. But where the small stream has cut through the massive gneiss (Plate II, Fig. 1) the foliation appears to strike in an east-west direction and dip about 10° toward the north.

The contact with the Hickory sandstone is rather well defined. At the eastern end of the hill the gneiss-schist unit has weathered and is now under cultivation, and the contact with the exposure of granite is obscured. The vegetation on the unit is limited to scrub oak and grasses.

George Miller Property

At this locality the gneiss-schist unit is almost entirely covered by a rocky soil formed by the weathering of the unit. Only occasional boulders protrude through the soil cover. The outcrop is completely surrounded by Hickory sandstone, and the contact between the two units was again determined by the rocky nature of the soil derived from the gneiss-schist unit. The exposure forms a hill slightly higher than the terrain of the surrounding Hickory sandstone.

About one-third of a mile east of the Miller home a small pit has been excavated in the gneiss-schist unit exposing a deposit of magnetite. The fine- to coarse-grained magnetite with associated quartz occurs intercalated with the gneiss and schist. The schist contains muscovite, biotite, and scattered grains of magnetite. The gneiss is light pink in color and contains quartz, biotite, and pink feldspar. Foliation strikes in a northwest direction and appears to dip about 10° toward the northeast.

The magnetite is only slightly magnetic and has a reddish-brown streak. According to Barnes, Goldich, and Romberg (1949, p. 19) the color of the streak and lack of strong magnetism indicates a large proportion of hematite that was formed by alteration of the magnetite. The altered material is called martite.

Barnes, Goldich, and Romberg (1949, pp. 18-20) discussed the occurrence of magnetite at this locality, which they referred to as the Gamble prospect, and stated that the structure of the ore-bearing gneiss, which they considered to be Valley Spring gneiss, was possibly a crumpled fold. Their investigation of the deposit included core drilling, and magnetic and gravity surveys.

The intercalated nature of the magnetite with the gneiss and schist suggests that the magnetite was derived from iron-bearing minerals in the original sediments that were later metamorphosed. Paige (1911, pp. 56-70) stated that the magnetite ore of the Llano-Burnet quadrangles occurs as layers within the metamorphic rock and locally grades into the country rock by a gradual decrease of iron, and nowhere were beds of magnetite observed to cut across neighboring beds.

Paige (1911, p. 70) concluded that the iron was probably deposited as oxides and carbonates in the original sediments. The manner in which the oxides and carbonates were changed to magnetite and the method of concentration is not clearly understood. Paige (1911, pp. 56-70) believed that these processes were due directly to metamorphism and that igneous intrusions had no bearing on the occurrence of the iron ore. Barnes, Goldich, and Romberg (1949, p. 9) contended that igneous activity and the intrusion of granitic magma into the metamorphosed sediments were responsible for redistributing and concentrating the magnetite.

Charlie Hoover and Roy Arms Properties

Hickory sandstone completely surrounds the exposure of the gneiss-schist unit at this locality, and again, due to the weathering of the unit, the contact was determined by the rocky nature of the soil derived from the gneiss-schist unit.

The rock at this outcrop is a light pink, massive gneiss. Occasional fragments of biotite schist are found on the soil surface between the exposures of gneiss. Ridges of the massive gneiss stand at a height of about 15 feet above the grass covered soil (Plate VI, Fig. 1) and trend in a general direction of about N. 45° E. Lineation in the gneiss is extremely poor but seems to strike about N. 30° E.

Quartz augen occur at places within the gneiss, and where the gneiss has weathered quartz pebbles and boulders are abundant. Plate VII shows a quartz dike intruded into the massive gneiss. Dikes such as this are the source of the quartz pebbles and boulders.

PLATE VI

EXPOSURES OF MASSIVE GNEISS

Fig. 1. Massive gneiss exposed on Charlie Hoover property.

Fig. 2. Exposure of gneiss ridges on Edward Jennings property.

PLATE VII

QUARTZ INTRUSION IN MASSIVE GNEISS

Quartz dike intrusion in massive gneiss on Charlie Hoover property.

Edward Jennings Property

The metamorphic rocks at this locality are in contact with the Cap Mountain member of the Riley formation. The contact between the units is mostly obscured due to weathering of the units, and the contact was established in a large part by the previously mentioned criteria.

The best exposures of the gneiss-schist unit occur as two small gneiss ridges, one approximately 150 by 40 feet and the other about 45 by 15 feet, which trend N 70° E. (Plate VI, Fig.2). The gneiss is light pink, massive, and badly weathered to the extent that it disintegrates readily when struck with a hammer. Lineation within the gneiss is poorly developed but appears to strike about N. 50° E. to N. 65° E.

Correlation of Gneiss-Schist Unit

Paige (1912) mapped a band of Valley Spring gneiss extending from the town of Pontotoc southeastward into the Llano quadrangle as far as Sandy Creek. This band extends to the western side of the Llano Quadrangle. East and slightly south of Pontotoc the band is only about one and one-fourth miles from the southeastern corner of the Pontotoc Northwest area. It is possible that the gneiss-schist unit within the Pontotoc Northwest area is correlative with this band of Valley Spring gneiss mapped by Paige.

The limited evidences suggesting equivalence of the two units are (1) the massive character of the gneiss, (2) the predominance of gneiss over schist in the exposures within the Pontotoc Northwest area, (3) the proximity and location of the Pontotoc Northwest area in relation to the trend of the band of Valley Spring gneiss mapped by Paige, and

(4) the occurrence of magnetite in the gneiss-schist unit within the Pontotoc Northwest area. Paige (1912, p. 91) stated that the occurrences of iron ores within the Llano region are mainly associated with the Valley Spring gneiss.

IGNEOUS ROCKS

Fine-Grained Granite

Granite crops out in two places within the Pontotoc Northwest area. The smaller of the two outcrops is located partially on the Stacy Miller farm and extends across the county road into the Carlos Capps property. The larger exposure of granite occupies a large portion of the C. W. Capps farm and is a dome-shaped mass having low relief (Plate VIII).

At both localities the granite is fine-grained, equigranular, and pink in color. Minerals megascopically identified are quartz, biotite, and pink feldspar.

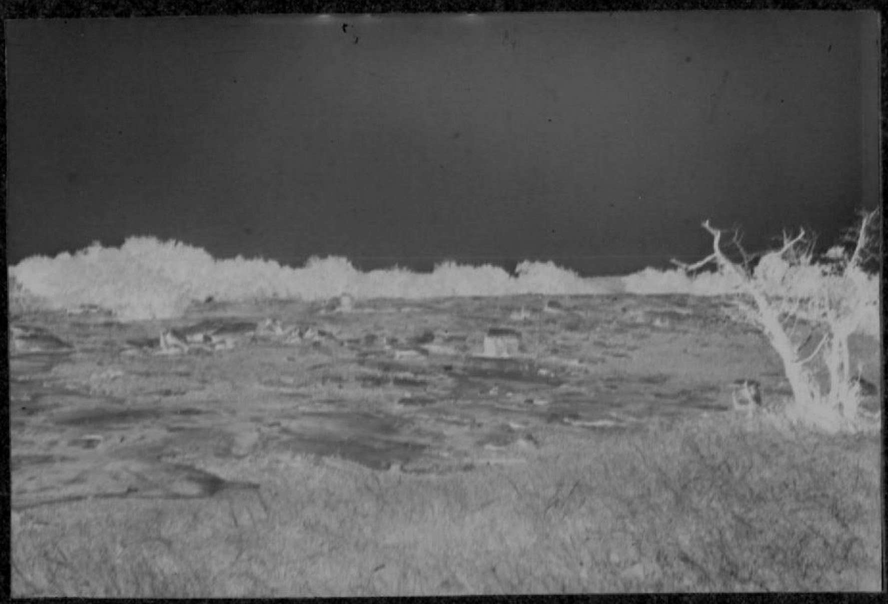
The relation of the granite to the surrounding units could not be determined because the contacts are obscured by a soil cover. The contacts were placed at the outermost occurrences of the granite boulders.

Aplite and Pegmatite Dikes

At many places aplite and pegmatite dikes have intruded the other rocks of Precambrian age. The pegmatite dikes are composed of large crystals of microcline, milky quartz, and minor amounts of biotite and muscovite. The aplite dikes appear to be composed mainly of pink feldspar and quartz.

PLATE VIII

OUTCROP OF GRANITE



Dome-shaped outcrop of granite on C. W. Capps property.

PRECAMBRIAN DEPOSITIONAL SURFACE

REGIONAL

Considerable relief existed on the Precambrian surface within the Llano region during the deposition of the Upper Cambrian formations. Bridge, Barnes, and Cloud, (1947, p. 113) stated that the relief is as great as 800 feet at certain localities. Many of the high areas existed as islands well into Late Cambrian time.

Several of the areas of high relief have been described by Barnes (1956), and the following discussion is based on his descriptions.

In the Silver Creek-Beaver Creek area, Burnet County, Barnes found that the exposed granite dome stood about 600 feet above the general level of the old erosional surface. The basal few feet of the Morgan Creek limestone contains microcline fragments derived locally from the granite. At this locality about 600 feet of sedimentary strata occur below the level of the microcline fragments in the basal Morgan Creek limestone.

In the Scott Klett area, Blanco County, a hill of Oatman Creek granite is surrounded by Cap Mountain limestone. Using the thicknesses of the Cap Mountain limestone and Hickory sandstone members in the general vicinity Barnes estimated that the granite hill is probably 700 feet high. The top of the granite hill occurs about 100 feet below the top of the Cap Mountain limestone.

A series of seven granite outcrops occur within the Iron Rock Creek area, Blanco and Gillespie counties, and at the two easternmost hills basal Lion Mountain sandstone is in contact with the Oatman Creek granite. Barnes made no estimate of the height of the granite hills, but by using the average thicknesses of the units as given by Bridge, Barnes, and Cloud (1947, p. 110) one may calculate a height of 640 feet for the hills.

In the Cedar Mountain area, Llano County, a buried hill of diorite occurs with its surface well up into the Cap Mountain limestone. In the Cedar Mountain area the Cap Mountain limestone is 425 feet thick, and the Hickory sandstone attains a thickness of about 340 feet.

Barnes and Parkinson (1940) reported Cap Mountain limestone resting on the Valley Spring gneiss north of Pontotoc in San Saba County. Bridge, Barnes, and Cloud (1947, p. 112) stated that this exposure is 2.5 miles north-northeast of Pontotoc. In the vicinity of the gneiss exposure the thickness of the entire Riley formation is probably less than 200 feet. Barnes and Parkinson (1940) reported that the Precambrian surface in the vicinity of Pontotoc is rugged.

LOCAL

In the southern part of the Edward Jennings property within the Pontotoc Northwest area the Cap Mountain limestone rests on the gneiss-schist unit. The Cap Mountain limestone surrounding the gneiss-schist unit is silty, only slightly calcareous, and for the most part weathered to a brown sandy soil.

Barnes (1956) reported quaquaversal dips in the sedimentary rocks surrounding the buried Precambrian hills at many localities. Weathering of the Cap Mountain limestone around the periphery of the gneiss-schist unit on the Edward Jennings property prevented the taking of dip and strike measurements, but in the small creek a short distance to the west of the exposure of the gneiss-schist unit the Cap Mountain limestone dips 4° slightly east of north.

The width of the outcrop pattern of the Cap Mountain limestone suggests a thinning of the member in the vicinity of the gneiss-schist hill. It is estimated that the Cap Mountain limestone thickness at this locality is between 170 and 180 feet, and the top of the gneiss-schist hill occurs just below the contact between the Cap Mountain limestone and Lion Mountain sandstone. A height of about 500 feet is suggested for the gneiss-schist hill.

Other buried Precambrian hills occur within the Pontotoc Northwest area, but the best example is the gneiss-schist hill on the S. S. Capps estate where the contact with the Hickory sandstone is rather well defined. At the top of the hill middle Hickory sandstone lies nonconformably on the gneiss-schist unit.

Plate IX, Figure 1, shows the topographic expression of the hill with the gneiss-schist unit on the left and the Hickory sandstone on the right. Figure 2 illustrates the nature of the contact between the Hickory sandstone and gneiss-schist unit on the side of the hill, and Plate X shows the nature of the contact at the top of the hill where middle Hickory sandstone is in contact with the gneiss-schist unit.

A study of the trend of the Precambrian exposures on the geologic map of the Pontotoc Northwest area suggests that the outcrops are relatively high hills on the rugged Precambrian surface.

PLATE IX

CONTACTS OF HICKORY SANDSTONE
AND GNEISS-SCHIST UNIT

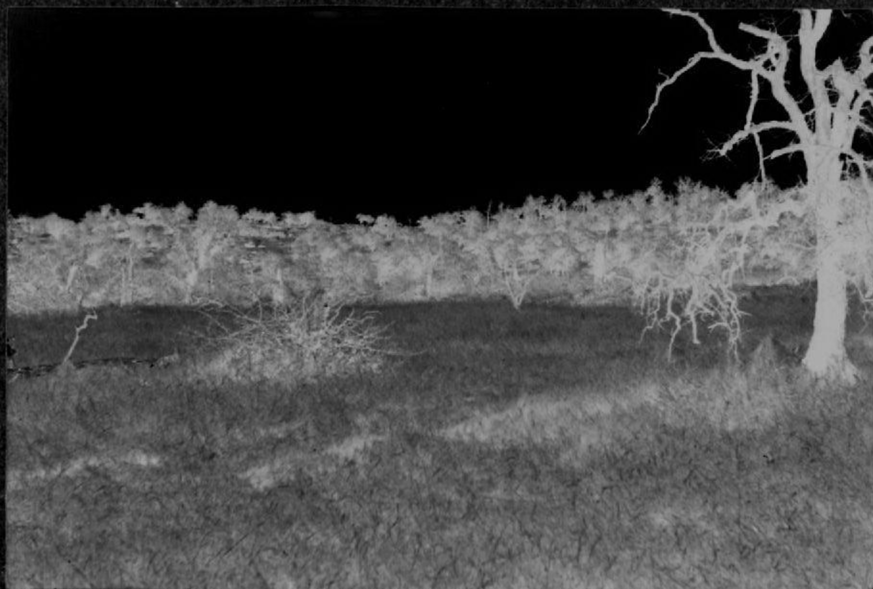


Fig. 1. Hill formed of gneiss-schist unit and Hickory sandstone on S. S. Capps estate.

Fig. 2. Contact between Hickory sandstone and gneiss-schist unit on side of hill shown in Figure 1.

PLATE X

CONTACT OF HICKORY SANDSTONE
AND GNEISS-SCHIST UNIT

Contact between Hickory sandstone and gneiss-schist unit at top of hill shown in Plate IX, Figure 1.

CAMBRIAN SYSTEM

Within the Llano region the Cambrian System is represented by the Upper Cambrian Series which has been divided into the Riley and Wilberns formations. The Riley formation is composed mainly of sandstone and limestone and is in nonconformable contact with the underlying metamorphic and igneous rocks of Precambrian age. The Wilberns formation unconformably overlies the Riley formation and is composed of sandstone, limestone, and shale.

RILEY FORMATION

The Riley formation was named and defined by Cloud, Barnes, and Bridge (1945, p. 154). The formation is divided into three members; from base to top they are: the Hickory sandstone member, the Cap Mountain limestone member, and the Lion Mountain sandstone member.

The thickness of the Riley formation varies greatly throughout the Llano region. Bridge, Barnes, and Cloud (1947, p. 112) reported that in measured sections the thickness ranges from 600 to 800 feet; however, north-northeast of Pontotoc where the Cap Mountain limestone rests on rocks of Precambrian age the thickness of the formation is about 200 feet. The formation is thinnest on the northwestern flank of the Llano uplift and thickest in southeastern Llano County.

Hickory Sandstone Member

Definition

The term Hickory was first used by Comstock (1890, p. 285) as a series name in his subdivision of the rocks of Paleozoic age in the

Llano region. Comstock applied the term Hickory series to the strata exposed along Hickory Creek in Llano County.

Paige (1911) retained the name Hickory from Comstock's "Hickory series" and changed it to the Hickory sandstone. The Hickory sandstone was redefined and designated a member of the Riley formation by Cloud, Barnes, and Bridge (1945, p. 154). Goolsby (1957, p. 53) proposed that the Hickory sandstone member be assigned formational rank as it could be divided into three members.

Lithology

The Hickory sandstone member is composed of medium- to coarse-grained, yellow, brown, and red sandstones. It is largely noncalcareous and nonglauconitic.

In the Pontotoc Northwest area a large part of the lower Hickory sandstone has weathered to a sandy soil that is under cultivation. Where it is exposed along creek beds, this portion of the member is composed of medium- to coarse-grained, tan and red to brown, massively bedded, quartzose sandstones. Occasional cross-bedding occurs in the lower Hickory sandstone (Plate XI).

At certain localities the lower Hickory sandstone contains fragments from the underlying gneiss-schist unit. In the small creek bed on the Carlos Capps property the lower Hickory sandstone contains grains of muscovite and biotite derived from the gneiss-schist unit.

The middle Hickory sandstone consists of white and tan to yellow, medium-grained, quartzose sandstones interbedded with thin silty shales and intraformational conglomerates. Small phosphatic brachiopods are common in this portion of the member.

PLATE XI

CROSS-BEDDING IN HICKORY SANDSTONE

Cross-bedding in lower Hickory sandstone member exposed in creek bed on Carlos Capps property.

The upper portion of the Hickory sandstone member consists of brownish-red to red, fine- to medium-grained, quartzose sandstone. The uppermost part of the unit is blood red in color and weathers to a conspicuous red, sandy soil. Hematite as a coating on the quartz grains and as a matrix in which the sand grains are imbedded is responsible for the red color. Oolites of hematite are also imbedded in the matrix.

Thickness

Bridge, Barnes, and Cloud (1947, p. 112) recognized that the Hickory sandstone varies in thickness from a thin laminae to about 415 feet and averages about 360 feet. They attributed the variations in thickness to the topography of the Precambrian depositional surface, lateral gradation of the upper beds to limestone, and to irregularities in deposition.

On the Edward Jennings property where the Cap Mountain limestone rests on the gneiss-schist unit the Hickory sandstone is absent. An estimated thickness of about 250 feet can be suggested for the Hickory sandstone member in the southeastern corner of the Pontotoc Northwest area. This calculated thickness may not be accurate for the following reasons: (1) the nature of the Precambrian surface is not known, (2) the member may in part be either omitted or repeated by undetected faults, and (3) the width of the outcrop pattern used in calculating the thickness was measured as a horizontal distance and does not take differences of elevation into account.

Distribution and Topography

The Hickory sandstone is more extensive in exposure than any other unit within the Pontotoc Northwest area. The large exposure in the southern and central parts of the area occurs in the normal stratigraphic relationship and forms a rather flat surface. In the northwestern corner of the area the Hickory sandstone has been exposed at several localities as a result of faulting and generally forms low areas.

Stratigraphic Relationship

The Hickory sandstone nonconformably overlies the metamorphic and igneous rocks of Precambrian age. Lower to middle parts of the Hickory sandstone are in contact with rocks of Precambrian age within the Pontotoc Northwest area.

A basal conglomerate occurs in the Hickory sandstone and is present at many places where the sandstone is in contact with the gneiss-schist unit. Most of the conglomerate is composed of angular fragments of milky quartz and probably does not have a very great lateral distribution. Plate IV shows the nature of the conglomerate at two localities where the Hickory sandstone overlies the gneiss-schist unit.

Cap Mountain Limestone Member

Definition

Paige (1911, p. 23) named the Cap Mountain formation for the beds overlying the Hickory sandstone at Cap Mountain in Llano County. Cloud, Barnes, and Bridge (1945, p. 154) redefined the Cap Mountain limestone and designated it a member of the Riley formation. Some sandy beds that were previously assigned to the upper Hickory sandstone were reassigned to the lower Cap Mountain limestone.

Lithology

The lower part of the Cap Mountain limestone member is composed of light to dark brown, calcareous sandstones which are overlain by brown, silty limestones. The silty limestone beds grade upward into granular, buff to gray, glauconitic limestones.

A silty facies occurs within the Cap Mountain limestone on the Wallace Wever property. The silty facies is exposed in the borrow ditches of the county road that crosses the escarpment formed by the Cap Mountain member. At this locality the lower part of the Cap Mountain limestone is composed of brown calcareous sandstones overlain by brown, silty, fin-grained, glauconitic limestones that are thick-bedded for the most part. The fine-grained limestone grades upward into slightly calcareous, brown siltstones. At the top of the escarpment the siltstones are noncalcareous, brown, and thin- to medium-bedded.

The lateral extent of the silty facies could not be determined due to lack of good exposures. But the escarpment persists eastward, and 1.7 miles north of Pontotoc an excellent exposure of the Cap Mountain limestone occurs where the new Ranch Road 501 cuts through the escarpment. A reconnaissance inspection at this locality revealed that noncalcareous, silty beds along with a few thin shale layers do occur near the top of the section.

Thickness

According to Bridge, Barnes, and Cloud (1947, p. 113) the Cap Mountain limestone member ranges in thickness from 135 to 455 feet and averages about 280 feet. The variations are attributed to lateral gradation to sandstone of the lower beds.

Within the Pontotoc Northwest area, as previously mentioned, there is an apparent thinning of the Cap Mountain limestone in the vicinity of the gneiss-schist hill on the Edward Jennings property. The member appears to be thicker on the eastern side of the area where an estimate of 275 feet is made for the thickness.

Distribution and Topography

In the southwestern corner and in the eastern part of the Pontotoc Northwest area the Cap Mountain limestone crops out in the normal stratigraphic sequence and forms an escarpment that is easily traced on aerial photographs. In the northwestern and western parts of the area several exposures occur that are the result of faulting, and the Cap Mountain limestone forms low, persistent ridges.

Stratigraphic Relationship

The Cap Mountain limestone conformably overlies the Hickory sandstone. The contact is gradational and as defined by Bridge, Barnes, and Cloud (1947, p. 113) is placed at a distinct topographical and vegetational change which is apparent on aerial photographs. The Cap Mountain limestone has a denser vegetational cover which appears as a dark gray pattern on aerial photographs in contrast to the light gray pattern of the Hickory sandstone.

Lion Mountain Sandstone Member

Definition

The Lion Mountain sandstone was named by Bridge (1937, p. 235) as the top member of the Cap Mountain formation. Cloud, Barnes, and Bridge (1945, p. 154) assigned the Cap Mountain limestone member status within the Riley formation. The Lion Mountain sandstone was redesignated as the top member of the Riley formation.

Lithology

The Lion Mountain sandstone member is primarily composed of glauconitic, coarse-grained, greenish-brown, cross-bedded sandstones. Lenses of limestone composed of trilobite fragments referred to as "trilobite hash" occur in the lower part of the member along with beds of silty, glauconitic limestone.

Within the Pontotoc Northwest area good exposures of the member were not found because it has weathered to a sandy soil. Fragments of "trilobite hash," small pieces of greenish-brown siltstone, and occasional hematite nodules occur within the sandy soil. The scarcity of the hematite nodules on the weathered Lion Mountain sandstone surface within the Pontotoc Northwest area is in marked contrast to the abundance of nodules present in the southern part of the Llano uplift. Very little variation from base to top of the member could be ascertained, but the occurrence of the small pieces of siltstone and hematite nodules appears to be limited to the upper part of the member.

Thickness

Bridge, Barnes, and Cloud (1945, p. 114) reported a thickness of 20 feet for the member at the type locality. In the southern part of the Llano region a thickness of about 64 feet has been measured (Fuller, 1957). Within the Pontotoc Northwest area the Lion Mountain sandstone and Welge sandstone could not be differentiated and were mapped as a single unit. The Lion Mountain sandstone is probably about 50 feet thick in the area.

Distribution and Topography

The Lion Mountain sandstone member crops out at several localities within the Pontotoc Northwest area. In the northeastern part of the area it occurs in normal stratigraphic sequence and along with the Welge sandstone forms a narrow, sandy, relatively flat strip that has in the past been under cultivation. At other localities in the northwestern and western portions of the area it is exposed in normal sequence and in fault contact with other units, and at these localities it forms rather flat, low areas.

Stratigraphic Relationship

The Lion Mountain sandstone member conformably overlies the Cap Mountain limestone member. The contact is gradational, and within the Pontotoc Northwest area it was placed at the first occurrence of fragments of "trilobite hash" within the sandy soil.

WILBERNS FORMATION

The Wilberns formation was named by Paige (1911, p. 23) who placed the lower boundary at the top of the Lion Mountain sandstone. The upper boundary was placed to coincide with the top of the Cambrian System by Cloud, Barnes, and Bridge (1945, p. 151).

Welge Sandstone Member

Definition

Bridge and Barnes (Barnes, 1944, p. 37) named the Welge sandstone and designated it the basal member of the Wilberns formation. Bridge, Barnes, and Cloud (1947, p. 114) first described the member. The Welge land survey between Threadgill and Squaw Creeks, Gillespie County, is the type locality.

Lithology

The Welge sandstone member consists of brownish-yellow, essentially nonglauconitic and noncalcareous, medium-grained sandstone. Many of the quartz grains form centers about which a secondary growth of quartz crystals has formed. A single quartz grain forms the center for each recomposed crystal. The recomposed crystal faces glitter in the sunlight.

Within the Pontotoc Northwest area the Welge sandstone has weathered to a sandy soil. The upper part of the member is exposed in the borrow ditch of the county road just northwest of Round Mountain. At this locality the sandstone is light yellow, well-sorted, and medium-grained. The individual grains are well-rounded.

Thickness

Bridge, Barnes, and Cloud (1947, p. 114) reported that the Welge sandstone member ranges in thickness from 9 to 35 feet and averages 18 feet. At the type locality it is 27 feet thick. In the Pontotoc Northwest area the Welge sandstone is estimated to be about 25 to 30 feet thick.

Distribution and Topography

The Welge sandstone occurs at essentially the same localities as the Lion Mountain sandstone, and like the Lion Mountain sandstone it forms relatively flat areas that have been cultivated. The topographic expression of the Welge sandstone within the Pontotoc Northwest area is in marked contrast to the Welge topography on the southwest flank of the Llano uplift where the Welge sandstone forms a prominent ledge that can be traced for long distances.

Stratigraphic Relationship

The Welge sandstone member disconformably overlies the Lion Mountain sandstone where it can be observed in other areas. Within the Pontotoc Northwest area the contact is obscured by a soil cover, and as previously mentioned the two members were mapped as a single unit.

Morgan Creek Limestone Member

Definition

The Morgan Creek limestone member was named for exposures along Morgan Creek, Burnet County, by Barnes (Bridge, Barnes, and Cloud, 1947, p. 114).

Lithology

The lower part of the Morgan Creek limestone member is composed of reddish-purple, arenaceous limestone beds. The arenaceous beds grade upward into gray, medium-grained, glauconitic, well-bedded limestone. Near the middle of the member the glauconitic limestone beds are interbedded with thin, glauconitic siltstones and shales. At several localities this portion of the member has weathered, and caliche has developed. The upper part of the member consists of light gray, medium-grained, glauconitic limestone beds with occasional interbedded gray siltstones. Near the top of the member small stromatolitic bioherms occur (Plate XII). The bioherms are composed of gray, dense, nonglauconitic limestone and are subspherical in shape.

Thickness

The Morgan Creek limestone varies in thickness from 70 feet to 160 feet and averages about 120 feet (Bridge, Barnes, and Cloud, 1947, p. 115). In the North Fredonia area Mosteller (1957, p. 29) measured a 99-foot section of the member. Due to the nature of exposures no thickness was calculated for the member within the Pontotoc Northwest area, but it is probably about 100 feet thick.

Distribution and Topography

The Morgan Creek limestone member occurs in the normal stratigraphic sequence in the northeastern and north-central portions of the area and forms an escarpment that rises above the Lion Mountain sandstone and Welge sandstone terrain. The Morgan Creek limestone exposure in the

PLATE XII

BIOHERMS IN MORGAN CREEK LIMESTONE

Bioherms in Morgan Creek limestone member exposed in bed of Hinton Creek.

west-central portion of the area forms low hills and has been cut by several faults.

Stratigraphic Relationship

The Morgan Creek limestone member conformably overlies the Welge sandstone member. The contact is transitional and was placed at the base of the purple arenaceous limestone.

Point Peak Shale Member

Definition

The Point Peak shale member was named by Bridge (Bridge, Barnes, and Cloud, 1947, p. 115) for the exposure at Point Peak near Lone Grove, Llano County.

Lithology

The Point Peak shale member is composed of grayish-green to reddish-brown, calcareous, thin-bedded shale interbedded with gray, calcareous siltstones, greenish-brown, thin- to medium-bedded limestones, and thin beds of intraformational conglomerates. The intraformational conglomerates occur as thin beds that average about 4 to 6 inches in thickness. The conglomerates consist of grayish-brown, flat, limonitic-stained fragments of calcareous siltstones in a fine-grained limestone matrix. In the upper part of the member symmetrical ripple marks in limestone were noticed at two localities within the area (Plate XIII, Fig. 1).

At the top of the member a zone of stromatolitic bioherms occurs. This zone was mapped as a separate unit, but because shale occurs directly

PLATE XIII

RIPPLE MARKS AND BIOHERMS IN
POINT PEAK SHALE

Fig. 1. Symmetrical ripple marks in limestone bed within Point Peak shale member exposed on Wallace Wever property.

Fig. 2. Biostromal mass in upper Point Peak shale member exposed in bank of Hinton Creek.

below the zone it is considered to be part of the Point Peak shale member. Bridge, Barnes, and Cloud (1947, p. 117) stated that where such a relationship exists the bioherm zone probably belongs at the top of the Point Peak shale member. The individual bioherms range from one foot to about twenty feet in diameter and coalesce to form biostromes in many places (Plate XIII, Fig. 2).

Good exposures of the member are limited within the Pontotoc Northwest area because the unit weathers readily, and at places the siltstones and shales have altered to caliche. Plate XIV, Figure 1, shows the nature of the unit where it is exposed in a pit on the west side of Round Mountain. The small folds are probably the result of differential compaction.

Thickness

The Point Peak shale member ranges in thickness from 25 to 270 feet and averages about 160 feet (Bridge, Barnes, and Cloud, 1947, p. 115). The member thins from the northeastern to the southeastern part of the Llano uplift.

In the North Fredonia area Mosteller (1957, p. 31) measured 85 feet of the member from the base to the bottom of the bioherm zone and estimated the bioherm zone to be about 70 feet in thickness. The nature of exposures within the Pontotoc Northwest area prevented calculation of a thickness for the member, but the Point Peak shale member is probably about 150 feet thick including the bioherm zone. The bioherm zone seems to vary in thickness from 50 to 70 feet.

PLATE XIV

EXPOSURES OF POINT PEAK SHALE

Fig. 1. Small folds in Point Peak shale member exposed on west side of Round Mountain.

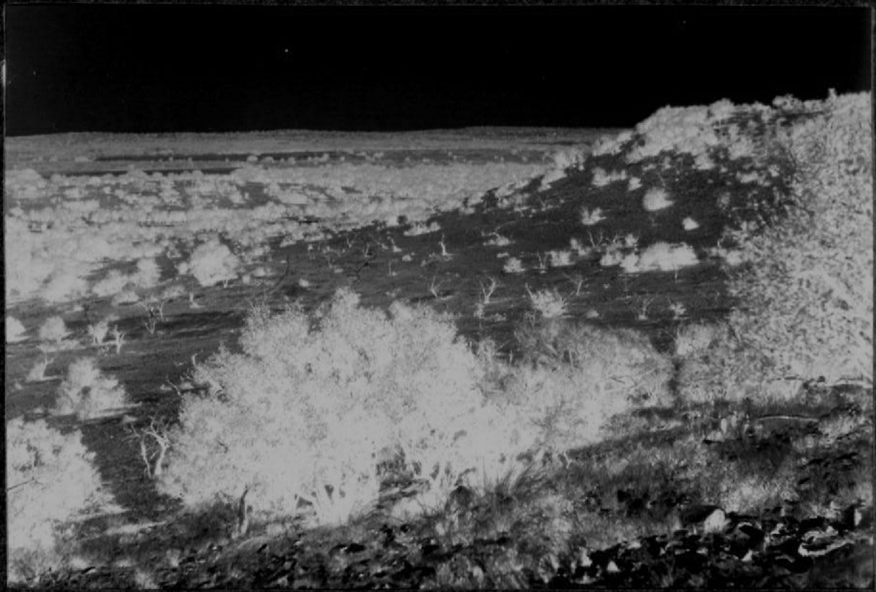


Fig. 2. Slope formed on Point Peak shale member on Wallace Wever property.

Distribution and Topography

With the exception of Round Mountain, exposures of the Point Peak shale are limited to the north-central and north-eastern portions of the area. However, on the western side of the area the bioherm zone does occur along the downthrown side of the Fredonia fault. Generally the Point Peak shale forms relatively steep slopes with sparse vegetation (Plate XIV, Fig. 2).

Stratigraphic Relationship

The Point Peak shale member conformably overlies and is transitional with the Morgan Creek limestone member. The contact was placed at a topographical and vegetational change that is apparent on aerial photographs. The vegetation on the Point Peak shale is not as dense as that on the underlying Morgan Creek limestone member and appears on aerial photographs as light gray patterns whereas the more dense vegetation on the Morgan Creek limestone appears as dark gray patterns.

San Saba Limestone Member

Definition

Comstock (1890, p. 566) first applied the term San Saba series to the limestone exposed near Camp San Saba in McCulloch County. Bridge, Barnes, and Cloud (1947, p. 117) defined the San Saba limestone as now recognized as the top member of the Wilberns formation.

Lithology

The lower portion of the San Saba limestone member consists of light-gray, thin-bedded, sublithographic to fine-grained, limestones which weather to a mottled grayish-yellow color. At places sub-spherical bioherms composed of gray, sublithographic limestone occur in this portion of the member. The bioherms range in size from a few inches to over a foot in diameter. Thin siltstones and shales are interbedded with the limestones. In the upper portion of the member the limestones are medium- to coarse-grained, gray and brown, and glauconitic. The beds range from a few inches to over a foot in thickness. Trilobite and brachiopod fragments are locally abundant in this portion of the member.

Thickness

At the type locality the San Saba limestone member is 280 feet thick, which represents the average thickness for the member throughout the Llano region (Bridge, Barnes, and Cloud, 1947, p. 117). Due to the nature of exposures an estimate was not made of the thickness of the member within the Pontotoc Northwest area.

Distribution and Topography

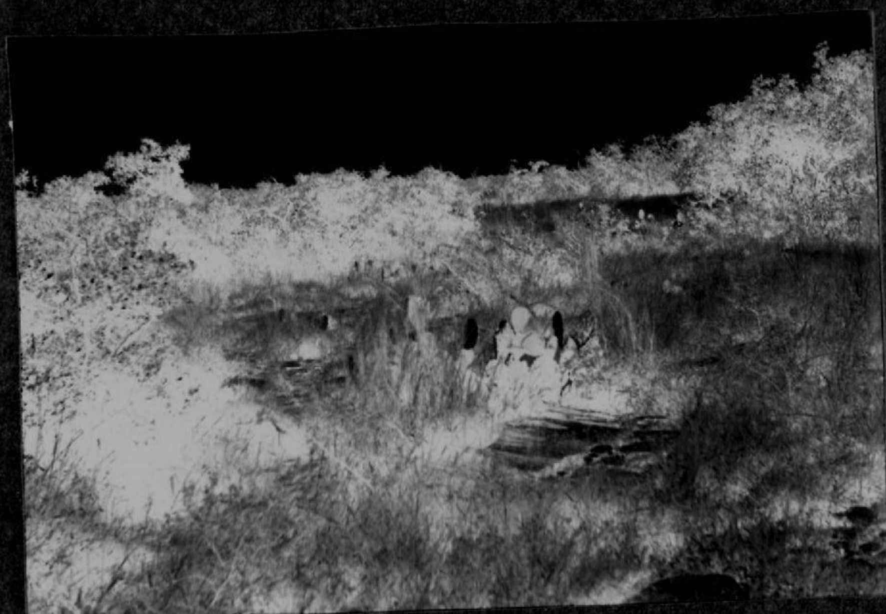
The San Saba limestone member occurs at two localities within the Pontotoc Northwest area. In the north-central and northeastern portions of the area it is present in the normal stratigraphic sequence and forms rolling hills that support a rather dense growth of grasses and scrub oak (Plate XV). On the western side of the area the member is exposed on the downthrown side of the Fredonia fault.

Stratigraphic Relationship

The San Saba limestone member conformably overlies the Point Peak shale member. The contact was placed at the top of the bioherm zone of the Point Peak shale member.

PLATE XV

VEGETATION ON SAN SABA LIMESTONE MEMBER



Scrub oak and grasses on San Saba limestone member in north-central part of Pontotoc Northwest area.

ORDOVICIAN SYSTEM

Rocks of Early and Late Ordovician age represent the Ordovician System in the Llano region. The Burnam limestone (Late Ordovician) occurs as a small deposit in a collapse structure in southern Burnet County (Barnes, Cloud, and Duncan, 1953, p. 1030). It is not present in the Pontotoc Northwest area, and rocks of Early Ordovician age are represented by the Ellenburger group.

ELLENBURGER GROUP

Definition

Paige (1911, p. 24) named the Ellenburger limestone for the Ellenburger Hills in the northwestern corner of the Burnet quadrangle. Cloud, Barnes, and Bridge (1945, p. 133) revised the definition of the Ellenburger limestone as defined by Paige and named the new unit the Ellenburger group. The group is divided into three formations, the Tanyard at the base, the Gorman, and the Honeycut at the top. The Tanyard formation is further divided into the Threadgill and Standebach members.

Within the Pontotoc Northwest area exposures of the Ellenburger group are poor, and no attempt was made to divide the group into formations. Instead, the rocks of Early Ordovician age were mapped as calcite and dolomite units.

Lithology

Within the Pontotoc Northwest area the calcareous facies of the Ellenburger group is represented by light gray, sublithographic, nonglauconitic limestones. The dolomitic facies is finely-crystalline and grayish-buff in color. It weathers to a mottled gray color and to rather thin, small pieces. The weathered soil surface of the dolomitic facies contains much chert that probably weathered from the unit.

Thickness

The maximum thickness of the Ellenburger group is 1,820 feet and occurs in the southeastern corner of the Llano uplift (Cloud and Barnes, 1948, p. 9). In the northwestern corner of the uplift the thickness is only 830 feet. Cloud and Barnes attributed the thinning primarily to pre-Devonian truncation and in a minor part to the thinning of the Tanyard formation. Poor exposures prevented the determination of the thickness of the group within the Pontotoc Northwest area.

Distribution and Topography

Both the calcitic and dolomitic facies of the Ellenburger group within the Pontotoc Northwest area are exposed along the downthrown side of the Fredonia fault. The dolomitic facies occurs only in fault contact with other units in the northwestern corner of the area. Along a small portion of its exposure the calcitic facies overlies the San Saba limestone in normal sequence. The Ellenburger group forms low rolling hills within the Pontotoc Northwest area.

Stratigraphic Relationship

The contact between the Ellenburger group and the underlying San Saba limestone member of the Wilberns formation is gradational. The contact is placed on the criteria of glauconite in the San Saba limestone and the occurrence of the uncoiled gastropod Lytospira gyrocera in the Ellenburger group. Within the Pontotoc Northwest area Lytospira gyrocera was not found, and the contact was placed on the basis of lithology. The basal Ellenburger limestone is nonglauconitic and sublithographic whereas the upper San Saba limestone is glauconitic and medium- to coarse-grained.

QUATERNARY SYSTEM

Deposits of Quaternary age within the Pontotoc Northwest area consist of alluvium and conglomerate. The conglomerate is composed of fragments of sandstone, limestone, and, in places, minor amounts of gneiss, in a calcareous matrix. Both the alluvium and the conglomerate occur as very small deposits and are found only along the major streams.

STRUCTURAL GEOLOGY

REGIONAL STRUCTURE

The Llano region is a structural dome from which erosion has removed overlying strata to expose rocks of Paleozoic and Precambrian ages. Rocks of Precambrian age in the region now occur at an elevation of over 1,000 feet above sea level while in the subsurface in adjacent regions they occur at 4,000 to 5,000 feet below sea level. The amount of uplift of the Precambrian rocks in the Llano region is about 6,000 feet.

The exposed core of the uplift is somewhat elliptical in shape with the long axis extending in a west-northwest direction for a distance of about 80 miles. The minor axis is about 40 miles in length.

Uplift of the region began in Mississippian time and resulted in thinning of the Chappel and Barnett formations over the uplift (Sellards, 1934, p. 84). Cloud and Barnes (1948, p. 121) inferred that the final stages of deformation occurred in post-Strawn and pre-Canyon time. The Strawn formation is faulted whereas strata of Canyon age overlap the faulted Ellenburger formation and are not involved in the faulting.

Cheney (1940, p. 65) suggested a structural relationship between the Llano uplift and the buried Concho arch and concluded that the Llano uplift represents the uplifted and denuded eastern end of the northwest trending Concho arch. The Concho arch did extend northwestward from the Llano region to the present Panhandle region of Texas, but subsidence beneath the Permian basin has caused the arch to loose prominence northwest of the Llano region (Cheney and Goss, 1952, p. 2262).

Examination of the isopach map of the equivalents of the Riley and Wilberns formations (Barnes, et al., 1959, p. 39) indicates that the Concho arch existed as a structural feature northwest of the Llano uplift in Late Cambrian time. About 100 miles northwest of the Llano uplift the Riley formation thins out due to onlap against rocks of Precambrian age, and the Wilberns formation extends about 120 miles northwestward from the feather-edge of the Riley formation before lapping out against rocks of Precambrian age (Barnes, et al., 1959, p. 38). In the subsurface the two formations have only very locally been affected by post-Ellenburger erosion, and the thicknesses shown by the isopach map represent original thicknesses of the formations and depict the thinning due to onlap against the Concho arch.

Cheney (1940, p. 99) stated that the Concho arch had begun development by early Ordovician time as indicated by loss of beds of early Ordovician age toward the arch. Further evidence of uplift and erosion northwest of the Llano region prior to Mississippian time is the loss of thickness of the Ellenburger group westward from the Llano uplift. According to Cheney (1940, p. 100) the Barnett formation rests on successively older beds of the Ellenburger group northwestward from the Llano uplift.

The major trend of the Concho arch is in a northwest direction and parallels structural trends within rocks of Precambrian age of the central and eastern Llano region. This parallelism of trends also suggests that the Llano uplift is a part of the Concho arch.

Deformation of rocks of Paleozoic age within the Llano uplift is primarily expressed by faulting with the major faults trending in a northeast direction. According to Cloud and Barnes (1948, p. 118) the faults are normal and have dips that range from 60° to 90°. Cheney (1940, p. 105) considered the major structural features of the region as being narrow, northeast-trending grabens between more stable areas or horsts. The stable areas, which are tilted parts of the Concho arch, were named by Cheney the Richland Springs, Pontotoc, San Saba, and Lampasas axes.

The Pontotoc Northwest area is located on the Pontotoc axis, and the fault on the west side of the axis occurs on the western side of the Pontotoc Northwest area. This fault was named the Fredonia fault by McGrath (1952) and is discussed under local structure. The eastern side of the Pontotoc axis is marked by a set of faults that extend northeastward from the vicinity of Smoothingiron Mountain.

Folding of rocks of Paleozoic age within the Llano region is relatively gentle and not nearly as extensive as faulting. Cloud and Barnes (1948, p. 121) stated that the axes of many of the folds are aligned in a northwest-southeast direction but recognized that alignments in other directions occur.

Pool (1960) reviewed the data pertaining to folding of Paleozoic strata within the Llano region and concluded that (1) folds trend north, northwest, northeast, and in one occurrence in an east-west direction, (2) folds generally plunge away from the uplift, (3) the strikes of major faults are almost perpendicular to the axes of some folds and nearly parallel to axes of others, and (4) folding antedates faulting.

Several theories have been proposed to explain the deformation within the Llano region. Paige (1912, p. 72) discussed both the Llano uplift and the Black Hills uplift and concluded that the forces involved in the uplifts were quite different. As both are dome-shaped uplifts such a comparison is justified but it reveals few similarities. The Black Hills have been uplifted about 9,000 feet, but the vertical movement did not result in any extensive faulting. According to Darton (1905) faults are rarely observed, and the ones noted have only a few feet of displacement and are short faults associated with igneous intrusions. The lack of faulting in the Black Hills uplift is in contrast to the extensive faulting present in the Llano uplift.

Paige (1912, p. 74) attributed the deformation within the Llano region to horizontal compression which produced folding accompanied by vertical faulting which relieved the compression. According to Paige the compressional stresses were in a northwest-southeast direction, and the resulting faults and folds trend in a northeast direction.

A somewhat similar concept involving horizontal compression was proposed by Cloud and Barnes (1948, p. 118) who related the deformation in the Llano region to the Ouachita orogeny and considered the Llano uplift as being a relatively stable mass with a geosyncline on the eastern and southern sides. Accordingly, the Llano region was placed under torque due to movement in the geosyncline to the east and south, and the resulting compression produced faults with a northeast trend.

Two main objections can be raised to the concept that horizontal compression alone was responsible for the deformation in the Llano region. Firstly, it seems probable that reverse faults as well as normal faults would occur if the deformation was due to compression, and secondly, as pointed out by Pool (1960), not all of the folds within the region trend in a northeast direction. The lack of clarity of the concept concerning the torque and compressive stresses suggested by Cloud and Barnes prevents a critical examination of the theory.

The method of deformation of the Llano region has not been satisfactorily explained, but it seems that differential uplift is the most likely manner by which the Paleozoic structure developed. As the Llano uplift is a part of the larger Concho arch structural feature, it is doubtful that uplift of the region progressed everywhere at the same rate.

A summary of the regional structure indicates certain generalities concerning the Llano region:

1. The Llano uplift is part of a larger structural feature named the Concho arch.
2. The major structural features of the rocks of Paleozoic age of the uplift are grabens and horsts that trend in a northeast direction.
3. Uplift of the region began before the Ouachita orogeny of Pennsylvanian time.
4. The rate of vertical movement was not constant throughout the region and resulted in differential uplift.

LOCAL STRUCTURE

The Llano region has twice undergone deformation, once during the Precambrian and once during the Paleozoic. Within the Pontotoc Northwest area both stages of deformation are recognizable, but the

Precambrian deformation is much more complicated and intensive than is the Paleozoic deformation.

PRECAMBRIAN DEFORMATION

The Precambrian deformation resulted in folding, metamorphism, batholithic intrusion, and dike intrusion. The structural relationships between the various units could not be accurately determined within the Pontotoc Northwest area. As previously stated, aplite, pegmatite, and quartz dikes have been intruded into the metamorphic rocks, but the nature of the contacts between the granitic rocks and the metamorphic rocks is obscured by a soil cover.

PALEOZOIC DEFORMATION

Faulting

Faults are abundant in the Pontotoc Northwest area and are the predominate structural features. Most of the smaller faults are related to the Fredonia fault.

The Fredonia fault is one of the longest faults of the Llano region and extends from the James River south of Mason, Mason County, northeastward almost to the San Saba River in the vicinity of Algerita, San Saba County, a distance of about 45 miles. On the structural map of Texas (Sellards and Hendriks, 1946) the fault strikes about N. 25° E. along most of its extent. At the northeastern end the strike of the fault is N. 50° E., and at the southwestern end the strike is about N. 30° E. The Fredonia fault is a normal fault downthrown to the northwest, and the fault plane is probably almost vertical. The fault can be traced along much of its extent on aerial photographs.

Detailed geologic mapping of the fault was first done by McGrath (1952) and Alexander (1952). McGrath, working in the vicinity of Fredonia, Mason County, named the northern portion of the fault after the town of Fredonia. Alexander, who mapped the South Mason area, Mason County, named the southern part the Simons fault. In the following discussion the fault will be referred to as the Fredonia fault throughout its extent.

The throw of the Fredonia fault varies from 200 feet to 1,400 feet along strike and appears to increase northeastward from the James River. In the Lower James River area, Mason County, Sliger (1957, p. 50) determined a throw that ranged from 200 to 630 feet. Parke (1953, p. 49) reported that the fault has a throw of 800 feet in the Southwest Mason-Llano River area, and in the South Mason area the throw is about 1,300 feet (Alexander, 1952). McGrath (1952) reported a throw ranging from 700 to 1,300 feet, and Mosteller (1957, p. 52) assigned a maximum throw of 1,400 feet to the Fredonia fault in the North Fredonia area.

Within the Pontotoc Northwest area the throw of the Fredonia fault varies from about 450 feet to a probable maximum of 1,200 to 1,300 feet in the northwestern corner of the area where Ellenburger dolomite is in contact with the Hickory sandstone member of the Riley formation. The strike of the fault is N. 10° E. with the exception of a short distance where the fault strikes a few degrees west of north. An obsequent fault-line scarp has developed along part of the fault.

Several smaller faults branch from the Fredonia fault and strike in a northeast direction. The throws of the minor faults range from a few feet to as much as 475 feet. The larger of the minor faults occurs on the southeast side of a graben (Plate I, A-A') and has a maximum throw of about 475 feet where upper Hickory sandstone is in contact with Point Peak shale.

The smaller faults are not long, and most of them do not extend beyond the limits of the Pontotoc Northwest area. The longest of the smaller faults is about four and one-half miles in length.

In the vicinity of Round Mountain the faults are closely spaced with many of them being only about 200 yards apart. Most of the faults are downthrown to the northwest, but a few exceptions do occur. The closely spaced faults have produced relatively long, narrow blocks with beds dipping in various directions. The fault planes are probably almost vertical. Several short cross-faults occur that generally strike almost due north or a few degrees west of north.

Folding

Dip and strike measurements indicate the presence of a small structural basin in the vicinity of Round Mountain where the Morgan Creek limestone dips toward Round Mountain on three sides. The small basin has been disrupted by several faults.

Small, sharp folds were noted in the Point Peak shale and appear to be confined to the member. The folds are probably the result of differential compaction related to bioherms within the shale unit.

In the northwestern corner of the area faulting has produced alternating exposures of Hickory sandstone and Cap Mountain limestone. The pattern of outcrop and the dip and strike measurements suggest a faulted limb of an anticline.

In the southern part of the area the outcrop pattern of the Hickory sandstone and the Cap Mountain limestone, the attitude of the beds, and outcrops of rocks of Precambrian age suggest that a broad anticlinal fold is present. Such a fold could have been produced as a result of differential compaction over a Precambrian high area combined with original dip.

GEOLOGIC HISTORY

Only a portion of the geologic history of the Pontotoc Northwest area can be determined from the area itself due to lack of exposures of rocks of certain periods. As the geologic history can only be interpreted from the lithologic record, it is necessary to go outside of the area for a more complete account of past geologic events.

The geologic history of the Llano region has been discussed by Paige (1912), Sellards (1932, 1934), Cloud and Barnes (1948), and Barnes (1956). The following discussion is based primarily on these works but with emphasis on evidence found in the Pontotoc Northwest area.

PRECAMBRIAN

A great thickness of sandstones, shales, and limestones accumulated within the Llano region during Precambrian time. The sediments were subsequently deeply buried and subjected to metamorphism that produced quartzites, marbles, schists, and gneisses. Granitic magma was intruded into the thick sequence, and extensive folding occurred. The extremely coarse texture of some of the granites indicates cooling at great depth.

The deposits of magnetite that occur intercalated with the gneiss and schist of Precambrian age probably originated as deposits of oxides and carbonates of iron in a lagoonal type environment. Through metamorphism or igneous intrusion, or both, the deposits of iron oxides and carbonates could have been concentrated and changed to magnetite. The martite that occurs within the deposits was formed by the oxidation of magnetite and is pseudomorphic after magnetite; therefore, the alteration of magnetite to martite occurred after and not contemporaneous with the formation of the magnetite. Whether this change is related to hydrothermal alteration or whether it occurred during the present erosional cycle or during a previous period of erosion is not known. The decrease with depth in the amount of martite present at Iron Mountain, Llano County, suggests that the alteration of the magnetite to martite is related to the present erosional cycle.

The occurrences of graphite schists within the metamorphic rocks of Precambrian age at certain localities in the Llano region probably resulted from the metamorphism of carbonaceous matter and suggest that life existed in the Llano region during Precambrian time.

Following batholithic emplacement the region was uplifted, and erosion truncated the folds and partially exposed the granitic bodies. The period of erosion probably lasted until Late Cambrian time as Lower and Middle Cambrian rocks are absent within the region.

CAMBRIAN

In Late Cambrian time the sea invaded from the southeast upon a rugged Precambrian depositional surface that exhibited relief as great as 800 feet. Goolsby (1957, p. 79) stated that relief was confined to local areas as the lithology of the lower Hickory sandstone is similar across the uplift. The area around Pontotoc was specifically cited as having high relief, and within the Pontotoc Northwest area the relief was at least 500 feet. Many of the local highs such as the buried hill surrounded by Cap Mountain limestone in the Pontotoc Northwest area existed as islands in the Cambrian sea well into Late Cambrian time.

The Llano region was probably arid or semi-arid at the time of encroachment of the Late Cambrian sea as suggested by the presence of feldspar in the basal Hickory sandstone and the presence of dreikanters above the base of the Hickory sandstone at certain localities. Barnes and Parkinson (1940) stated that dreikanters continued to form after deposition of the Hickory sandstone was well under way. However, it is possible that the dreikanters were formed on the beach just above sea level, and if so they do not necessarily indicate the occurrence of an arid environment during deposition of the lower Hickory sandstone.

Barnes (Barnes, et al., 1949, p. 25) cites a manuscript by Bell and Barnes, and gives the following lines of evidence that indicate the aridity of the region: (1) Wind abraded pebbles and cobbles occur at the base of the Cambrian sequence. (2) The clay fraction is mostly absent or scarce in the Cambrian sequence and was probably removed by wind before the coarser sediments were carried into the sea. (3) Marble forms ridges in the Precambrian surface indicating lack of moisture to cause solution. (4) The sand grains show chatter marks that can be produced only by the work of wind.

The feldspar content and poor sorting of the basal conglomerate of the Hickory sandstone are indicative of rapid transgression by the sea, and in part the basal deposit was probably derived from the underlying rocks.

The seas were probably shallow during the deposition of most of the Hickory sandstone as cross-bedding occurs in the lower and upper parts, and intraformational conglomerates and symmetrical ripple marks are present in the middle Hickory sandstone. The better sorting and smaller grain sizes of the middle Hickory sandstone suggest that low relief existed in the source area.

An increase in grain size occurs in the upper Hickory sandstone and suggests a renewal of supply that may be attributed to uplift of the source area or to an increase in rainfall.

The hematite that occurs within the upper part of the Hickory sandstone was probably precipitated from solution under conditions that were similar to the depositional conditions that existed when the oxides and carbonates of iron were deposited in the Precambrian seas. Such conditions were probably more extensive during Late Cambrian time than during Precambrian time, and it is possible that the rapid influx of arenaceous material into the Late Cambrian sea prevented the accumulation of the hematite in quantities sufficient to constitute an ore deposit. The origin of the iron may have been similar to that of the Clinton iron ores in the southern Appalachian Mountains. These iron ores were deposited as hematite in a lagoonal type of environment.

Barnes (1956. p. 8) located the source for much of the Hickory sandstone to the west, northwest, or north of the Llano region. Goolsby (1957) stated that the Hickory sandstone exhibits the characteristics of a near shore facies in the western part of the uplift whereas in the eastern part it has a deeper-sea facies. It is probable that the source area was to the northwest of the Llano region, and the Concho arch may have contributed sediments to the area. The Precambrian surface sloped upward to the northwest, north, and northeast of the Llano region during Cambrian deposition.

The transitional contact between the Hickory sandstone and the Cap Mountain limestone indicates an increase in carbonate deposition and a decrease in the supply of clastic material. The glauconite of the Cap Mountain limestone is indicative of shallow depths of water and slightly reducing conditions at the time of deposition of the Cap Mountain limestone. The silt in the upper Cap Mountain limestone within the Pontotoc Northwest area probably resulted from uplift in the source area to the west.

The transition from the Cap Mountain limestone to the Lion Mountain sandstone resulted from a regression of the sea. The abundance of glauconite in the Lion Mountain member suggests deposition in relatively quiet waters, but the presence of "trilobite hash" indicates somewhat turbulent conditions. It is possible that alternating quiet and turbulent conditions existed during deposition of the Lion Mountain sandstone, or that either the trilobite fragments or the glauconite, or both, may have been brought into the area by currents.

According to Daugherty (1960) the grain size and the percent by weight of heavy minerals of the Lion Mountain sandstone member increase toward the north and suggest a source in that direction.

The disconformity between the Welge sandstone and the underlying Lion Mountain sandstone indicates emergent conditions. The area probably did not remain above sea level for any great length of time, as erosion of the Lion Mountain sandstone apparently was not extensive.

Following the emergence after the deposition of the Lion Mountain sandstone the sea again transgressed, and the Welge sandstone was deposited. Daugherty (1960) suggested that the Welge sandstone may represent a dune deposit that was partially reworked by a transgressive sea. The sand grains are uniform in size, frosted, and pitted, and suggest that they were at one time transported by wind. The absence of the clay fraction from the Welge sandstone tends to support the concept that the member may be a reworked deposit because wind would have removed the clay fraction. The dune deposits may have formed from the sandy residium developed on the Lion Mountain by weathering.

Continued transgression of the sea is suggested by the gradational contact between the Welge sandstone and the Morgan Creek limestone and by the decrease in detrital material and increase in calcareous material in the lower part of the Morgan Creek limestone. The silt in the middle part of the Morgan Creek limestone probably resulted from a slight uplift within the source area. The sea was shallow during the time of deposition of the Morgan Creek limestone as indicated by glauconite and bioherms within the member. The bioherms near the top of the member are indicative of warm and probably shallow water. Cross-bedding of some of the detrital limestone beds and of some of the beds containing glauconite indicates near shore conditions of deposition.

Following the deposition of the Morgan Creek limestone a slight regression of the sea occurred and is reflected in the transitional nature of the contact between the Morgan Creek limestone and the Point Peak shale. Ripple marks, intraformational conglomerates, and bioherms within the Point Peak shale are indicative of relatively shallow water. It is possible that some of the intraformational conglomerates are a result of dessication followed by reworking by the movement of shallow water.

The bioherms within the Point Peak shale are of algal origin and were probably formed under conditions similar to those required for the algae living today. The bioherms were probably formed in well-lighted, clear, warm, quiet, and shallow water. The bioherm zone is rather persistent throughout the Llano region, and depositional conditions must have been the same over the region. However, there is some indication that the environment transgressed time and also occurred several different times. Barnes and Bell (1954) reported that northwest of Camp San Saba, McCulloch County, the bioherm zone occurs at the base of the San Saba limestohe. South of Mason, Mason County, the zone occurs at the top of the Point Peak shale. Bridge, Barnes, and Cloud (1947, p. 117) stated that on Squaw Creek, Gillespie County, a bioherm zone occurs within the San Saba limestone member. This zone and the one in the upper part of the Point Peak shale were also noted by Peterson (1959) and Caughran (1959).

The source area for the argillaceous material of the Point Peak shale member lay to the west of the Llano region. Cloud and Barnes (1948, p. 112) reported that the Point Peak shale gives place to carbonate rocks in the eastern part of the Llano region.

A slight subsidence of the region followed the deposition of the Point Peak shale, and the San Saba limestone was deposited. The bioherms, glauconite, siltstone, and shale within the member indicate relatively shallow water at the time of deposition. Intraformational conglomerates occur within the San Saba limestone in other parts of the Llano region and indicate that the shallow water conditions were widespread. The sandstones and siltstones within the San Saba limestone occur in the western portion of the Llano region and suggest a source to the west.

The small stromatolites called Girvanella sp. which are abundant within the San Saba limestone at certain other localities of the Llano region were not noticed in the Pontotoc Northwest area, and it is assumed that they are not as common as at the other localities. It is possible that conditions were not as favorable for th growth of these particular algae in the Pontotoc Northwest area during the time of deposition of the San Saba limestone. However, bioherms ranging in diameter from a few inches to over a foot were formed during this time.

According to Cloud and Barnes (1948, p. 112) the Llano region was probably tilted slightly toward the northwest near the end of deposition of the San Saba limestone. The tilting resulted in exposure and truncation of highest Cambrian strata in the southeastern part of the region. In the western part of the region sedimentation was probably continuous from Cambrian to Ordovician time.

ORDOVICIAN

According to Cloud and Barnes (1948, p. 100-105) the seas in which the Ellenburger group was deposited were probably less than 100 fathoms deep, warm, well oxygenated, and intermittently turbulent. The limestone of the Ellenburger group was probably derived from chemically precipitated lime-muds.

Following deposition of the Ellenburger group the Llano region was tilted eastward as is indicated by truncation of Ellenburger beds to the northwest. Barnes (1956, p. 9) reported that Lower Ordovician rocks attain a thickness of 1,826 feet in the southeastern part of the uplift but in the northwestern part they are only 830 feet thick.

Middle Ordovician rocks have not been reported within the Llano region, and Upper Ordovician rocks are preserved only in collapse structures in the Ellenburger group. Rocks of Silurian age have not been reported within the Llano region, and it is assumed that the region was above sea level during this period.

DEVONIAN

Devonian seas invaded the Llano region from east to west as indicated by the occurrence of older rocks in the east and younger rocks in the west. Outcrops of rocks of Devonian age are small and patchy in the Llano region and are mostly confined to collapse structures within the Ellenburger group. It is probable that during the deposition of rocks of Devonian age the area was very near sea level.

After the rocks of Devonian age were deposited the area again underwent erosion, and rocks of Mississippian age are separated from the underlying rocks by a widespread unconformity.

CARBONIFEROUS

During both the Mississippian and the Pennsylvanian Periods marine invasions of the Llano region occurred several times. Fossiliferous limestones, shales, and lesser amounts of conglomerates and sandstones were deposited.

The thinning of the Chappel and Barnett formations toward the center of the uplift indicates that uplift of the region began in Late Mississippian time. The final stages of uplift occurred in post-Strawn and pre-Canyon time.

PERMIAN, TRIASSIC, AND JURASSIC

Rocks of Permian, Triassic, and Jurassic ages do not occur within the Llano region. If sedimentation did occur during these periods erosion has since removed all traces of it. It is most likely that the region was emergent and undergoing erosion during these periods.

CRETACEOUS

By the beginning of Cretaceous time the Llano region was reduced to a peneplane. The transgressive Cretaceous seas innundated the region for the last time and deposited in succession conglomerate, sandstone, siltstone, and limestone.

Following withdrawal of the Cretaceous seas the Llano region has remained above sea level. Subsequent erosion has removed the rocks of Cretaceous age from the Llano region and exposed rocks of Paleozoic and Precambrian ages. Deposition since Cretaceous time has been restricted to stream valleys.

ECONOMIC RESOURCES

The agrarian nature of the economy of the Pontotoc Northwest area makes underground water the most important resource. As far as is known all ground water is produced from the Hickory sandstone which at the present amply supplies the needs of the area.

Domestic and ranch supplies are the primary uses of water. In only one instance is irrigation practiced and this is on the Charlie Hoover property where approximately forty acres are irrigated from one well by the sprinkling method. The well, which evidently did not completely penetrate the Hickory sandstone, is 360 feet deep and produces at a rate of 350 to 400 gallons per minute. Jim Hoover (personal communication) reported that in the 1958-1959 growing season $10,000 worth of grass seed was produced from the small field. Another well suitable for irrigation is located in the southern part of the Dee Miller property, but at the present it is not in use. Numerous wells within the area are pumped by windmills for ranch use.

Two springs occur within the area that have continued flowing since the days of the first settlers. The spring directly in front of the C. W. Capps farm home flows at a rate of 60 gallons per minute and more than satisfies domestic and ranch needs. The second spring is located at the old ranch house on the Jim Harkrider property and is used at the present only for ranch needs. This spring appears to be located directly on a fault, and water movement is probably related to the fault zone.

Recent interest in the lower Hickory sandstone as a source of sand for "sand fracturing" strata in wells gives promise of bolstering the economy of the Llano region to a small degree. At present two known plants are in operation at the Voca community in McCulloch County.

The Roy Arms property in the Pontotoc Northwest area is now under lease for such development. Two water wells were completed about November 1, 1959, in the southern part of the property for a water supply to use in washing the sand. One well was drilled to a depth of 189 feet and produces 110 gallons per minute; the other is 247 feet deep and produces 225 gallons per minute.

As previously mentioned, magnetite occurs in the metamorphic rocks on the George Miller property. According to local reports, about 20 years ago a few truck loads of ore were taken from the area. According to Barnes, Goldich, and Romberg (1949, pp. 18-21) core drilling and gravity observations indicate that the magnetite is limited to the surface outcrop and that an ore body is not present at the locality. It is estimated that only a few hundred tons of ore remain.

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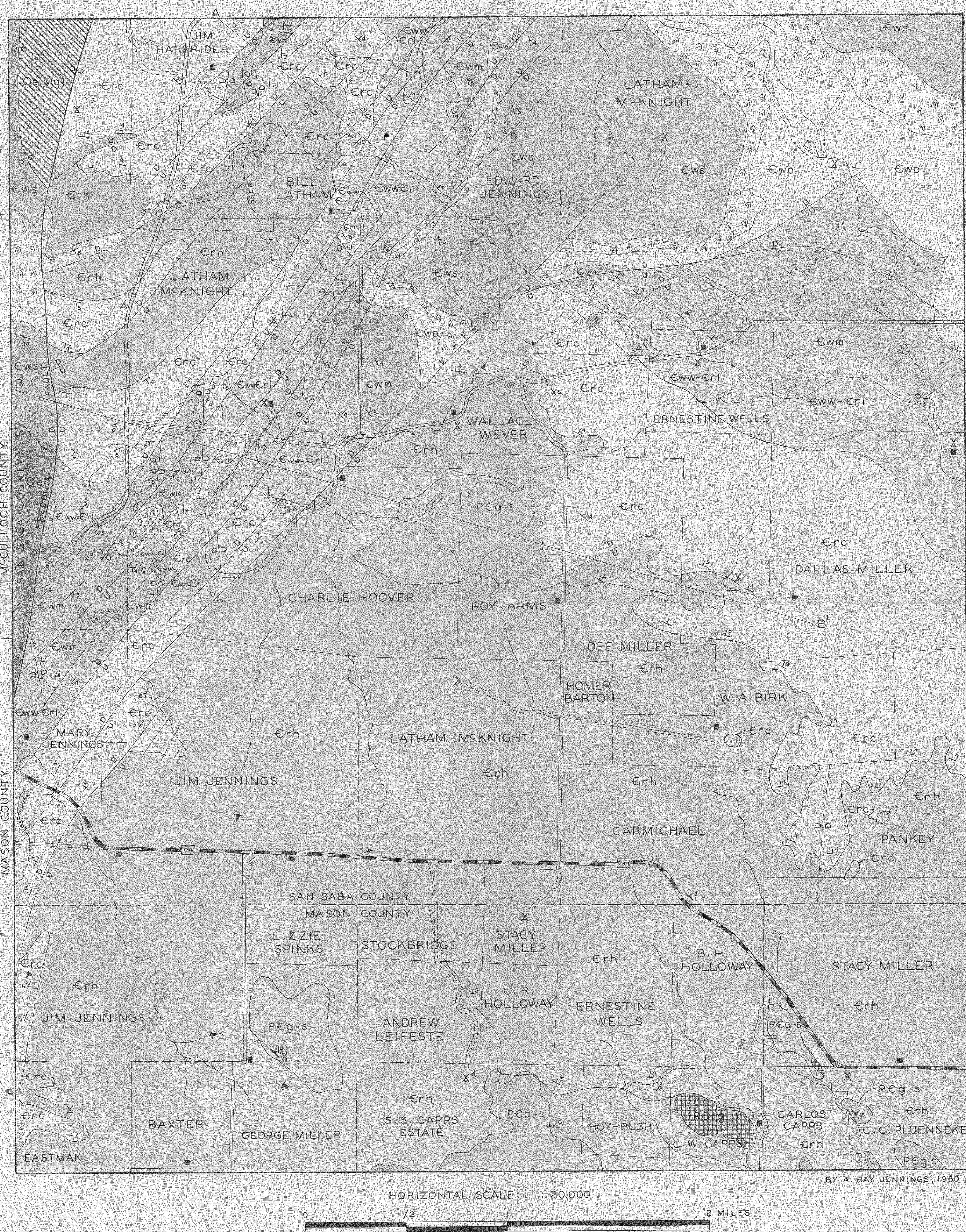

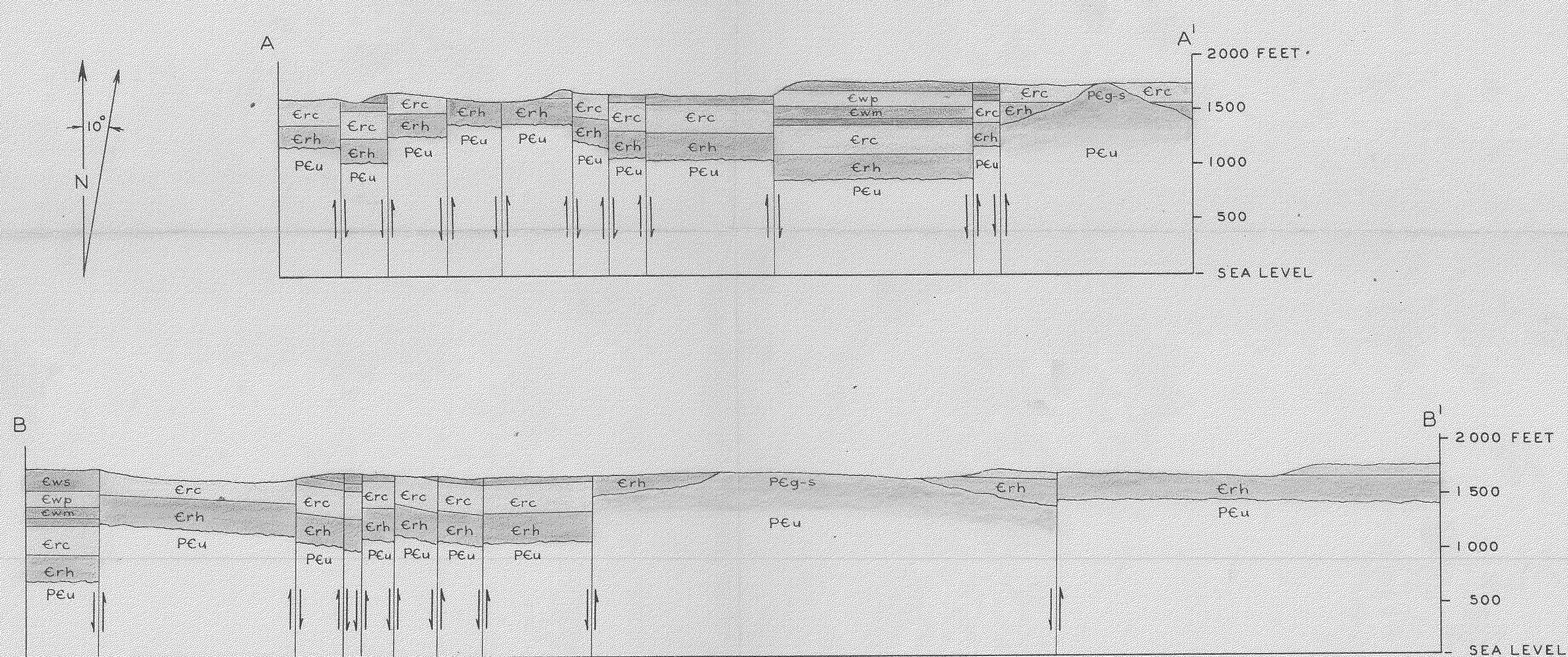

STRUCTURE SECTIONS

VERTICAL SCALE 1.6 X HORIZONTAL, TOPOGRAPHY AND DIPS OF FAULTS ESTIMATED

EXPLANATION

GEOLOGIC COLUMN

LOWER ORDOVICIAN — ELLENBURGER GROUP
- Oe(Mg) — ELLENBURGER DOLOMITE
- Oe — ELLENBURGER LIMESTONE

UPPER CAMBRIAN — WILBERNS FORMATION
- €ws — SAN SABA LIMESTONE MEMBER
- €wp — POINT PEAK SHALE MEMBER (BIOHERM ZONE AT TOP)
- €wm — MORGAN CREEK LIMESTONE MEMBER
- €ww — WELGE SANDSTONE MEMBER

UPPER CAMBRIAN — RILEY FORMATION
- €rl — LION MOUNTAIN SANDSTONE MEMBER
- €rc — CAP MOUNTAIN LIMESTONE MEMBER
- €rh — HICKORY SANDSTONE MEMBER

PRECAMBRIAN
- P€g — FINE-GRAINED GRANITE
- P€gs — GNEISS-SCHIST UNIT (LINES SHOW LINEATION)
- P€u — UNDIFFERENTIATED (CROSS SECTIONS ONLY)

SYMBOLS

- PAVED ROAD
- MAINTAINED COUNTY ROAD
- RANCH TRAIL
- NORMAL FAULT
- INFERRED NORMAL FAULT
- GEOLOGIC CONTACT
- INFERRED GEOLOGIC CONTACT
- PROPERTY LINE
- COUNTY LINE
- STRIKE & DIP OF BED
- STRIKE & DIP OF FOLIATION
- HOUSE
- WINDMILL
- STOCK TANK
- CEMETERY
- INTERMITTENT STREAM
- STRUCTURE SECTION LINE
- MINE

PLATE I

GEOLOGIC MAP OF THE PONTOTOC NORTHWEST AREA, SAN SABA, AND MASON COUNTIES, TEXAS

BASE MAP FROM U. S. DEPARTMENT OF AGRICULTURE AERIAL PHOTOGRAPHS, 1958