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GEOLOGY OF THE HILDA-SOUTHWEST AREA

MASON COUNTY, TEXAS

A Thesis

By

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

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May, 1969

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GEOLOGY OF THE HILDA-SOUTHWEST AREA,

MASON COUNTY, TEXAS

ABSTRACT

The Hilda-Southwest area is a 16 square mile rectangle with its northeast corner located near Hilda, Texas in southeastern Mason County. It is situated on the southwestern flank of the Llano uplift.

Rocks of Paleozoic, Mesozoic, and Cenozoic age crop out within the Hilda-Southwest area. The Paleozoic rocks are of Late Cambrian age and have been divided into two formations and seven members. The Riley formation is the basal unit, and includes, in ascending order, the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone members. The Wilburns formation unconformably overlies the Riley and includes, in ascending order, the Welge sandstone, the Morgan Creek limestone, the Point Peak shale, and the San Saba limestone members.

Rocks of Early Cretaceous age unconformably overlie the Upper Cambrian strata and are composed of a conglomerate unit at the base, a sandstone unit, a siltstone unit, and a limestone unit at the top.

The Cenozoic rocks consist of stream and alluvial deposits derived from the Paleozoic and Cretaceous strata.

In general, the Paleozoic rocks dip about 5° to the southeast. The Cretaceous rocks are almost horizontal.

Two major faults and numerous minor faults disrupt the Paleozoic strata. The Holbrook fault in the north-central part of the area and the

Daffan fault in the south-central part each have a throw of greater than 300 feet. In general, the faults in the Hilda-Southwest area trend northeast-southwest and are downthrown to the northwest. All the faults are normal.

A gentle syncline which plunges northward at a low angle is present in the north-central part of the area.

Mineral or oil deposits have not been found. The most important resources are grazing land, and ground water derived from the Hickory sandstone and Lion Mountain sandstone aquifers.

GEOLOGY OF THE HILDA-SOUTHWEST AREA,

MASON COUNTY, TEXAS

INTRODUCTION

LOCATION

The thesis area lies on the southwestern flank of the Llano uplift, in the southeast part of Mason County, Texas. The area is approximately sixteen square miles with the northeast corner located near Hilda, Texas. Hilda is about 15 miles south of Mason, Texas. The Hilda-Southwest area is bounded by the parallels of latitude $30^{\circ} 34' N$ and $30^{\circ} 32' N$ and by the meridians of longitude $99^{\circ} 07' W$ and $99^{\circ} 13' W$ (fig. 1).

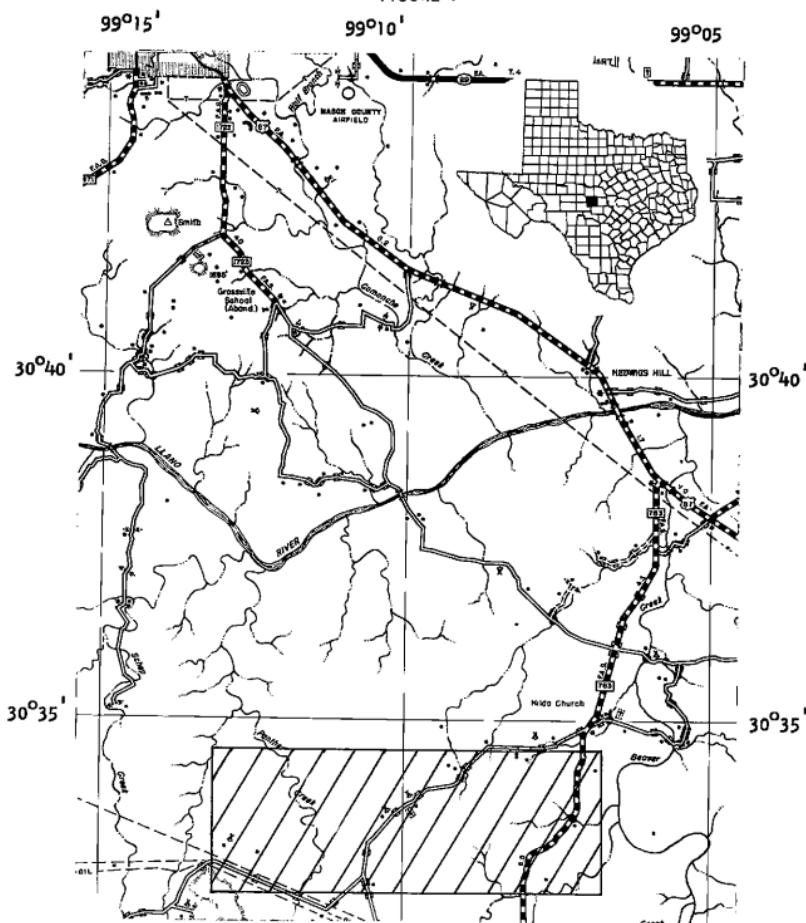
ACCESSIBILITY

The Hilda-Southwest area is easily reached from Mason via Farm-to-Market road 763 (fig. 1). This road crosses the eastern half of the thesis area. An all weather county road extends diagonally across the area from Hilda to the southwest corner. Numerous unimproved ranch roads provide access by automobile to most parts of the area. All parts of the area are within an hour's walk from a road.

ACKNOWLEDGMENTS

Dr. M. C. Schroeder of the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas supervised the field

FIGURE I



Reproduction from Highway Map
Mason County, Texas, prepared
by Texas Highway Department,
1954.

Scale



LOCATION OF THE HILDA - SOUTHWEST AREA, MASON COUNTY, TEXAS

work and offered many helpful suggestions during the progress of this study. Dr. Peter Dahlinger and Mr. Clay Seward of the same department gave constructive criticisms that were of aid in preparing this thesis.

Messrs. George Bryant, Theodore Coughran, Hollis Marshall, and Don Peterson aided in the mapping of parts of the thesis area in which mutual studies were involved.

The aerial photographs, instruments, and other equipment used were the property of the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas.

METHODS OF FIELD WORK

The field work for this study was done between June 2 and August 10, 1958. Mapping was carried out on acetate-covered U. S. Department of Agriculture aerial photographs made in 1950. The thesis area is covered by photographs DFZ-1P-45, -55, -100, and -117. The scale of the photographs is 1:20,000 or about three inches to one mile.

Stratigraphic contacts and faults were located and followed in the field and plotted on the acetate overlays. The photographs were then examined under a stereoscope to aid in plotting on the map the location of the contacts and faults seen in the field.

A Brunton compass was used to determine the attitude of the rocks. The compass was set with a magnetic declination of ten degrees east for the strike measurements. The strike and dip values shown

on the map (pl I) represent an average of several measurements made in the vicinity.

Thicknesses of the various units were measured by sighting with a Brunton compass, set at the correct angle of dip, from a known height on a measuring rod. The rod was then moved to the point sighted on and a new sighting taken. This process was continued until the total thickness was obtained. These measurements were taken perpendicular to the strike of the beds.

REVIEW OF THE LITERATURE

Although detailed geologic work has not been done in the Hilda-Southwest area, geologic maps to the east, northwest, and south have been prepared. Woolsey (1958) described the geology of the Loyal Valley area located about three miles east of the eastern boundary of the thesis area. The Lower James River area, situated approximately two miles northwest of the Hilda-Southwest area was mapped by Sliger (1957). Barnes (1952) published a detailed geologic map of an area along Threadgill Creek in northern Gillespie County, about three miles south of the thesis area.

Numerous papers have been written on the geology of certain areas in Macon County. Several theses have been prepared by students of the Agricultural and Mechanical College of Texas. Also, much work has been done under the auspices of the Texas Bureau of Economic Geology. It should be noted, however, that many of the earlier studies in this region have been reinterpreted to such an extent that the earlier interpretations are at present of historical significance only.

In the middle 1800's, several geologists made studies of the Llano uplift region. Some of the more prominent were: Roemer (1848, 1852), Shumard (1861), Walcott (1884), and Hill (1888). Their work ranged from general reconnaissance of the region to fairly detailed studies of certain areas.

The Texas State Geological Survey, established in 1889, recognized the possible mineral resources of the Llano region and

initiated a systematic geologic study of the area under the direction of T. B. Comstock (1880). During this study Comstock introduced the terms Hickory series, Riley series, and San Saba series.

Tarr (1880) discussed the drainage system in Central Texas, and concluded that the present drainage system originated in Tertiary time upon Cretaceous strata.

The Cap Mountain, Wilburns, Ellenger, and Smithwick formations were named and described by Paige (1911). According to his definition, the Cap Mountain formation included most of the Cap Mountain member and all of the Lion Mountain member of the present Riley formation. He refers to Comstock's Hickory series as the "Hickory sandstone". Paige did not include the San Saba limestone in the Wilburns formation; instead, he defined it as part of the Ellenger formation. He redefined the Valley Springs gneiss and Packsaddle schist, originally defined by Comstock, and dated them as of Algonkian age.

A geologic map of Texas was published by the Bureau of Economic Geology and Technology (Udden et. al., 1916) in which the rocks cropping out in the Llano region were mapped as Cretaceous, Pennsylvanian, undivided Paleozoic, Ordovician, Cambrian, and Precambrian.

Sellards et. al. (1932) described the Precambrian, Cambrian, Ordovician, Mississippian, and Pennsylvanian systems of the Llano region. Included in this publication is a review of the paleogeography of these periods. Sellards (1934) dated the age of initial Paleozoic uplift in the Llano region as Mississippian.

Precambrian rocks of the Llano region were divided by Stenzel (1934) into three series according to the attitude of the rock relative to existing structures. He also determined the major structures of the Precambrian rocks.

Bridge (1937) named a thick unit of glauconitic sandstone, included by Paige in the Cap Mountain formation, the Lion Mountain sandstone of the Riley formation.

Barnes and Parkinson (1937) postulated that ventifacts occurring in the basal part of the Hickory sandstone were the result of an arid climate in which aeolian erosion was active.

A new geologic map of the state showing the Paleozoic rocks of the Llano area divided into the Hickory sandstone, Cap Mountain limestone, Wilburns limestone, and Ellenburger limestone was issued by the U. S. Geological Survey in 1937 (Barton et. al. 1937).

Barnes (1944) refers to an unpublished paper by Bridge and Barnes in which the Wilburns formation was divided into the following four members, in ascending order: the Velge sandstone, the Morgan Creek limestone, the Point Peak shale, and the San Saba limestone.

Cloud, Barnes, and Bridge (1948) elevated the Ellenburger limestone formation to group status and restricted it to Ordovician age. They divided the Ellenburger into three formations: the Tanyard formation at the base, the Gorman formation, and the Honeycut formation. They also proposed the name Riley formation for all pre-Wilburns rocks of Cambrian age.

Under this classification the Riley formation contains the following members, in ascending order: the Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone.

All Upper Cambrian units in the Llano region were described by Bridge, Barnes, and Cloud (1947). This paper is the standard reference for all of the Cambrian strata in Central Texas.

Detailed geologic maps of various areas in the Llano region are included in a paper on the Ellenburger group by Cloud and Barnes (1948).

Plummer (1950) described the Carboniferous rocks of the Llano uplift and also briefly discussed the pre-Carboniferous stratigraphy of the area.

Typical exposures of Upper Cambrian units were described by Barnes and Bell (1954) in the San Angelo Geological Society's guide-book for a Cambrian field trip to the Llano area. Several measured sections are included in this publication.

GEOGRAPHY

CLIMATE

The Hilda-Southwest area is located in a semi-arid region of Texas. It has an average annual precipitation of about 22 inches during a normal year. This precipitation usually occurs in the form of widely spaced, heavy rains which result in a high percentage of runoff.

The temperature ranges from below 15°F in the winter to over 100°F in the summer, with a mean annual temperature of 70°F. During the summer months the average daytime temperature ranges from 80°F to 105°F.

VEGETATION

In the thesis area the vegetation is of a type adaptable to semi-arid climates, wide temperature ranges, and steep, rocky slopes.

To a large degree, the variation and distribution of the vegetational cover is a function of the bed rock. Therefore, changes in the type or abundance of vegetation may be used to establish contacts between the various members. Because of this, the types of vegetation occurring on the different units will be included in the discussion of individual members.

INDUSTRY

The chief industry in the Hilda-Southwest area is the raising of cattle, sheep, and goats. However, in some places the land is

cultivated and grain crops, peanuts, and watermelons are grown. Most of the farm land is irrigated on a small scale.

PHYSIOGRAPHY

PHYSICAL FEATURES

The Hilda-Southwest area is located on the southwest flank of the Llano uplift. Although this is structurally an uplift, the region is at present a topographic basin. In general, Precambrian rocks are in the center of the basin with more resistant Paleozoic and Cretaceous rocks forming the periphery. The maximum relief in the Llano region is about 1,600 feet, and the maximum elevation is more than 2,200 feet.

In the northeast portion of the thesis area, the Hickory sandstone member forms a broad valley broken occasionally by low hills. This is bounded on the southeast by northeast-southwest-trending ridges formed by the more resistant limestone members. A poorly defined dissected plateau is present in the north-central part of the area. The dissected plateau suggests that the region approached peneplanation before deposition of the Cretaceous strata. The northwest part of the area is a series of northeast-southwest-trending ridges. Nearly horizontal beds of Cretaceous age form a high, broad plateau in the southwest section of the area.

DRAINAGE

The Llano region is drained by the Colorado, San Saba, Llano, and Pedernales Rivers. They are consequent in origin and have been superimposed upon the domed Paleozoic and Precambrian strata. According to

Tarr (1890), these rivers developed on an eastward-tilted plain during the Tertiary period and have since been entrenched in Paleozoic and Cretaceous rocks with only a slight modification of their original courses.

All of the streams in the thesis area are intermittent. Panther Creek, which meanders northward across the western portion of the area to the Llano River, is the largest stream in the area. This creek originated in Cretaceous strata and has since been superimposed upon Paleozoic rocks. The eastern two-thirds of the Hilda-Southwest area is drained by small, easterly trending streams which are tributaries of Beaver Creek. These streams follow the existing structure and are subsequent.

STRATIGRAPHY

GENERAL STRATIGRAPHY

Rocks of the Cambrian and Cretaceous systems are exposed in the Hilda-Southwest area. They consist of limestone, shale, siltstone, sandstone, and conglomerate. The Cambrian system is represented by the Wilberns and Riley formations with the middle Hickory sandstone member of the Riley formation being the oldest unit exposed. Lower Cretaceous limestone, siltstone, and sandstone unconformably overlie the Cambrian units in the southwest part of the area. A columnar section of the stratigraphic units exposed in the thesis area is:

CENOZOIC

Quaternary System

Recent alluvium

MESOZOIC

Lower Cretaceous (Comanchean) Series

Limestone unit

Siltstone unit

Sandstone unit

Lange's Mill Conglomerate

PALEOZOIC

Cambrian System

Upper Cambrian Series

Wilberns Formation

San Saba limestone member

Point Peak shale member

Morgan Creek limestone member

Welge sandstone member

Riley formation

Lion Mountain sandstone member

Cap Mountain limestone member

Hickory sandstone member

CAMBRIAN SYSTEM

Rocks of late Cambrian age crop out over all but a small area in the southwestern corner of the thesis area. These Upper Cambrian rocks have been divided by Bridge, Barnes, and Cloud (1947) into two formations and seven members consisting of limestone, shale, siltstone, and sandstone. Stromatolitic bioherms are present in the three upper members of the Wilburns formation.

Riley Formation

Comstock (1880) proposed the name "Riley series" for the strata which are now included in the Hickory sandstone and the Cap Mountain limestone of present usage. Cloud, Barnes, and Bridge (1946, p. 154) reduced this unit to formation rank and redefined it to include all Cambrian strata in Central Texas beneath the Wilburns formation. So defined, the Riley formation is composed, from base to top, of the

Hickory sandstone, the Cap Mountain limestone, and the Lion Mountain sandstone. The members are separated by gradational contacts.

The type locality for the Riley formation is in the Riley Mountains of southeastern Llano County. In the Moore Hollow area of the Riley Mountains the total thickness of the formation is 780 feet according to Cloud, Barnes, and Bridge (1946, p. 154). However, due to the irregular topography of the Precambrian erosional surface upon which the formation was deposited, the thickness varies considerably. In general, the thickness ranges from about 600 to 800 feet, but in southwestern San Saba County the Cap Mountain limestone member rests directly on Precambrian rock, resulting in a total thickness for the Riley formation of less than 200 feet. According to Barnes and Bell (1964, p. 36), the average thickness of the formation is about 695 feet.

The contact between the Riley formation and the Precambrian is not exposed in the Hilda-Southwest area. Also, the Cap Mountain limestone member is cut by numerous faults; therefore an accurate thickness for the Riley formation can not be determined.

Hickory Sandstone Member

Definition and Thickness

Comstock (1880) first used the term "Hickory" as a series name for beds cropping out in the valley of Hickory Creek in Llano County. This name was later changed by Paige (1912, p. 42) to Hickory sandstone, and the upper boundary of the unit was placed at the top

of the uppermost sand beds in the basal Upper Cambrian strata. The Hickory sandstone was reduced to member rank by Cloud, Barnes, and Bridge (1945, p. 154) and defined as the basal member of the Riley formation.

The Hickory member varies in thickness from a feather edge to over 400 feet, according to Bridge, Barnes, and Cloud (1947), and has an average thickness of about 380 feet. The variations in thickness are due mainly to irregularities of the Precambrian surface upon which the member was deposited, to unequal rates of deposition, and to lateral gradation to limestone in the upper part of the formation.

Blocks of the middle and upper parts of the Hickory sandstone are exposed in the thesis area. They attain a thickness of about 350 feet. However, small faults which could not be recognized in the soil-covered fields may have caused errors in this estimate.

Lithology

The middle part of the Hickory sandstone consists of gray to tan to orange, intricately cross-bedded, fine- to medium-grained, non-calcareous sandstones. Interbedded with these sandstones are greenish-gray to tan siltstones and occasional beds of intraformational conglomerate. The siltstones are generally persistent; however, in places they grade laterally into sandstone.

Oscillation ripple marks are quite common in this part of the section. They range in wave length from less than one inch to more than 18 inches, with amplitudes or trough depths from .2 inches to

Plate II

F



Oscillation ripple marks in the Hickory sandstone, located three-fifths mile south of R. Geistweidt ranch house on State Highway 783.

2.5 inches. Those shown in Plate II measure 6 inches from crest to crest and have an amplitude of 1.2 inches.

The base of the upper part of the Hickory sandstone unit is placed, according to Goolsby (1957, p. 59), at the top of the uppermost intraformational conglomerate. Because good exposures of the Hickory sandstone in the thesis area are scarce, a line of contact between the middle and upper units was not mapped. However, in locations where it was possible to determine the stratigraphic unit exposed, the unit symbol was plotted on the map.

The upper part of the Hickory sandstone is, in general, a dark brown to dark red, fine- to medium-grained, massive sandstone with a ferruginous cementing material. The sand grains are generally coated with layers of iron-oxide. Some very thin, dark red shale beds lie between the sandstone layers (pl. III, fig. 1). Phosphatic brachiopods are present throughout the unit. A dark red soil resulting from the weathering of the ferruginous sandstone is characteristic of this part of the member.

Topography and Vegetation

The Hickory sandstone generally underlies flat, open fields in the north-central portion of the thesis area. Most of these fields are under cultivation. In certain parts of the area, however, the rock is more resistant to weathering and forms low hills. At these places, the land is cleared and utilized as pasture.

Plate III
EXPOSURES OF THE HICKORY SANDSTONE



Figure 1.

Silty beds of the Hickory sandstone located three-fifths mile south of R. Geistweidt ranch house on State Highway 783.



Figure 2.

Sandstone beds of Hickory sandstone, located one-half mile from E. Geistweidt ranch house.

In areas that have not been cleared, the Hickory sandstone supports a moderately dense vegetation consisting of oak, mesquite, elm, Spanish persimmon, bee brush, several types of cacti, and various grasses.

Cap Mountain Limestone Member

Definition and Thickness

The term "Cap Mountain" was first proposed by Paige (1911, p. 46) as a formation name. It included the present Lion Mountain sandstone member at the top, and its lower boundary was above the present upper boundary of the Hickory sandstone. The Cap Mountain limestone, of present usage, is a redefinition of Paige's formation by Cloud, Barnes, and Bridge (1945, p. 184). It has been reduced in rank to the middle member of the Riley formation. The lower boundary is placed where the beds first become predominantly calcareous and the upper boundary is now placed at the top of the uppermost thick limestone bed. The type locality is at Cap Mountain in eastern Llano County.

The thickness of the Cap Mountain limestone, in the Llano region, varies from 455 feet to 135 feet and averages about 280 feet, according to Bridge, Barnes, and Cloud (1947, p. 113). This variation in thickness is attributed to a northwestward lateral gradation of the lower beds into sandstone.

A reliable estimate for the thickness of the Cap Mountain limestone in the Hilda-Southwest area could not be made because of faulting.

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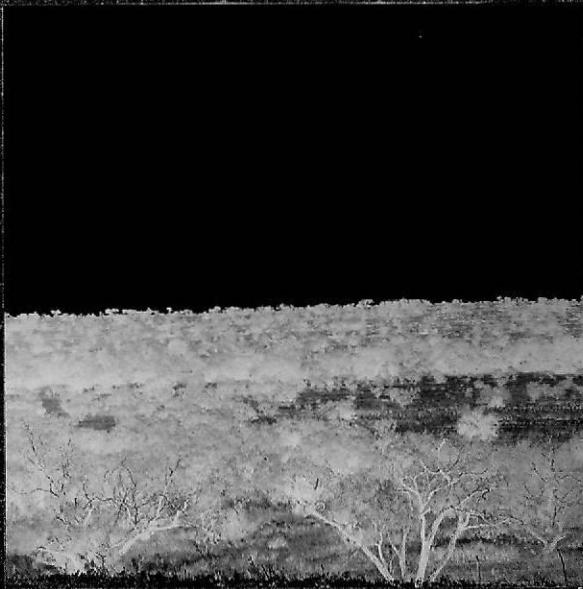
However, the thickness of the member in the Lower Schep Creek-Panther Creek area, just northwest of the present thesis area, is 315 feet, according to Bryant (1958, p. 18).

Lithology

The contact with the Hickory sandstone is highly gradational. The dark red, non-calcareous sandstone of the Hickory member grades into and interfinger with the light red to brown, sandy limestones of the Cap Mountain member. According to Bridge, Barnes, and Cloud (1947, p. 113), the contact is placed at the base of the first predominantly calcareous bed. It should be noted that in the thesis area this contact, so defined, does not correspond to the abrupt change from the gentle slopes of the Hickory member to the steep slopes of the Cap Mountain member. Instead, it is from 5 feet to 10 feet stratigraphically higher up the slope than the topographic change (pl. IV).

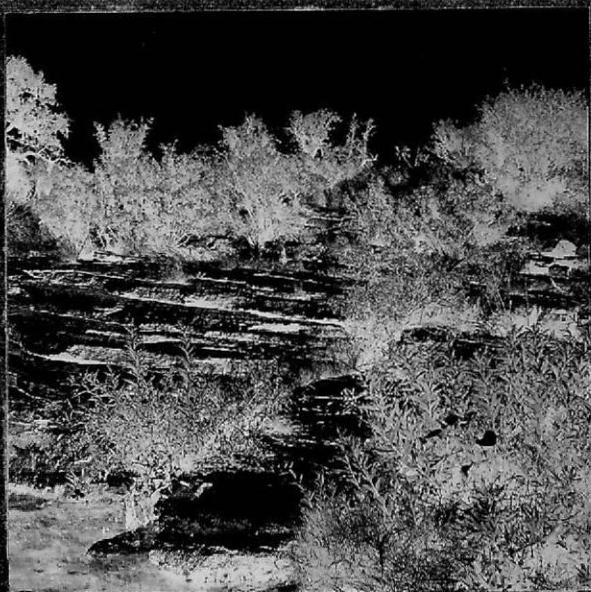
The lower part of the member is essentially a brownish-red to gray, medium- to massive-bedded, arenaceous limestone, interbedded with some reddish-brown to rust, fine-grained, non-calcareous sandstone. The lower beds grade upward into generally pure, medium-grained, slightly glauconitic, light brown to gray limestone which comprises most of the member. In this relatively pure limestone are some thick beds of light brown, medium- to fine-grained, thick bedded, slightly calcareous sandstone. In the upper part, the member becomes a gray to brown, fine- to medium-grained, glauconitic, slightly fossiliferous limestone. Some shale beds are present in this part of the member.

Plate IV



Contact between the Hickory sandstone and the Cap Mountain limestone, located one-fourth mile east of State Highway 783.

Plate V



Thin beds of Cap Mountain limestone located
100 yards east of State Highway 783.

The Cap Mountain limestone is well jointed; therefore, in many places it weathers out into large blocks, some of which may be several feet across. This seems to be a distinctive feature of the member in this area.

Topography and Vegetation

In the southeastern part of the thesis area, the lower portion of the Cap Mountain member underlies relatively flat, cultivated fields. These fields are the result of weathering which causes the formation of sand due to disaggregation of the sandstone beds. In the rest of the thesis area, cuestas are formed by the lower part of the Cap Mountain limestone. Where middle and upper portions of the member crop out, ridges of moderate relief, trending northeast and southwest, are formed.

Vegetation growing on the Cap Mountain outcrop generally consists of scrub oak, mesquite, Spanish persimmon, prickly pear, tamaulillo, Spanish bayonet, and various grasses.

Lion Mountain Sandstone Member

Definition and Thickness

The "Lion Mountain" was designated by Bridge (1937, p. 234) as the upper member of the Cap Mountain formation. It was named from Lion Mountain in northwestern Burnet County. The Lion Mountain sandstone was established by Cloud, Barnes, and Bridge (1940, p. 154) as the uppermost member of the Riley formation.

The member is 20 feet thick at its type locality. However, the thickness varies throughout the Llano uplift, attaining a maximum of about 50 feet. The average thickness is 37 feet. In the Hilda-Southwest area it is about 40 feet.

Lithology

The contact between the Cap Mountain limestone and the Lion Mountain sandstone is gradational and is capped at the lower limit of a sparsely vegetated topographic bench. This bench is formed by the sandstone of the Lion Mountain and can usually be identified on aerial photographs.

The Lion Mountain member is principally a coarse-grained, cross-bedded, highly glauconitic, calcareous sandstone. The abundant glauconite is one of its distinctive features. Lenses of limestone composed essentially of trilobite fragments, referred to as "trilobite hash", are found near the base of the member. These lenses weather out and become scattered on the surface (pl. VI, fig. 1). Toward the top of the member, the sandstone is dark green, highly glauconitic, and intricately cross-bedded (pl. VII).

A characteristic feature of the sandstone on the surface is the abundance of hematite nodules found on the weathered surface (pl. VI, fig. 2). These fairly well-rounded, metallic-black nodules are the result of a chemical alteration of glauconite. The presence of replaced trilobite fragments and quartz grains in the nodules is proof of the secondary origin of the nodules.

Plate VI

CHARACTERISTIC SURFACE EXPOSURES OF THE LION MOUNTAIN SANDSTONE



Figure 1

Lenses of "trilobite hash", which litter the Lion Mountain sandstone surface, located 300 yards south of L. Loeffler's ranch house. The large blocks belong to the overlying Welge sandstone.

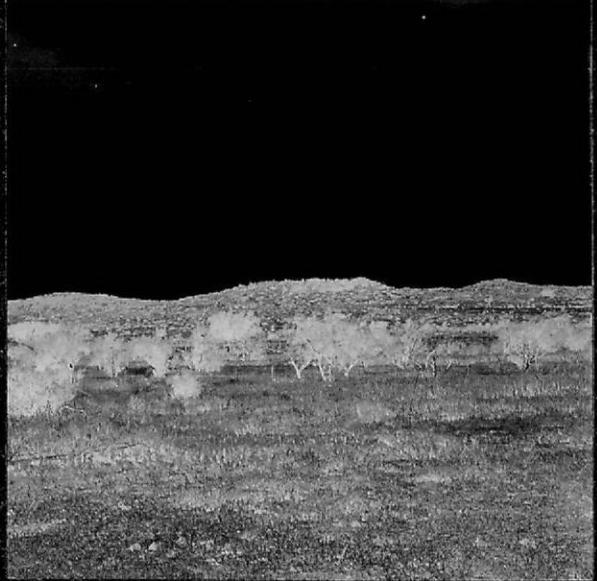


Figure 2

Hematite nodules scattered on the surface of the Lion Mountain member (foreground) located 100 yards south of L. Loeffler's ranch house. Welge sandstone forms the top of the hill in center.

Plate VII



Cross-bedded, glauconite sand at the top of the Lion Mountain member located one mile southeast of the R. Geistweidt ranch house.

Topography and Vegetation

The Lion Mountain sandstone generally forms a narrow, sparsely vegetated bench in the Hilda-Southwest area. In the northwest corner of the area, the outcrop has been cleared and is under cultivation.

Vegetation on the outcrop of this member is sparse, primarily consisting of scattered clumps of mesquite and scrub oak, along with various forms of cacti and grasses.

Wilberns Formation

The Wilberns formation was first named by Paige (1912, p. 46) for rocks exposed at Wilberns Glen in northeastern Llano County. The lower boundary as established by Paige has remained the same; however, the upper limit was redefined by Bridge, Barnes, and Cloud (1945, p. 140) and placed at the top of the Cambrian. As defined by Bridge, Barnes, and Cloud (1947), the Wilberns formation consists of four members. In ascending order these are: the Welge sandstone, the Morgan Creek limestone, the Point Peak shale, and the San Saba limestone.

According to Barnes and Bell (1954, p. 36) the thickness of the Wilberns formation ranges from 540 to 620 feet, and averages about 600 feet. The total thickness can not be measured in the Hilda-Southwest area because Cretaceous rocks mask the upper portion of the San Saba member.

Welge Sandstone Member

Definition and Thickness

The Welge sandstone was named by Barnes (Bridge, Barnes, and Cloud, 1947, p. 114) from the Welge land survey between Threadgill and Squaw Creeks in Gillespie County. It is defined as the lowest member of the Wilberns formation.

At its type locality along Squaw Creek, one half mile north of the Gillespie County line, the Welge sandstone is 27 feet thick.

The average thickness of the member throughout the Llano uplift region is 20 feet, according to Barnes and Bell (1954, p. 36). A thickness of 16 feet was measured in the thesis area.

Lithology

The Welge sandstone unconformably overlies the Lion Mountain sandstone. In the thesis area the contact between the two units is very sharp (pl. VIII). This contact is placed at a distinct change from the green, abundantly glauconitic sand of the Lion Mountain member to the yellowish-brown, massively bedded sandstone of the Welge member. This corresponds, in general, to an abrupt change in vegetation and topography which shows distinctly on aerial photographs.

The Welge member is a reddish-brown to yellowish-brown, moderately sorted, slightly glauconitic, medium-grained sandstone. It is thick-bedded and somewhat cross bedded. Many of the quartz grains in this member glitter or sparkle in the sunlight due to reflection

Plate VIII



Contact between the thinly-bedded Lion Mountain sandstone and the thick-bedded Welge sandstone located one mile southeast of R. Geistweidt ranch house.

from their recomposed or recrystallized faces. When not recomposed, the quartz grains in the member are well rounded.

Tenography and Vegetation

The Welge sandstone forms a sharp ledge at the upper edge of the bench formed by the Lion Mountain sandstone. This relationship holds true throughout the thesis area. This member supports a more abundant vegetative growth than the Lion Mountain. Mesquite, scrub oak, Spanish persimmon, and *tusajillo* are the most common types of vegetation.

Morgan Creek Limestone

Definition and Thickness

The Morgan Creek limestone was first defined by Bridge, (Bridge, Barnes, and Cloud, 1947, p. 114). The member was named from exposures just north of the junction of the north and south forks of Morgan Creek in Burnet County.

The Morgan Creek member varies in thickness from 70 to 180 feet. Its average thickness is 130 feet according to Barnes and Bell (1954, p. 37). In the Hilda-Southwest area, this unit is 118 feet thick.

Lithology

The massively bedded, yellowish-brown sandstone of the Welge member grades into a purplish-red, thinly-bedded, arenaceous limestone of the Lower Morgan Creek member. On the land surface the contact is expressed by a slight topographic and vegetational change. A small

escarpment formed by the more resistant limestone of the Morgan Creek member is usually present in the thesis area. The member supports a less dense vegetative cover than the Welge sandstone and the contrast is recognizable on aerial photographs.

From the lower portion, the member grades upward into a greenish-gray, medium-bedded, medium-grained, glauconitic, fossiliferous limestone.

The fossils within this member consist of trilobites, brachiopods, and cystoids. Boorthis, a genus of the phylum Brachiopoda, occurs abundantly in a zone 40 to 50 feet above the base. This zone consists of a "hash" of brachiopod and trilobite fragments, which is distinctive of the Morgan Creek limestone. Near the top of the member, thin, silty, calcareous shale layers are interbedded with the limestone (pl. IX).

Several bioherm zones are found in the upper part of this member. The lower zones are from 1 to 5 feet thick and consist of small, grey to purple, stromatolitic bioherms (pl. X, fig. 1). The individual bioherms of the zone are ellipsoidal to almost spherical in shape, and range from about 3 inches to over one foot in diameter. At or near the top of this member is a bioherm zone which ranges from 5 to 15 feet in thickness. The individual bioherms in this zone are much larger than those in the lower zones (pl. X, fig. 2). They may be as much as 8 feet in diameter. Many of the bioherms exhibit the so called "cabbage head structure".

Plate IX

EXPOSURES OF MORGAN CREEK LIMESTONE

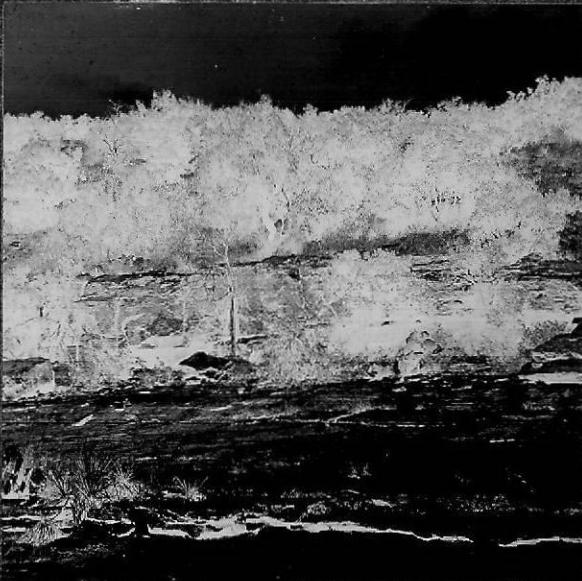


Figure 1

Thick beds of Morgan Creek limestone on Panther Creek.

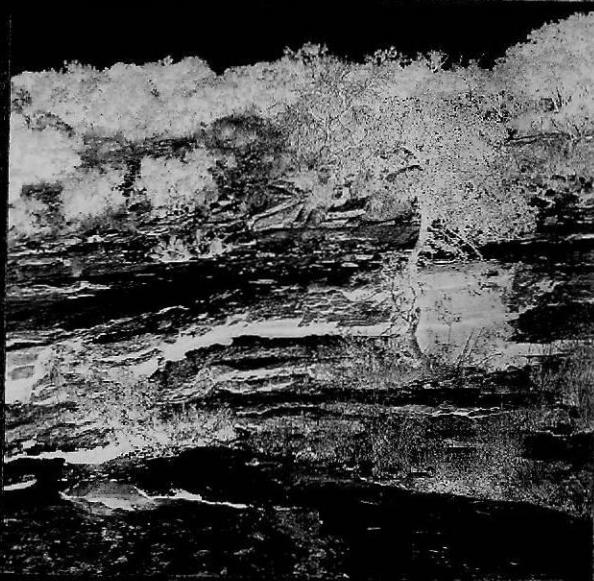


Figure 2

Shale bed in the Morgan Creek member on Panther Creek.
Note limestone bed bending over shale.

Plate X
BIOHERMS IN THE MORGAN CREEK MEMBER



Figure 1

Small bioherms in the lower part of the Morgan Creek limestone located on Panther Creek.



Figure 2

Large bioherms near top of Morgan Creek limestone,
one mile southwest of R. Geistweidt's ranch house.

Topography and Vegetation

The limestones of the Morgan Creek member form steep stair-stepped slopes above the Welge sandstone bench. The member forms a series of ridges trending northeast-southwest in the central and southwestern part of the thesis area.

Vegetation on the Morgan Creek is fairly uniform. Scrub oak, Spanish persimmon, tassajillo, agarita, and various grasses are the dominant plant life.

Point Peak Shale MemberDefinition and Thickness

The Point Peak member was named by Bridge, (Bridge, Barnes, and Cloud, 1947, p. 115) from exposures on the south slope of Point Peak about 4 miles northwest of Lone Grove, Llano County. It is underlain by the Morgan Creek limestone and overlain by the San Saba limestone.

The thickness of the type section is 270 feet, but the thickness throughout the Llano uplift is highly variable, due mainly to facies changes. Barnes and Bell (1954, p. 37) give an average thickness for the member of 130 feet. The thickness of the Point Peak member in the thesis area is about 142 feet.

Lithology

The contact between the Morgan Creek limestone and the Point Peak shale is gradational. It is placed at the last thick-bedded limestone. In general, this corresponds to a slight vegetational change and

a narrow bench which is recognizable on aerial photographs. The contact was placed at the lower edge of this bench.

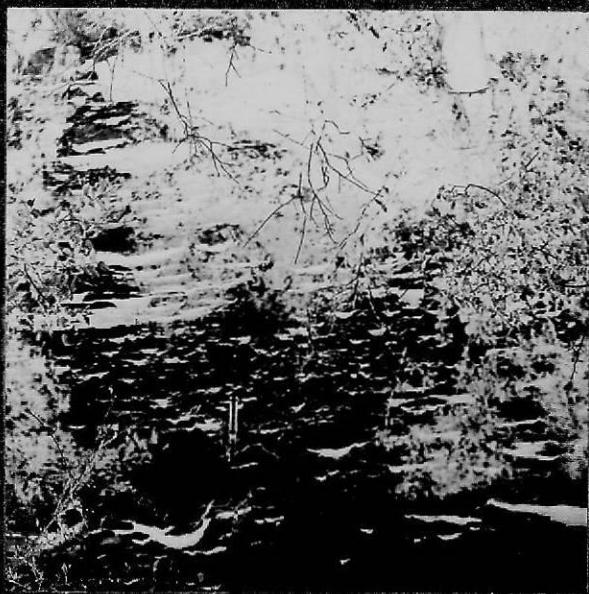
The lower part of the Point Peak member consists of greenish-gray to buff, thin-bedded, calcareous shales and siltstones interbedded with thin layers of gray, medium-grained, glauconitic limestones closely resembling the limestones of the upper part of the Morgan Creek. This grades upward into alternating shales and siltstones (pl. XI) containing occasional beds of intraformational conglomerate. These conglomerate beds vary from 1 to 6 inches in thickness and consist of flat, yellowish-green siltstone and limestone pebbles in a matrix of brown, fine-grained limestone.

Good exposures of this member are scarce, for the shale weathers readily into a light gray soil littered with rock debris and caliche which mask the outcrops.

Three fairly persistent biorherm zones, generally ranging in thickness from 5 to 20 feet, occur in the member. These zones are large enough to be mapped separately, but it should be noted that, in addition several thinner biorherm layers are present in the Point Peak member in the thesis area. Locally, all of these biorherm zones, large and small, grade laterally into shale, silt, and limestone. For this reason, it is very difficult to state, with any assurance, that the zones which have been mapped are the same throughout the area.

The biorherm zones consist of gray to slightly-purple, sub-lithographic, hard, massive limestone. A single biorherm may be as much

Plate XI



Exposure of Point Peak shale and siltstone beds,
one mile south of L. Loeffler's ranch house.

as 30 feet in diameter; however, the usual diameter is about 5 feet (pl. XIII, fig. 1). The individual bioherms may at places coalesce to form biostromes. Thin-bedded, gray to yellowish-brown, fine- to medium-grained limestones and brown to gray, thin-bedded, calcareous shales are interbedded with the bioherms.

In the Hilda-Southwest area, many of the bioherms directly overlie or actually form around beds of intraformational conglomerates. These intraformational conglomerates are believed to have been formed by shoaling and temporary withdrawal of the waters followed by desiccation and mud cracking. The relation of the conglomerates to the bioherms suggests that they provided a base on which the bioherms could grow.

Topography and Vegetation

The Point Peak member forms gentle slopes that have a few irregularities toward the base of the slopes due to limestone beds in the lower part of the member. The gently sloping Point Peak hills are usually capped by bioherms (pl. XII, fig. 2).

The vegetation on the shaly portion of the member is rather sparse, consisting of scattered mesquite, grasses, and cacti. In contrast to this, the bioherm zones support a dense growth, consisting of some oak and mesquite, Spanish persimmon, and tassajillo along with various forms of cacti and grasses.

PLATE XII

BIOHERMS IN THE POINT PEAK MEMBER



Figure 1

Bioherms in the middle part of the Point Peak shale on Panther Creek.



Figure 2

Bioherms capping a Point Peak hill on Panther Creek. Note the typical Point Peak slope.

San Saba Limestone Member

Definition and Thickness

San Saba was first used as a series term by Comstock (1890, p. 566) for exposures of limestone along the San Saba River near Camp San Saba in McCulloch County. The term has been revised to its present status by Bridge, Barnes, and Cloud (1947, p. 117) who have defined it as the uppermost member of the Wilburns formation.

The type section of the San Saba limestone, located along both sides of the Mason-Brady highway near the San Saba River bridge, is 280 feet thick according to Bridge, Barnes, and Cloud (1947, p. 117). As calculated by Barnes and Bell (1954, p. 37), the average thickness of the member is 270 feet. The upper part of the San Saba limestone is not exposed in the thesis area.

Lithology

Only the lower beds of the San Saba member are exposed in the thesis area. The base of the San Saba member is placed at the top of the last thick biherm zone in the Point Peak shale. Above the biherm zone are gray to tannish-brown, arenaceous, medium-bedded, fine- to medium-grained, slightly glauconitic, fossiliferous limestones with several beds of fine- to medium-grained, calcareous sandstones (pl. XIII). The fossils in the formation consist of various forms of brachiopods, gastropods, and trilobites.

Many of the limestones in this member contain light gray to light tan, sublithographic, subspherical, marble-sized masses believed

Plate XIII



San Saba limestone interbedded with thin sandstone and siltstone beds located one half mile west of E. Geistweidt's ranch house.

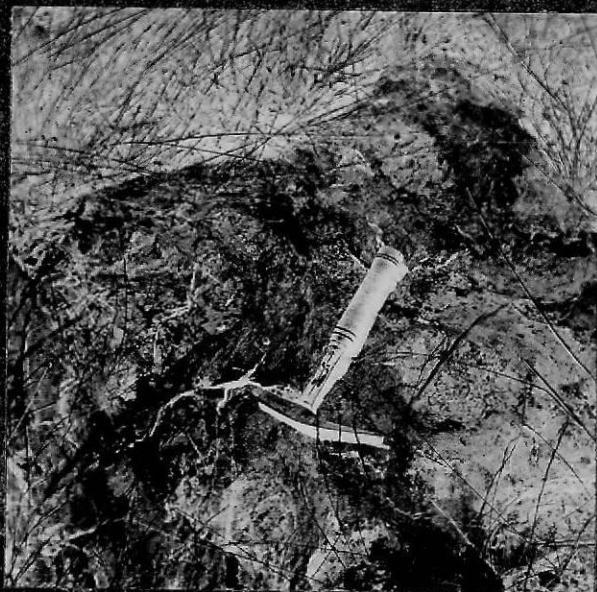
to be of algal origin. These bodies are referred to by Bridge, Barnes, and Cloud (1947, p. 120) as Girvanella. They appear on the surface of weathered limestones as light spots or "eyes" and are present throughout the portion of the San Saba member exposed in the thesis area.

Although Girvanella seems to be characteristic of the San Saba limestone in the Hilda-Southwest area, they have been reported by Bridge, Barnes, and Cloud (1947) to be present in limestones of the Point Peak shale and the Cap Mountain limestone.

Large individual bioherms are present throughout the exposed portion of the member. These bioherms range in size from less than one foot to 20 feet across. Most of them are composed of bluish-gray to purplish-gray, sublithographic limestone. On the weathered surface the bioherms exhibit a typical "cabbage head" structure (pl. XIV). It should be noted that at the type locality of the San Saba member all the bioherms are considered to belong to the Point Peak member. However Bridge, Barnes, and Cloud (1947, p. 117) mention large stromatolitic bioherms in the San Saba limestone exposed on Squaw Creek, southeast of the thesis area.

In the southwest part of the thesis area, alluvium washed down from the Cretaceous outcrops masks much of the surface exposure of the San Saba limestone member.

Plate XIV



San Saba bioherms exhibiting typical "cabbage head" structure located one half mile west of abandoned ranch house on A. Geistweidt's property.

Topography and Vegetation

The San Saba member forms a plateau above the fairly steep slopes of the Point Peak shale. In the west-central part of the area, the member caps a small plateau.

Vegetation on the San Saba member is scattered and consists of clumps of oak and Spanish persimmon with many varieties of grasses. The vegetational change between the Point Peak shale and the San Saba limestone is distinct in most places.

CRETACEOUS SYSTEM

Comanchean SeriesGeneral Statement

Rocks of Early Cretaceous age border all except the northwest side of the Llano region. The Cretaceous strata in the thesis area are almost horizontal. They unconformably overlie the Paleozoic formations.

According to Plummer (1950, p. 101), the Cretaceous units present in the Llano region are:

Fredericksburg group

Edwards limestone

Comanche Peak limestone

Walnut clay

Trinity group

Paluxy sand (northeast only)

Glen Rose limestone

Travis Peak formation

Cloud and Barnes (1948, p. 189) state that, in the Squaw Creek quadrangle, Gillespie and Mason Counties, one mile southeast of the Hilda-Southwest area, the Hensell sandstone member of the Travis Peak formation unconformably overlies Paleozoic rocks. A conglomerate consisting of material of Upper Cambrian and Lower Ordovician carbonate rocks is present in the basal part of the Hensell sandstone member. This conglomerate is referred to by Barnes (1952) as the Lange's Mill conglomerate. It should be noted that Cloud and Barnes (1948, p. 189) believe that part of the Hensell sandstone member is actually a shoreward facies of the Glen Rose limestone. Above the Hensell sandstone is the Walnut clay overlain by the Comanche Peak limestone and Edwards limestone.

In the Hilda-Southwest area, the Cretaceous beds have been mapped as the Lange's Mill conglomerate and as sandstone, siltstone, and limestone units (pl. XV).

Lange's Mill Conglomerate

This unit consists almost entirely of pebbles and cobbles from Upper Cambrian and Lower Ordovician carbonate rocks with a carbonate or ferruginous cement. The individual particles are fairly well rounded and range in size from 4 inches to less than .1 inch in diameter. At the base, the particles are well cemented; however, toward the top the material readily disaggregates and forms a soil littered with pebbles.

Plate XV



Cretaceous sand, silt, and limestone units located 1.6 miles south of Leroy Ioeffler's ranch house and 100 yards south of graded country road.

In the thesis area, the unit ranges in thickness from 20 feet to a feather edge.

Cretaceous Sandstone Unit

Except where the conglomerate unit is present, the Paleozoic rocks are unconformably overlain by a sandstone unit. The sandstone is red at the base but grades upward to buff. It is a medium- to coarse-grained, poorly consolidated, slightly calcareous sandstone. In the lower part of the unit the sandstone is cross bedded and contains many rounded quartz pebbles. It contains much ferruginous material. This lower part grades upward into a slightly calcareous, massively bedded sandstone which in places grades laterally into siltstone. The sandstone unit weathers very readily into a red, sandy soil which looks like that of the Hickory sandstone. This soil masks the Paleozoic rocks in the southwestern part of the thesis area. The thickness of this unit is about 100 feet.

Cretaceous Siltstone Unit

The contact between this unit and the underlying sandstone is placed at a point where the silt-sized material becomes predominant. The unit is a buff to gray, massively bedded, slightly fossiliferous, calcareous siltstone. The calcareous content increases toward the top. The large amount of calcareous cement in the upper siltstone beds makes them stand out as resistant ledges. Gastropods and Brachiopods are scattered through the unit.

In the Hilda-Southwest area, this unit is about 50 feet thick.

Cretaceous Limestone Unit

The contact between the siltstone unit and limestone unit is placed at the first predominantly calcareous bed. This unit is buff to gray, medium- to fine-grained, arenaceous limestone. Near the contact with the siltstone unit the limestone contains many black to gray, dense chert nodules which weather out and litter the surface. Only the lower 15 feet of this unit is exposed in the Hilda-Southwest area.

QUATERNARY SYSTEM

Recent Alluvium

In the Hilda-Southwest area, the Cenozoic sediments are limited to stream and alluvial deposits which consist of sands, gravels, and conglomerates derived from Paleozoic and Cretaceous rocks.

These deposits range from a feather edge to over 20 feet in thickness. They are present in stream valleys and at the base of many hills.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

Although intense structural deformation occurred during Pre-Cambrian time, these conditions do not seem to be reflected in the Paleozoic strata.

The uplift in the Llano region, according to Sellards (1934, p. 84), began in Late Mississippian time, as evidenced by the thinning of Lower Mississippian strata over the Llano region. Sellards (1934, p. 87) states that the major uplift was of post-Bend and pre-Canyon age.

Cloud and Barnes (1948, p. 121) report that in the Llano region rocks of Strawn age have been faulted and that Canyon strata show no faulting. Because the faults in the region cut all strata deposited prior to Canyon time, the faulting may be dated as of post-Strawn and pre-Canyon age. In general, the strikes of the major faults in the Llano uplift region trend northeast-southwest. These are normal faults and have dips ranging from 60° to 80° , according to Cloud and Barnes (1948, p. 118). The actual dip of the fault planes could not be determined in the thesis area. The minor faults vary greatly as to strike and direction of throw.

In most of the Kilda-Southwest area, the dip of the Paleozoic strata is toward the southeast at about 5° . The Cretaceous rocks are almost horizontal.

FAULTING

Detection of Faulting

Faults in the Hilda-Southwest area were detected by several different methods. In certain cases, vegetational lineation indicated the trace of a fault plane (pl. XVI). Many faults were recognized where they caused the repetition or omission of strata. Erratic strikes and dips, abrupt termination of beds, presence of fault breccia, and actual observation of the fault surface are other criteria which were used to detect faulting.

In faults where the Welge sandstone member was involved thin slivers of hard quartzitic sandstone stand out on the surface.

The faulting, in most parts of the thesis area, was so complex that it was necessary to trace out on the surface each individual fault.

Description of Faulting

Most of the faults occur in a one half mile wide, north-south zone that crosses the center of the thesis area. Although there are numerous faults on either side of this zone, their displacement is not as great as that of the faults in the central zone.

In general, the larger faults in this central band trend north-south with smaller branch faults trending northeast-southwest. With only three exceptions, all the faults in the central zone are downthrown to the west. In all, the fault zone has a total displacement of more than

Plate XVI



Aerial photograph showing the vegetational lineation along the strike of faults in the thesis area.

600 feet. Two major faults account for most of this throw. In the northern part of this zone, the Holbrook fault, named by the author from the H. Holbrook Survey, brings the middle part of the Hickory sandstone into contact with strata of the middle part of the Morgan Creek limestone. In places, the throw of this fault is estimated to be greater than 540 feet. The Hickory sandstone on the upthrown side of the Holbrook fault has been eroded down below the Morgan Creek limestone and Cap Mountain limestone on the downthrown side, thus forming an obsequent fault-line scarp (pl. XVII). The Daffan fault, named by the author from the M. Daffan Survey, is present in the southern part of the central fault zone. This fault displaces beds of Cap Mountain limestone into juxtaposition with Point Peak shale, Morgan Creek limestone, Welge sandstone, and Lion Mountain sandstone beds. The fault varies in throw from somewhat more than 314' feet in the extreme southern part of the thesis area to less than 50 feet where the fault is intersected by a minor fault in the central part of the area. An obsequent fault-line scarp is formed by the Daffan fault. The remainder of the faults in the central zone, other than the Holbrook and Daffan faults, are of minor magnitude. In general, they have a throw of less than 50 feet and trend northeast-southwest.

The area to the west of the central fault zone is cut by numerous minor faults trending northeast-southwest. In general, these faults are downthrown to the northwest and have an average displacement of less than 50 feet. They are responsible for the repetition of the

Plate XVII



Obsequent fault scarp formed by the Holbrook fault.

Morgan Creek, Point Peak, and San Saba members on the surface. In the southern part of this area the faults are obscured by alluvial outwash from the Cretaceous hills, which makes it difficult to locate their actual position. The faults in the extreme southwestern part of the thesis area are overlapped by undisturbed Cretaceous strata.

To the east of the central fault zone are numerous, small, northeast-southwest trending faults which, for the most part, are entirely within the Cap Mountain limestone member (pl. XVIII). Many of them have a throw of less than 10 feet. They are downthrown to the northwest. These faults, although they are quite minor, were mapped because it is believed by the author that they explain the excessive width of the Cap Mountain limestone outcrop in the Hilda-Southwest area.

The Monsola fault, named by the author from the P. Monsola Survey, is the largest fault in this eastern part of the thesis area. It brings middle Hickory strata against the upper part of the Cap Mountain strata. It trends northeast-southwest and is downthrown to the northwest. This fault has, in places, a throw of greater than 200 feet. It forms an obsequent fault-line scarp. In the extreme southeastern part of the thesis area, small faults downthrow to the northwest, cause the repetition of Lion Mountain and Welge strata.

Age of Faulting

In the thesis area, rocks of San Saba age are the youngest rocks faulted. Cretaceous strata seem to be undisturbed by faulting.

Plate XVIII



Small fault in the Cap Mountain limestone member, showing tilted beds and fault breccia, located 200 yards east of State Highway 783.

Therefore, the faulting in the Hilda-Southwest area occurred after deposition of the San Saba limestone and prior to the deposition of Cretaceous rocks.

Origin of Faulting

Cloud and Barnes (1948, pl. 118) have attempted to associate the faulting in the Llano uplift region with the Late Paleozoic folding of the Llanoria geosyncline. The Llanoria geosyncline was developed around the eastern and southern sides of the Llano uplift. The folding involving the sediments in the geosynclines was probably accompanied by a movement to the east and to the south. This movement placed the Llano region under torque causing it to fracture. Cloud and Barnes state that:

The theoretical tensional couples developed by active compression from east and south would result in fractures aligned dominantly in the northeast quadrant, as faulting in the Llano region is.

The theory that the faults in the Llano region were formed entirely by tensional stresses is not believed to be adequate by the author.

It seems possible that the stresses in the area could be related to the Mohr-Coulomb theory of fracture (Terzaghi, 1947). Under homogenous conditions, a normal fault will occur when the maximum principal stress direction is vertical, the minimum principal stress direction is horizontal and perpendicular to the strike of the faults, and the intermediate

stress direction is horizontal and parallel to the strike of the faults. This situation should result in dips of about 60 to 70 degrees.

As the dips of the faults in the Llano region are higher than the dips of the theoretical faults, it would seem that other factors are also involved in the stress system.

Using the Mohr-Coulomb theory, the maximum principal stress in the Llano region would be vertical, the minimum principal stress would be oriented in the northwest-southeast direction, and the intermediate principal stress would be in a northeast-southwest direction. Inhomogeneities of the rock and slight modifications in the stress directions could account for the variations of the actual structures from the theoretically anticipated structures.

Except for a few minor cross faults, the trends of the faults in the Hilda-Southwest area are in accordance with the postulated stress system.

The faulting in the Llano region is related to the Late Paleozoic uplift of the area.

FOLDING

Description of Folding

There is no major folding in the Hilda-Southwest area. However, a gentle syncline forms a long, narrow plateau in the north central part of the thesis area. The dips on the flank of this syncline are about 3° and it plunges northward at about 2° . It should be noted that the

dip readings were taken on the San Saba limestone which is affected by collapse structures and slumping over biocerms.

Origin of Folding

The syncline in the Hilda-Southwest area could have been caused by drag due to fault movement or to tectonic folding.

The general dip of the beds in the thesis area is toward the southeast. It is possible that the Holbrook fault with its downthrown side to the west could have resulted in enough drag to have formed the syncline.

It is probable that the syncline was formed by tectonic movements along with other slightly warped areas in the Llano region.

According to Cloud and Barnes (1943, p. 121), gentle folds have been reported in other areas but "not enough observations have been made on this type of folding over the uplift as a whole to determine whether these folds have a pattern showing a relationship to the major stresses affecting the Llano uplift or whether they are without pattern or have a different pattern for individual fault blocks". If the syncline is due to tectonic folding, it must have formed prior to or during the faulting in the area, as the Holbrook fault cuts its eastern limb.

GEOLOGIC HISTORY

GENERAL STATEMENT

In summarizing the geologic history of the Llano region, certain minor modifications of the regional history will be made so as to conform to local variations in the environment of deposition. These modifications will be discussed in a comparison of the Hilda-Southwest area with the regional geologic history.

Since only Cambrian and Cretaceous rocks are exposed in the Hilda-Southwest area, the geologic history of the Precambrian, Ordovician, Devonian, Mississippian, and Pennsylvanian periods will be taken from other sources. Detailed discussions on the geologic history of the Llano region have been presented by Paige (1911), Sellards (1932), Cloud and Barnes (1948), and Barnes (1956).

SUMMARY OF GEOLOGIC HISTORY OF LLANO REGION

During Precambrian time, great thicknesses of sandstones, shales, and limestones were deposited. These sediments were then folded, metamorphosed, and intruded by igneous rocks.

These Precambrian igneous and metamorphic rocks were exposed and extensive erosion took place prior to the deposition of Paleozoic strata. The surface upon which the Cambrian rocks were laid down had a great amount of relief.

It appears that at least part of the erosion of the Precambrian surface took place in an arid environment as evidenced by the presence

of ventifacts and frosted sand grains in the basal part of the Hickory sandstone.

The absence of Lower and Middle Cambrian sediments indicates that either erosion took place throughout this interval or that these sediments were removed prior to the deposition of the Upper Cambrian units.

In Late Cambrian time, shallow seas transgressed over the Precambrian surface and deposited the Hickory sandstone. Barnes (1956, p. 6) believes that the lower part of the Hickory sandstone, although it is grouped with the overlying sandstones containing Late Cambrian fossils, may not be Late Cambrian in age. His belief is based on the fact that the ventifacts and frosted grains in the basal part represent a different environment than does the rest of the member.

That the Hickory sandstone was laid down in a shallow sea is evidenced by small amounts of glauconite, cross-bedding, oscillation ripple marks, and the presence of marine fossils. The presence of intraformational conglomerates indicates a fluctuation of the sea level. The poorly lithified pieces of sandstone, coarse sand grains, and fossil fragments which compose the conglomerate were probably caused by a shallowing of the sea and the breaking up of the sea floor by wave action. The broken pieces were then cemented as conglomerate layers.

An increasing amount of calcareous material and the fineness of the sand toward the top of the Hickory member suggests a slow wearing

down of the source area. This lowering of the land continued until carbonate material was the predominant sediment. It is possible, however, that the change from the sandstone of the Hickory member to limestone of the Cap Mountain with no appreciable amount of shale deposition was due to a depletion in the amount of disaggregated clastic material in the source area. As the sandy mantle of the low lying land mass was removed, precipitation of carbonate from the sea became predominate. However, the arenaceous material present in the middle part of the Cap Mountain limestones indicates that the land mass was still a positive area.

A lowering of the land mass almost to base level is indicated by the relatively pure limestones in the upper part of the Cap Mountain member.

The gradual change from the relatively pure limestones of the Cap Mountain to the calcareous sandstone of the basal Lion Mountain member suggests a gentle uplift of the source and a regression of the sea.

The excessive amount of glauconite in the Lion Mountain member indicates that reducing conditions were present during the time of deposition. If the glauconite was deposited in waters of oxidizing conditions it would probably have been altered to limonite or hematite. The beds in which the glauconite is found are intricately cross-bedded and contain certain broken and worn fossil fragments. This indicates

that the glauconite was deposited, probably in quiet water, and then reworked when turbulent conditions prevailed.

The change from the thinly bedded, highly glauconitic, fossiliferous Lion Mountain sandstone to the thickly bedded, non-glauconitic, slightly fossiliferous sandstone of the Welge represents an interruption in deposition resulting in a slight disconformity. A change from the reducing conditions of the Lion Mountain member to oxidizing conditions in the Welge member could account for the absence of glauconite in the Welge sandstone. The thicker beds in the Welge sandstone are indicative of more rapid sedimentation or to deposition under more uniform and less turbulent deposition.

The gradual increase in the amount of carbonate from the Welge sandstone upward in the Morgan Creek limestone is due to a slow transgression of the sea and a general wearing down of the land. Oscillation ripple marks in the basal Morgan Creek, found in the thesis area, indicate that the seas were shallow.

A continued transgression of the sea and a lowering of the source area during Middle Morgan Creek time formed a condition in which relatively pure limestone was deposited. In the Hilda-Southwest area, the fossils and fossil fragments of the Dorothy and other fossil zones are worn and show random orientation which indicates turbulent conditions caused by wave action.

The appearance of thin layers of shale in the upper part of the Morgan Creek suggests a periodic influx of fine clastic sediments.

This could be due to slight regressions of the sea and gentle uplifts of the land area or to an increase in the amount of precipitation in the source area. Bioherms present in this part of the member are indicative of a shallow, relatively warm, quiet sea.

The seas slowly regressed until the fine-grained, argillaceous material of the Point Peak member became predominant. The occasional limestone beds and the fine-grained, clastic material seem to imply a source area near base level.

Intraformational conglomerates, ripple marks, and bioherms are indications that the Point Peak shale was deposited in a warm, shallow sea. The occurrence of mud cracks along with the conglomerate seems to suggest that the sediments were at times exposed on tidal flats. The fact that, in the Hilda-Southwest area, many bioherms were found to form on or around the intraformational conglomerates indicates that the bioherms grew at or very near the surface, possibly on the tidal flat itself.

Gradation into the glauconitic, sublithographic limestone of the San Saba member implies a transgression of the sea. Warm, shallow seas were probably in existence throughout San Saba time as evidenced by bioherms and Girvanella. At times, slight regressions of the sea caused the deposition of thin sand and silt beds.

In the western part of the Llano region, deposition continued uninterrupted into Ordovician time. During Early Ordovician time the

source area was low and relatively stable as evidenced by the lack of clastic material in the Ellenburger sediments.

The absence of sediments from Middle Ordovician through the Silurian suggests that a general withdrawal of the sea and erosion of the land took place during this time.

The presence of isolated outcrops of Devonian rocks indicates a return of the sea, which laid down sediments on an irregular erosion surface. According to Barnes (1945), the Devonian rocks are older in the eastern and younger in the western parts of the Llano region. This suggests that the sea transgressed from east to west.

It is not known whether the Devonian sea was very shallow and deposited sediments only in depressions or if pre-Mississippian erosion removed all the deposits except those occupying the depressions. In either case, Mississippian sediments were thus deposited in some places on Ordovician and at others on Devonian strata.

During Mississippian time marine conditions existed in the Llano region as evidenced by the Chappel and Barnett formations. The thinning of the Barnett formation over the Llano region suggests that some uplift occurred during this time. After deposition of the Mississippian strata, uplift continued and the Barnett formation was eroded and truncated.

The Marble Falls formation of Pennsylvanian age was deposited on the eroded Mississippian surface. The presence of the Smithwick

shale, according to Paige (1912) implies extensive swamp conditions.

After deposition of the Smithwick formation, the region was cut by numerous faults trending northeast-southwest.

The absence of Permian, Triassic, and Jurassic rocks in the region suggests a long period of erosion in which the Llano region was truncated. The plateau in the north-central part of the thesis area indicates that a condition of peneplanation existed prior to the deposition of the Cretaceous sediments.

The sequence of Cretaceous rocks, which grade from conglomerate at the base, to sand, to silt, and to limestone at the top, suggests a steadily transgressing sea and a continual lowering of the source area.

A widespread uplift and prolonged erosion followed the deposition of the Cretaceous strata. This erosion has removed much of the Cretaceous rock from the center of the Llano uplift region, thus forming a topographic basin.

No marine inundation has occurred since the deposition of Cretaceous strata. The only Cenozoic rocks are stream and alluvial deposits consisting of detrital material derived from Paleozoic and Cretaceous strata.

COMPARISON OF HILDA-SOUTHWEST AREA WITH REGIONAL

GEOLOGIC HISTORY

In general, the geologic history of the Hilda-Southwest area is the same as the rest of the Llano uplift region. However, certain

features are present in the thesis area which suggest slight variations in the environment of deposition from that of the region as a whole.

The presence of thick beds of sandstone in the upper part of the Cap Mountain member indicates a local influx of clastic material which is not evidenced throughout the Llano region. This may have been caused by minor oscillations of the land mass or sea level near the western part of the Llano region or to abnormal runoff caused by an increase in rainfall in the source area.

An abnormally thick bioherm zone in the upper part of the Morgan Creek limestone indicates that warm, shallow seas persisted in the area for a long period of time. In the Hilda-Southwest area, the bioherms first occur during Morgan Creek time.

The great number of bioherms throughout the Point Peak shale along with mud cracks and intraformational conglomerates is evidence that the member was deposited in a warm, shallow sea. The fact that most of the bioherms in the thesis area occur in numerous zones suggests that the environmental conditions fluctuated to some extent. At certain times, optimum conditions for algal growth resulted in the accumulation of thick biohermal deposits. An influx of clastic material could have resulted in the burial of the bioherm zones and the cessation of their growth. Other factors which could have stopped the bioherm growth are changes in sea level, temperature, and chemical composition of the water.

ECONOMIC GEOLOGY

The most important resource in the Elida-Southwest area is the grazing land. The Hickory sandstone, the Lion Mountain sandstone, and the Cretaceous wash are suitable for the cultivation of crops.

The Hickory sandstone is the best aquifer in the thesis area. Most of the wells in the area derive their water from this unit. However, in places where the Hickory sandstone is too deep a poorer quality water may be derived from the Lion Mountain sandstone.

Some of the resistant sandstone of the Hickory member is used locally for building stone. The caliche associated with the Point Peak member is used locally for road metal.

Petroleum and ore deposits have not been found in the area.

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