GEOLOGY OF THE UPPER SCHEP CREEK AREA, MASON COUNTY, TEXAS

A Thesis

By

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A B S T R A C T

The Upper Schep Creek area is located on the southwest flank of the Llano uplift in southern Mason County, Texas. Rocks exposed in this area are Late Cambrian, Early Ordovician, and Early Cretaceous in age.

The Upper Cambrian strata are divided into the Riley and Wilberns formations which are further subdivided into three and four members, respectively. The Riley formation unconformably overlies the Precambrian rocks and consists of the Hickory sandstone member, the Cap Mountain limestone member, and the Lion Mountain sandstone member. The Hickory sandstone has no outcrop in the Upper Schep Creek area. The Wilberns formation unconformably overlies the Riley formation and consists of the Welge sandstone member, the Morgan Creek limestone member, the Point Peak shale member, and the San Saba limestone member, listed in ascending order.

Deposition was continuous throughout Late Cambrian and Early Ordovician times in this part of the Llano uplift. Rocks of the Ellenburger group (Lower Ordovician) occur in the area but are limited to a few small outcrops.

Rocks of the Comanche series, that are Early Cretaceous in age, occur in the southern part of the Upper Schep Creek area. These beds are

herein differentiated according to changes in lithology, and no attempt was made to recognize the individual formations. These rocks consist of a basal conglomerate unit, a sandstone and siltstone unit, a siltstone unit, and a limestone unit, listed in ascending order.

The major structural features of the area consist of southwest-northeast trending faults most of which are downthrown to the northwest. There are a great number of faults in this area but none of them have large displacements.

Intense deformation and alteration of the Precambrian sediments has obscured the criteria for deciphering that part of the geologic history of the Llano region. Epeiric seas covered this region during most of Late Cambrian and Early Ordovician time. A fluctuation in sea level is responsible for a break in sedimentation or an unconformity between the Riley and Wilberns formations. There does not seem to be a depositional break between the Upper Cambrian and Early Ordovician rocks in the local area, however there is a faunal and depositional break between these systems in other parts of the Llano region. Minor uplift and erosion probably occurred during the remainder of Ordovician and Silurian time. Marine deposition occurred during parts of Devonian, Mississippian and Early Pennsylvanian time. The major uplift of the region occurred during Middle and Late Pennsylvanian and the area remained above sea level until the Early Cretaceous. Cretaceous sediments were deposited over the region, and subsequent upwarping and erosion have formed the present topographic features.

A C K N O W L E D G M E N T S

The writer would like to express his appreciation and gratitude for the assistance given to him on this research problem by the staff of the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas. The field work was supervised by Dr. M. C. Schroeder who provided many helpful suggestions in regard to the problems encountered in this research. Mr. F. E. Smith, Dr. E. L. Harrington, and Dr. H. R. Blank have offered invaluable suggestions and constructive criticism in the preparation of this report.

Special appreciation is expressed for the generous hospitality of Mr. Ormond Markwendt who invited the writer to stay in his home during the course of the field mapping. Appreciation is also expressed to the property owners of the area.

Cooperative field work of a part of the area was completed with Messrs. George Bryant, William E. Harwood, and Bobby R. Ammer, who had slightly overlapping adjacent thesis areas. The measured sections were completed in cooperation with Thomas D. Daugherty.

The aerial photographs, Brunton compass, stereoscopes, and measuring rod used on this project were the property of the Department of Geology and Geophysics of the Agricultural and Mechanical College of Texas.

GEOLOGY OF THE UPPER SCHEP CREEK AREA, MASON COUNTY, TEXAS

INTRODUCTION

LOCATION

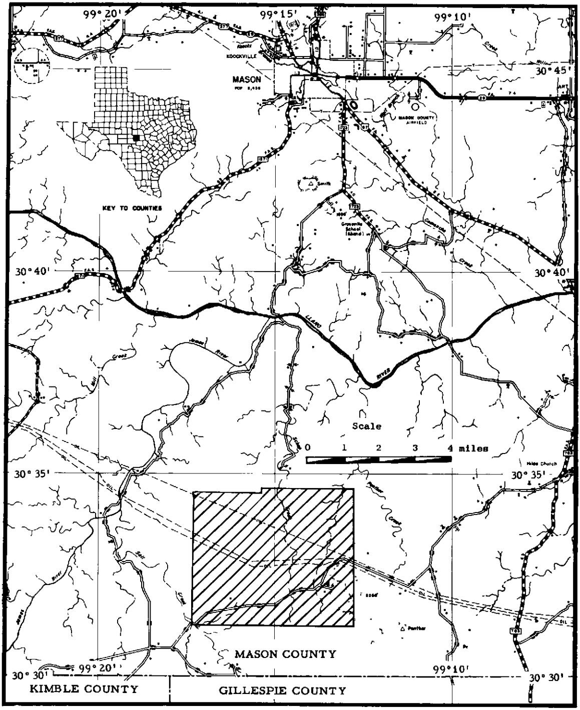
The Upper Schep Creek area is located in southern Mason County on the southwest flank of the Llano uplift in Central Texas. The location and shape of the area are shown in Figure 1. As the name implies, the upper part of Schep Creek, as well as the west branch of Panther Creek, are within the area.

ACCESSIBILITY

Accessibility by road to the Upper Schep Creek area is rather limited; only one graded road provides access to this area. This all-weather road has no formal name and in this report it will be called a county road. It originates near Hilda Church on Ranch-to-Market Road 783 and extends southwest to beyond the Kimble County line. This road enters the Upper Schep Creek area near the center of its eastern boundary, at a point about eight miles southwest from Hilda Church, and crosses the southern portion of the area to its southwest corner. The remainder of the area has a limited network of very rough ranch trails that can be traveled only in fair weather.

METHODS OF FIELD WORK

The field work for this investigation was carried out during the summer of 1958. The geologic data were compiled on four acetate-covered



Base map from state highway map of Mason County, Texas, revised to January 1, 1958

Figure I - LOCATION MAP OF THE UPPER SCHEP CREEK AREA

MASON COUNTY, TEXAS

aerial photographs that were used as a base map. These aerial photographs, numbers DFZ-1P-173 and 174, and DFZ-3P-202 and 203, were made in 1955 for the Commodity Stabilization Service of the U. S. Department of Agriculture. The aerial photographs were very helpful in determining outcrop patterns and faults. Vegetation lineations, abundance of vegetation, and offset ridges can be readily seen on aerial photographs; these criteria were used to predict and determine structural features. A three-dimensional effect was obtained by viewing overlapped photographs with a stereoscope. This effect was found to be very useful in supplementing field investigations and in constructing geologic cross-sections.

The Brunton compass was used to obtain dips and strikes from the suitable outcrops of this area; it was also used, in conjunction with a Jacob's staff, to measure the thickness of the outcrops.

PREVIOUS INVESTIGATIONS

Prior to 1900, many geologists observed and described the igneous, metamorphic, and sedimentary rocks of the Llano uplift region. Some of the more important work was done by the following geologists: Roemer (1846), who recognized Cretaceous, Carboniferous, and older Paleozoic rocks, Walcott (1884), who established the Potsdam group as being of Late Cambrian age; R. T. Hill (1887), who reviewed the geology of Texas and named the Comanche series which includes the Trinity, Fredricksburg, and Washita groups; Comstock (1890), who first introduced the terms Hickory, Riley, and San Saba series; and Tarr (1890), who first described the present drainage of the Llano region.

Since the turn of the century, extensive geological investigations have been carried on in this region by a small group of geologists who have specialized in the problems of this area. It is impossible to recognize all who have worked in this field, but the following paragraphs include some of the more pertinent reports on the geology of the Llano uplift.

Paige (1912), working in the Llano and Burnet quadrangles, named and described the Wilberns, Cap Mountain, Ellenburger, and Smithwick formations; he used the term Hickory sandstone instead of Hickory series which had been used by Comstock (1890).

Udden (1916) compiled data on the geology of Texas and included the first comprehensive geologic map of the state. This map, on the scale of 1:1,500,000, differentiated Precambrian and Early Paleozoic rocks of the Llano uplift.

Deen (1931) studied the algal reefs of the Wilberns formation and submitted a paper that was printed in abstract form in the Bulletin of the Geological Society of America.

Dake and Bridge (1932) correlated the Ellenburger fauna with faunal zones of the Ordovician of Missouri. The estimated thickness of the Ellenburger was revised from 1000 to 2000 feet.

Sellards et. al. (1932) reviewed the stratigraphy of Texas and emended the definition of the Trinity group of the Lower Cretaceous. (In 1934), Sellards reported on the structure and paleogeography of the Llano region. This evidence indicated a Mississippian age for the beginning of structural uplift.

Bridge (1937) studied the Upper Cambrian strata on the western side of the Llano uplift and named the Lion Mountain sandstone member of the Cap Mountain formation.

Cloud, Barnes, and Bridge (1945) reduced the Riley series to a formation composed of the Hickory, Cap Mountain, and Lion Mountain members. Further proposals restricted the Wilberns formation to the Upper Cambrian and also revised the Ellenburger limestone to group status.

Bridge, Barnes, and Cloud (1947) completed their investigations of the Upper Cambrian rocks of the Llano region. This paper, the recognized standard for this region, divides the upper Cambrian strata into two formations and seven members.

Cloud and Barnes (1948) presented the final results of an extensive study of the Ellenburger group of central Texas. This report also includes stratigraphic studies of the Cretaceous rocks of this region.

Plummer's (1950) report on the Carboniferous rocks of this area also included stratigraphy and geologic history of some of the Cretaceous units encountered in the Llano uplift.

Barnes (1952) described the geology of the Squaw Creek quadrangle in Mason and Gillespie Counties; this included a complete geologic report on the Upper Cambrian, Lower Ordovician, and Lower Cretaceous rocks of this quadrangle.

Cheney and Goss (1952) discussed the tectonic features of Central Texas. They suggested that the Llano uplift is a part of an extensive northwest-trending structural arch; that the uplift started in the Mississippian and was completed in the Pennsylvanian.

Barnes and Bell (1954) wrote a paper on the Upper Cambrian strata of the Llano uplift that included detailed descriptions of some of these stratigraphic sections. They also listed the average, and variations in, thickness of these stratigraphic units.

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

CLIMATE

Mason County is located in the semi-arid zone of Texas. The mean annual rainfall for the county is 22.5 inches; however, the rainfall will vary widely from year to year. Most of the rainfall occurs in the late winter and spring months, and most of it occurs in a few short storms that result in high rates of runoff.

The mean annual temperature is 64° F, with extreme temperatures ranging from over 100° F in the summer to below 0° F in the winter.

VEGETATION

The vegetation of Mason County is controlled primarily by the variation in rainfall and, secondarily, by the variation in soil type. With the exception of vegetation that grows in the larger stream valleys, the vegetation is necessarily stunted in growth and consists of hardy varieties.

In the Upper Schep Creek area, the vegetation consists principally of mesquite, Mexican persimmon, scrub oak, and several varieties of grasses and cacti. The limestone outcrops have a sparse irregular growth of vegetation. The sandstone and shale outcrops, in general, have a denser and more uniform growth of vegetation than the limestone outcrops. An extremely dense growth of vegetation is encountered on the outcrops of the Welge sandstone and the bioherm zones, and also along fault zones. This is probably due to the fact that more precipitation is caught and held; this moisture supports the heavy growth of vegetation.

TOPOGRAPHY

In regional extent the Llano uplift forms a topographic basin, roughly elliptical in shape, whose dimensions are approximately 80 miles east-west and 60 miles north-south. The basin floor consists of a very rugged hilly terrain formed by outcrops of Precambrian and Paleozoic rocks, whereas its rim is composed of rocks of Cretaceous age that form extensive plateaus to the south and west.

The Upper Schep Creek area can be divided into three major physiographic units that trend east-west and a fourth minor unit that trends north-south and consists of narrow stream valleys. From north to south the major units rise in stair-step effect and are: (1) a narrow sandy bench composed of outcrops of the Lion Mountain sandstone, (2) a much wider, gently-sloping, pre-Cretaceous remnant plateau or old land surface composed of Point Peak shale and San Saba limestone, and upon which the Cretaceous sandstone and siltstone unit was deposited, and (3) a flat plateau composed of the Cretaceous limestone unit that is actually a part of the Edwards Plateau. The first and second physiographic units are separated by steep slopes formed by the resistant outcrop of the Welge sandstone, Morgan Creek limestone, and parts of the Point Peak shale. The second and third physiographic units are also separated by steep slopes, formed by the upper part of the Cretaceous sandstone and siltstone unit and the resistant ledges of the siltstone unit. That the various topographic units are directly related to the outcrop pattern is quite evident when a comparison is made between the geologic map and aerial photographs of the area.

The maximum relief in the Upper Schep Creek area is estimated to be about 300 to 400 feet. About half of this amount is due to the height of the basin-rim hills above the remnant-plateau, and the other half is caused by two intermittent streams that are deeply incised into this plateau. The west branch of Panther Creek, which is the eastern most stream, has developed a network of very short steep lateral canyons in the areas of resistant limestone outcrops. This has resulted in very rugged topography near this stream.

DRAINAGE

The Colorado River flows across the eastern part of the Llano uplift on its way to the Gulf of Mexico. Three major streams (the San Saba River, the Llano River, and the Pedernales River) flow eastward across the respective northern, central, and southern parts of the uplift to join the Colorado River.

The Upper Schep Creek area is drained by three small streams. Two of these streams, Schep Creek and the west branch of Panther Creek, flow northward into the Llano River and drain all but the southwest corner of the area. The southwest corner of the area is drained by several small washes or gullies that flow into Salt Creek a tributary of the James River.

According to Tarr (1890), the present drainage system of this region was superimposed on an elevated land surface of Cretaceous age and subsequent erosion removed these rocks and formed a topographic basin.

The major streams of the Upper Schep Creek area flow in the opposite direction to the regional dip and they cross, with negligible effect, the structures caused by faulting. However, it must be pointed out that some of the very short, steep, side-canyons on the west branch of Panther Creek do follow lines of faulting. These major streams are superimposed on the Paleozoic rocks and they are not affected by faulting; some of the minor streams are subsequent as they are affected by structural features.

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

GENERAL STATEMENT

The Upper Schep Creek area includes outcrops that are Cambrian, Ordovician, Cretaceous, Tertiary, and Quaternary in age. With the exception of the Hickory sandstone member of the Riley formation the complete section of the Upper Cambrian strata is exposed. The outcrops of this area have an average strike of approximately N 70° E and an average dip of 3°-4° SE. These outcrops thus become successively younger toward the southern part of the area. Paleozoic outcrops of the Riley and Wilberns formations of the Cambrian System and the Ellenburger group of the Ordovician System form the northern half and the southwest corner of the area. The units of the Cretaceous System form the greater part of the remainder of the area.

The geologic column for the rocks exposed in this area is as follows:

- Cenozoic Era
  - Cenozoic Systems
    - Recent Sediments
    - Tertiary or Quaternary Conglomerates
- Mesozoic Era
  - Cretaceous System
    - Lower Cretaceous

Comanche series

Limestone unit

Siltstone unit

Sandstone and Siltstone unit

Langes Mill (?) conglomerate

Paleozoic Era

Ordovician System

Lower Ordovician series

Ellenburger group

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

PALEOZOIC ERA

CAMBRIAN SYSTEM

The Cambrian System is represented in the Upper Schep Creek area, and in the Llano uplift, by rocks of the Upper Cambrian series. These strata are divided into two formations, containing three and four members respectively.

Riley Formation

The Riley formation was named by Cloud, Barnes, and Bridge (1945, p. 154). It was defined "-- to include all of the Cambrian strata in Central Texas beneath the Wilberns formation". The Riley formation is composed of three members which are listed from bottom to top as (1) Hickory sandstone member, (2) Cap Mountain limestone member, and (3) Lion Mountain sandstone member. The Hickory sandstone member was deposited unconformably on the underlying Precambrian rocks.

The Riley formation is about 780 feet thick at the type locality, which was selected from outcrops at the Riley Mountains in southeastern Llano County. However, the average thickness is about 695 feet, according to Barnes and Bell (1954, p. 36). The thickness of the Riley formation cannot be determined in the Upper Schep Creek area because the Hickory sandstone and most of the Cap Mountain limestone are not exposed.

Cap Mountain Limestone Member

Definition and Thickness: The Cap Mountain limestone was first named by Paige (1912, p. 23) and was used as a formation name. The present-day usage is the same as that of Cloud, Barnes, and Bridge (1945, p. 154), who redefined the upper and lower boundaries and reduced the rank from formation to a member of the Riley formation. The type locality is at Cap Mountain in Llano County.

The thickness of the Cap Mountain limestone varies from 135 feet to 455 feet with the average being 280 feet, according to Bridge, Barnes, and Cloud (1947, p. 113). Only the upper 50 to 70 feet of the Cap Mountain limestone is exposed in the area.

Lithology: As the lower part of the Cap Mountain member is not exposed in the Upper Schep Creek area, personal observations elsewhere and observations by Barnes and Bell (1954, p. 43) are used to describe this part of the section. The lower part of this member consists of alternating beds of maroon, fine-grained, calcareous sandstones and siltstones, and buff, arenaceous limestones. These beds grade upward to a series of brown to tan, thick- and thin-bedded, glauconitic, crystalline limestones that are separated by buff, thin-bedded, calcareous siltstones. Near the top of the member the beds are more massive, and they consist of gray, glauconitic, medium-grained, crystalline limestones that weather to a dull, dirty-brown surface. Some of these beds are lithologically similar to the strata in the middle and upper parts of the Morgan Creek limestone member.

Topography: The Cap Mountain limestone forms a wide, relatively flat bench that is dissected by Schep Creek and the west branch of Panther Creek.

Stratigraphic Relation: The upper contact with the Lion Mountain sandstone is gradational and, for field mapping purposes, is placed at the occurrence of a very slight change in slope.

Lion Mountain Sandstone Member

Definition and Thickness: The Lion Mountain sandstone was named and defined by Bridge (1937, p. 234). It was made the uppermost member of the Riley formation by Cloud, Barnes, and Bridge (1945, p. 154).

The thickness of the Lion Mountain sandstone is about 20 feet at the type locality, which is in Burnet County. However, according to Bridge, Barnes, and Cloud (1947, p. 114), the maximum thickness of this member is approximately 50 feet. In the Upper Schep Creek area, its thickness is approximately 48 feet.

Lithology: There is a slight variation in the lithology of the lower part of the Lion Mountain member between the eastern and central portions of the Upper Schep Creek area. Alternating beds of limestone and fine-grained sandstone occur in the eastern portion of the area, and they seem to grade laterally, in a westward direction, into glauconitic sandstone.

With the exception of the lower beds in the eastern portion of the area, this member consists principally of cross-bedded, very glauconitic, calcareous sandstones that contain abundant lenses of whitish-gray, coarsely crystalline, "trilobite hash" limestone. A fine-grained, extremely glauconitic sandstone occurs near the top of the member, and is succeeded by a weathered reddish-brown, fissile siltstone that just underlies the Welge sandstone member.

The outcrop of the Lion Mountain member is littered with reddish-black hematite nodules and lenses of "trilobite hash" limestone, both of which are very characteristic of the member and are a very useful aid in surface mapping. The hematite nodules contain an abundance of silica and are believed to be weathering products of glauconite. Monroe (1947, p. 1509) noted that cores of glauconitic sand which had been exposed to oxidation, through failure of an air-tight seal, formed limonitic crusts within a year. It seems possible that hematite could also form in this way. Casts of trilobite fragments in some of these nodules is further proof of their secondary origin.

The lithology of the Lion Mountain member is principally calcareous sandstone, glauconite, and lenses of "trilobite hash" limestone. The occurrence of cross-bedded sandstone and lenses of limestone is suggestive of deposition under turbulent conditions, whereas the occurrence of abundant authigenic glauconite in these cross-bedded deposits is suggestive of quiet, reducing conditions. Thus the Lion Mountain sediments seem to imply deposition under alternating quiet and turbulent conditions.

Topography: The Lion Mountain sandstone forms a narrow, gently sloping bench between the more resistant underlying and overlying members.

Stratigraphic Relation: The lower contact is gradational and is placed at a slight change in topography. The upper contact between the Lion Mountain sandstone and the Welge sandstone is sharp and clearly defined. There is a definite contact between the underlying maroon, bedded, fissile siltstone and the overlying brown, medium-grained, massive quartz sandstone of the Welge. This contact occurs at a break in deposition that is the unconformable contact between the Riley and Wilberns formations.

Wilberns Formation

The Wilberns formation was first named and defined by Paige (1912, p. 23), and was redefined by Cloud, Barnes, Bridge (1945, p. 140). The new definition retained the lower boundary, but the upper boundary was changed to include the San Saba limestone member. This change placed the upper boundary at the contact between the Cambrian and Ordovician Systems. The Wilberns formation consists of the Welge sandstone member, the Morgan Creek limestone member, the Point Peak shale member, and the San Saba limestone member, listed in ascending order.

The type locality of the Wilberns formation is near Wilberns Glen in Llano County. According to Barnes and Bell (1954, p. 35) the thickness of this formation will vary from 360 to 619 feet, the average being 550 feet.

Welge Sandstone Member

Definition and Thickness: The Welge sandstone was named by Barnes according to Bridge, Barnes, and Cloud (1947, p. 114). The type locality is half a mile north of the Gillespie County line on Squaw Creek in Mason County.

The thickness of the Welge sandstone is 27 feet at the type section. However, the thickness varies from 11 to 28 feet, and the average is 20 feet according to Barnes and Bell (1954, p. 35). The measured section at the Upper Schep Creek area was 15 feet thick.

Lithology: The lithology of this member is very uniform with the exception of the lowermost several feet. The basal beds consist of a yellow-brown, medium-grained, sparingly glauconitic, quartz sandstone that weathers to a dirty-brown color. The remainder of the Welge member is a light-yellow to reddish-brown, massive, fine-to medium-grained, quartz sandstone. Recomposed quartz-grain crystal faces that glitter in the sunlight, as well as unaltered quartz grains that are very rounded, are a very characteristic feature of the Welge.

The Welge sandstone occurs as a blanket sand that is fairly uniform in lithology and thickness over the entire Llano region. The sands of this unit were probably derived from a land area that had been deeply weathered. Fine clastic material is entirely absent in this member which probably indicates that, prior to deposition of the Welge, erosional agents had removed the finer material and left accumulations of sand-size particles. These particles were then deposited due to an increase in energy of the erosive agents.

Topography: In the Upper Schep Creek area the Welge sandstone forms a distinct resistant ledge that is easily recognized on aerial photographs because a thin dark band of heavy vegetation grows on the outcrop. However, various writers (Scaife, 1957; Fuller, 1957) have stated that the Welge sandstone is unconsolidated in some areas and does not form ridges. The Welge is fairly well indurated and forms distinct ledges on the southwest flank of the Llano uplift, whereas on the west and northwest flanks it is unconsolidated and forms a flat bench. In the latter areas it is very difficult to differentiate from the Lion Mountain member as together they form a deeply weathered flat bench between the Cap Mountain and Morgan Creek members. However, the Welge and Lion Mountain are easily differentiated by lithology if good exposures occur.

Stratigraphic Relation: The lower contact with the Lion Mountain sandstone is very sharp and distinct. The upper contact with the Morgan Creek limestone is gradational, and the base of the Morgan Creek limestone is placed at the first purplish-red, bedded, arenaceous limestone.

Morgan Creek Limestone Member

Definition and Thickness: The Morgan Creek limestone was named by Bridge (1937, p. 236). The type locality is just north of the junction of the North and South forks of Morgan Creek in Burnet County.

The thickness of the Morgan Creek limestone is 110 feet at the type locality. According to Barnes and Bell (1954, p. 35) its thickness varies from 114 to 143 feet with an average of 130 feet.

Lithology: The beds in the lower part of this member are composed of purplish-red, thin-bedded, glauconitic, arenaceous limestones. Higher in the section the beds are lighter in color and are less sandy. Several cystoid zones occur in the lower part of this member.

The middle part of the Morgan Creek contains a zone of "hashy" limestones that are composed of trilobite and brachiopod fossil fragments. The middle and upper beds of the Morgan Creek member are composed of blue-gray, thick-and thin-bedded, crystalline, glauconitic limestones that are separated by thin siltstone partings.

The brachiopod Eoorthis texana occurs at approximately 55 feet above the base of the member in the Upper Schep Creek area. According to Barnes and Bell (1954, p. 59), the Eoorthis texana zone was found to be approximately 37 feet above the base of the Morgan Creek at the Camp San Saba section, which is on the northwest flank of the Llano uplift. This fossil zone may have a restricted vertical range. As a result, the Eoorthis texana zone may be a very useful stratigraphic marker.

Approximately 30 feet below the Morgan Creek-Point Peak contact, a 10 foot light-green, calcareous shale zone was found in the bed of the west branch of Panther Creek. The lithology of this shale is very similar to the lithology of the Point Peak shale.

Relatively pure limestones occur just above the lowermost Morgan Creek beds and in the middle part of this member. This interval contains very little clastic material but the upper part of the member contains large amounts of silty or shaly material and a 10 foot calcareous shale zone. This upper part of the Morgan Creek also contains several zones of bioherms. These zones indicate a renewed clastic source area and shallow water conditions that favor algal growth. The deposition of muds reduce water clarity and result in soft bottom conditions; both factors inhibit algal growth. The deposition of muds was probably responsible for the limited growth of bioherms in this member.

Topography: The beds of the Morgan Creek member generally form a fairly steep slope above the Welge sandstone ledge. Ledges of rock and vegetation lines on the slopes follow the contours of the hills and are quite evident on aerial photographs.

Stratigraphic Relation: Both the upper and lower boundaries of the Morgan Creek member are gradational. The Morgan Creek limestone-Point Peak shale contact was placed above the last thick-bedded limestone, and below the first thin-bedded, calcareous shale and siltstone. This contact was clearly defined in the bed of the west branch of Panther Creek, where the last thick limestone bed containing small bioherms can be seen below the thin-bedded shale and siltstone (pl. 11, fig. 1).

Plate 11

BIOHERMS IN THE MORGAN CREEK AND POINT PEAK MEMBERS

Figure 1

Small bioherms in the Morgan Creek member that occur just below the boundary with the Point Peak member.

Figure 2

Beehive shaped bioherms that occur in the lower part of the Point Peak member.

Point Peak Shale Member

Definition and Thickness: The Point Peak member was named by Bridge (1937, p. 236), according to Bridge, Barnes, and Cloud (1947, p. 115). The type locality is at Point Peak in Llano County.

The Point Peak is 270 feet thick at the type locality. However, the average thickness is 130 feet according to Barnes and Bell (1954, p. 35).

Lithology: This member is chiefly composed of thin beds of alternating shale or siltstone and limestone. Several bioherm zones occur within this member but they are limited in extent. The shale beds, in the Upper Schep Creek area, are generally gray-green, fine-to medium-grained, and calcareous, whereas the limestone beds are gray-brown, finely-crystalline, and slightly glauconitic. Both rock types are characteristically thin-bedded and indurated; the shale is fissile and laminated as well.

In the Upper Schep Creek area the Point Peak member contains two or more zones of bioherms. The lower zone, or zones, occurs approximately thirty to forty feet above the base of the member. It consists of two different types of bioherms, one of which occurs in the central part of the area and the other in the eastern part. These two different types of bioherms cannot be traced laterally, due to insufficient outcrops, so it is not known whether this is actually one or two zones.

In the central part of the area the bioherms occur as isolated, sub-spherical units whose diameters range from 1 foot to 2 feet. Several of them have been dug from the pipe line ditch that traverses the area (pl. II, fig. 2). They have the appearance of a large bee hive, and are composed of light-purple, sublithographic limestone.

In the eastern part of the area the bioherms occur as large biostromes, 4 to 6 feet thick and up to 30 feet long, that exhibit the typical "cabbage head" structure. They are composed of light gray, sublithographic limestone.

The other bioherm zone is at the top of the Point Peak member. The bioherms grade laterally into shale beds that belong to the Point Peak member; therefore, in this paper, the upper zone of bioherms is included in the Point Peak. This zone consists of large biostromes of the "cabbage head" type that are composed of a gray sublithographic limestone. This bioherm zone is more persistent laterally than the lower zone. However, even this zone of bioherms is absent over much of the area.

A number of intraformational conglomerates occur in the Point Peak member, and they are composed of flattened, elongate, partly-rounded limestone and siltstone pebbles cemented by calcium carbonate. The shape of these pebbles indicates that they have not undergone long transportation and extensive abrasion before consolidation. These conglomerates were probably formed under subaerial conditions from fragments loosened by dessication cracks and later consolidated. The region was probably unstable and several fluctuations of sea level are indicated by the occurrence of several of these zones.

These intraformational conglomerates are significant as it was observed that many of the bioherms grew on them. A firm foundation was provided by the conglomerates for the growth of algal colonies.

The deposition of muds and calcium carbonates seems to indicate an alternation in the availability of clastic material. This alternation is noted also in beds that are lateral equivalents of the bioherm zones. Some of these equivalent beds are composed of limestone and others are composed of shale. It was noted that the zone of larger bioherms was associated with equivalent beds of limestone, which seems to suggest that conditions favoring calcium carbonate deposition were also more favorable for algal growth. These conditions are quiet, warm, clear, shallow seas and the absence of clastic material.

Topography. The topography of the Point Peak shale consists of steep, talus-littered slopes between the more resistant Morgan Creek and San Saba members, and wide, shallow, predominantly soil-covered valleys. The outcrops of this member are usually weathered to a rocky soil that contains numerous small, thin, shale and siltstone fragments. The shale and siltstone outcrops are characterized by a heavy, evenly-spaced growth of shrub type vegetation that is distinctive on the aerial photographs.

The bioherm zone usually caps the steep slopes. The bioherms are very hard and dense and contrast sharply with the lithology and appearance of the shale and siltstone. This zone usually has a much thicker growth of vegetation that appears as a distinct band on aerial photographs.

Stratigraphic Relation: The contact between the Point Peak shale and the San Saba limestone is variable. In most places the contact is gradational between the underlying thin-bedded shales and siltstones and the overlying thick-bedded limestones, and the contact is placed at the base of the first thick-bedded limestone. At those places where the upper bioherm zone is present, the contact is placed at the base of the first thick-bedded limestone above the bioherms.

San Saba Limestone Member

Definition and Thickness: Comstock (1890, p. 301) originally used the name San Saba as a series term. This was later revised by Bridge (1937, p. 237), who reduced the San Saba to member status. The San Saba limestone is now the uppermost member of the Wilberns formation. It includes "the entire series of more or less glauconitic limestone overlying the Point Peak shale member of the Wilberns formation and underlying the Threadgill member of the Tanyard formation", according to Bridge, Barnes and Cloud (1947, p. 117).

The San Saba limestone is 280 feet thick at the type section that is located near the crossing of the San Saba River and the Mason-Brady highway. Barnes and Bell (1954, p. 35) stated that the average thickness of this member is 270 feet. In the thesis area outcrops of the San Saba limestone were quite numerous but were so extensively faulted that the thickness of the member could not be measured.

Lithology: The San Saba limestone is poorly exposed in the area except along the stream bed of the west branch of Panther Creek. Here good exposures occur in the upper and lower parts of the member but some of the middle section is faulted out.

The lower beds of the San Saba member are composed of gray and light-brown, medium- and thick-bedded, glauconitic limestone. The limestone surface weathers brown with numerous large, rusty splotches.

The middle beds of the San Saba, with one exception, are essentially like the lower ones. This exception is the occurrence of beds of brown, fine-grained, glauconitic, calcareous sandstone in the stratigraphic section along the western part of the area. These sandy beds are not present in the eastern part of the area, probably because they have been faulted out. According to Cloud and Barnes (1948, p. 156) there are four of these sandy zones in the Bear Springs Area, where the upper sand zone is useful in finding the San Saba limestone-Ellenburger limestone contact, which is approximately 30 feet above the sandstone.

The upper beds of the San Saba member are essentially gray, sublithographic, sparingly-glauconitic limestones. Glauconite becomes extremely rare near the upper contact with the Ellenburger limestone, this is one of the criteria for locating this contact, which is the boundary between the Cambrian and Ordovician Systems.

The San Saba limestone is fossiliferous, especially in the lower part where small pea-sized bodies of algal origin called Girvanella are found near the Point Peak shale-San Saba limestone contact. According to

Bridge, Barnes and Cloud (1947, p. 120) *Girvanella* occur in the Cap Mountain, Point Peak, and San Saba members. In the local area these algal bodies were found only in the lower part of the San Saba. Several zones of small, distinctive gastropods were also found in the San Saba beds.

The lithology of the San Saba member is predominantly limestone with lesser amounts of shale, siltstone, and sandstone. The lower and middle parts of the San Saba contain quantities of fine-grained clastics interbedded with the limestones, but the upper part consists of granular limestone and very little shale or siltstone. The uppermost beds are composed of sublithographic limestone. The conditions of deposition indicate that the clastic source area was depleted or choked off during deposition of the upper part of the member. The calcilutites in the uppermost part of the San Saba were probably formed from lime muds that were deposited in broad, shallow, protected areas.

Topography: The San Saba limestone member usually caps the steep Point Peak slopes and forms a broad gently rising slope to the overlying Cretaceous beds. These San Saba beds have very poor outcrops because of the thin rocky soil that has developed on them. This is especially true near the contact with the Cretaceous sandstone and siltstone unit where sandy soil has covered much of the San Saba beds. Vegetation on the San Saba limestone is generally rather sparse and is composed principally of clumps and patches of scrub oak that are distinctive on the aerial photographs. The San Saba cuestas have bands of vegetation that conform to the outcrop pattern on the hillsides as the scrub oaks grow on the less resistant beds.

Stratigraphic Relation: Where the bioherm zone is absent the contact at the base of the San Saba limestone is gradational. The contact is placed just above the bioherms if they are present. In the normal stratigraphic sequence, the San Saba limestone of Late Cambrian age is in contact with the overlying Ellenburger limestone of Early Ordovician age. However, in most of this area, beds of the lower Cretaceous units have covered the truncated Ellenburger limestone and are in contact with the San Saba limestone. In the few places where it was found, the boundary between the San Saba limestone and the Ellenburger limestone was placed just below the occurrence of the uncoiled gastropod, Lytospira gyrocera. Generally, the contrast between light colored (Ellenburger) and dark colored (San Saba) growths of vegetation can be seen on the aerial photographs.

The contact of the San Saba limestone with the Cretaceous sandstone and siltstone unit is an angular unconformity. This is of little value in the field as the lower Cretaceous beds are unconsolidated and have no apparent bedding, and the contact was placed at the very last appearance of recognizable San Saba outcrops. There is a definite lithologic difference between these units, but a loose sandy soil has covered the contact between them. Often this contact will be fairly conspicuous on aerial photographs, as the grass and mesquite growth on the Cretaceous soils will show as lighter colored areas.

Plate III

LITHOLOGIC SIMILARITY BETWEEN BEDS THAT OCCUR JUST ABOVE AND BELOW THE CAMBRIAN-ORDOVICIAN BOUNDARY

Figure 1

Limestone beds of the Ellenburger group (Ordovician System).

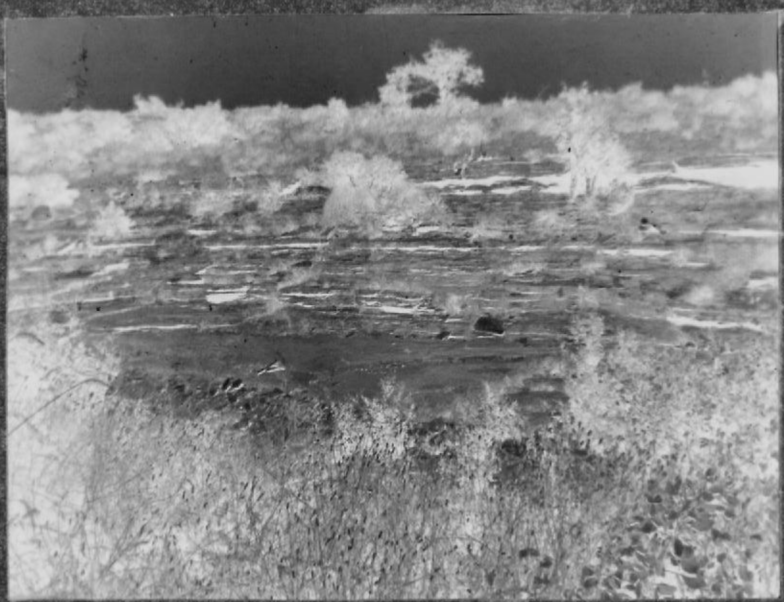


Figure 2

Limestone beds of the San Saba member (Cambrian System).

ORDOVICIAN SYSTEM

The Ordovician System is represented in the Llano uplift, and the Upper Schep Creek area, by rocks of the Ellenburger group that are Early Ordovician in age. The Ellenburger outcrops are small in areal extent and are widely separated in the area; no effort was made to identify the individual formations.

Ellenburger Group

Definition and Thickness: The Ellenburger formation was first named by Paige (1911, p. 24) for the Ellenburger hills in the northwest corner of the Llano-Burnet Quadrangle. The Ellenburger limestone was redefined by Cloud, Barnes, and Bridge (1945, p. 133), who raised it to group status, subdivided it into three formations -- the Tanyard, Gorman, and Honeycutt listed in ascending order --, and restricted it to rocks of the Ordovician System.

This group has a maximum thickness of 1820 feet in the southeastern corner of the Llano uplift, but it has been truncated westward and in Mason County has a thickness of only 970 feet according to Cloud, Barnes, and Bridge (1945, p. 140). Its thickness was not measured in the Upper Schep Creek area due to the very limited, almost insignificant, occurrence of the Ellenburger outcrops but it was estimated to be less than 25 feet thick.

Lithology: The Ellenburger beds exposed in the Upper Schep Creek area consist of pearl-gray, medium- and thin-bedded, fossiliferous, sublithographic limestone. The only variation in lithology was one small outcrop of pinkish-gray, thin-bedded, sublithographic limestone that occurred in the southwest part of the area. The dull, whitish-gray, weathered surface of these limestones is quite characteristic of the Ellenburger beds.

The lowermost beds of the Ellenburger group are extremely fine-grained and individual grains cannot be seen with the aid of a hand lens. These limestones are calcilutites, and their origin is probably similar to that of the lime muds that are found on the Bahama Banks today. They were probably derived by biochemical processes and were deposited in shallow protected areas.

Topography: The topography of the Ellenburger limestone is also quite distinctive. The prevalent topographic expression of this outcrop is its gently rolling hills that are littered with characteristic thin slabs of weathered limestone. These outcrops have less brushy and more grassy vegetation that shows as lighter colored areas on the aerial photographs.

Stratigraphic Relation: The lower contact with the San Saba limestone is placed below the occurrence of *Lytospira gyrocera* and above the last occurrence of glauconite, which is very scarce, in the upper part of the San Saba limestone.

Plate IV

VIEWS OF THE HILLS THAT OCCUR IN THE SOUTHERN AND EASTERN PARTS OF THE UPPER SHEEP CREEK AREA AND FORM PART OF THE RIM OF THE TOPOGRAPHIC BASIN

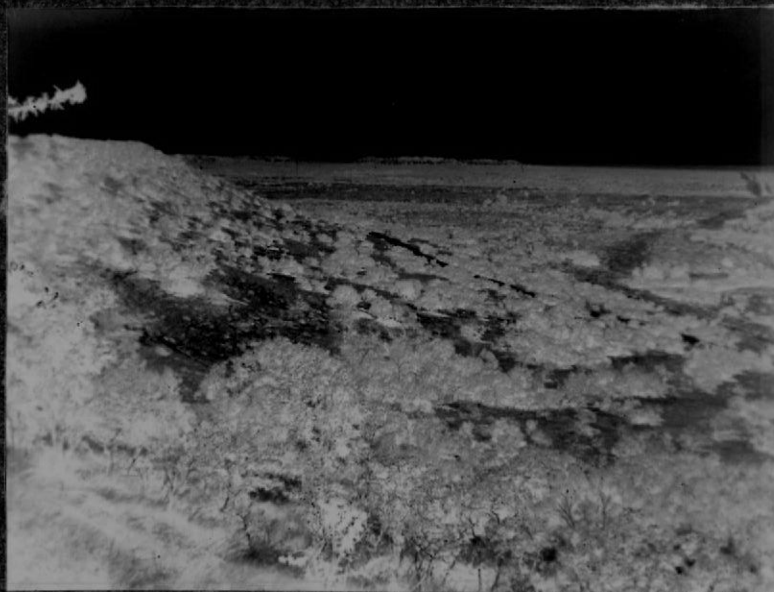


Figure 1

View from the hills on the eastern edge of the area looking to the southwest.

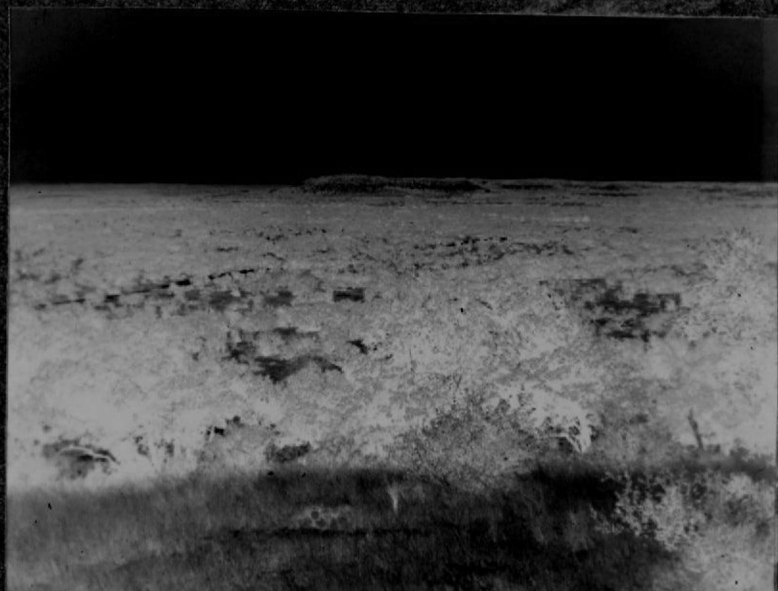


Figure 2

View of the hills on the eastern edge of the area.

CRETACEOUS SYSTEM

The Cretaceous rocks found in the Upper Schep Creek area are Early Cretaceous in age and belong to the Trinity and Fredericksburg groups of the Comanche series. These nearly horizontal beds lie in slight angular unconformity with the truncated Paleozoic rocks below.

Comanche Series

The Comanche Series was named by R. T. Hill (1887, p. 298), and included in ascending order, the Trinity, Fredericksburg, and Washita groups. The Trinity group was emended by Sellards (1932, p. 237), and the Fredericksburg group was revised by White (1931, p. 503) to exclude some of Hill's lower formations.

In ascending order, the Travis Peak and Glen Rose formations of the Trinity group and the Walnut, Comanche Peak, and Edwards formations of the Fredericksburg group are recognized by Cloud and Barnes (1948, p. 288) in the Lange's Mill area, which is approximately ten miles east of the Upper Schep Creek area. At Blue Mountain, which is approximately ten miles west of the area, Plummer (1950, pp. 101-116) also recognizes the Travis Peak, Glen Rose, Walnut, Comanche Peak, and Edwards formations. Using the above information and a comparative reconnaissance with the Cretaceous units in the Lange's Mill area, it seems probable that these same formations exist in the Upper Schep Creek area. However, no attempt is made to recognize formation boundaries, and the Cretaceous beds are mapped according to lithologic units. They are listed, in ascending order, as follows: (1) Lange's Mill (?) conglomerate, (2) sandstone and siltstone unit, (3) siltstone unit, and (4) limestone unit.

Lange's Mill (?) Conglomerate

Definition and Thickness: The Lange's Mill conglomerate is a term used by Cloud and Barnes (1948, p. 189) to describe the valley-fill conglomerate, composed of Upper Cambrian and Lower Ordovician rocks, that is found in the vicinity of Lange's Mill in southern Mason County.

This unit was deposited over an eroded land surface, and consequently the thickness of the outcrop is not constant. The maximum thickness of the conglomerate in the Lange's Mill area is approximately 45 feet, but in the Upper Schep Creek area the maximum thickness is only 20 to 25 feet.

Lithology: The outcrop pattern of the conglomerate in the Upper Schep Creek area suggests that it is also a valley-fill type of deposit. The Early Cretaceous topographic low of this area must have been in the vicinity of the west branch of Panther Creek, where the conglomerate is found to overlie beds of the San Saba and Ellenburger limestones. This conglomerate is composed chiefly of gray and brown glauconitic limestones, brown and red quartzites, chert, hematite nodules, and milky quartz pebbles. The unit consists of pebbles and cobbles that range in size from 1 to 4 inches in diameter, with the larger rocks occurring at the base. The interstices between the pebbles and cobbles contain an abundance of small angular and sub-angular rock particles whose composition is the same as the cobbles. The upper part of the conglomerate is more indurated than the lower part and seems to have a combined calcareous and ferruginous cement. The pebbles and cobbles of the conglomerate are derived from the underlying Paleozoic and Precambrian rocks.

The lithology and appearance of the basal Cretaceous conglomerate in the Upper Schep Creek area are almost identical to those of the Lange's Mill conglomerate of Cloud and Barnes (1946, p. 189). The latter conglomerate, because of the nature of its occurrence, cannot be traced laterally to the thesis area. However, the writer does think that these conglomerates are probably the same stratigraphic unit.

Topography: The Lange's Mill (?) conglomerate is small in outcrop area and actually has no distinctive topographic form.

Stratigraphic Relation: This unit has a sharp contact with both the underlying Paleozoic rocks and the overlying Cretaceous sandstone and siltstone unit.

Sandstone and Siltstone Unit

Definition and Thickness: The sandstone and siltstone unit is defined to include all beds that overlie the basal conglomerate and that underlie the more consolidated siltstone unit that generally forms the steeper slopes of the hills. This unit was also deposited on an uneven surface and, consequently, varies in thickness from approximately 80 to 120 feet.

Lithology: The lower part of the sandstone and siltstone unit consists of colorless to light-red, coarse-grained, cross-bedded, quartz sand and coarse quartz pebbles and grades vertically to red, fine-grained, loosely consolidated quartz sandstone. The middle part of this unit consists of alternating beds of red sandstone and gray siltstone that weather to a black soil. This part of the unit is very poorly exposed. The upper part of this unit changes from red sandstone to gray-and-yellow fine-grained siltstone and poorly-sorted calcareous quartz-sandstone.

Topography: This unit forms a wide bench that slopes gently up to the base of the hills. It sometimes forms the lower slopes of these hills. This unit can be seen on aerial photographs as lighter-colored areas that are due to the evenly spaced, sparse growth of mesquite and heavy growth of grasses.

Stratigraphic Relation: The lower contact with the Lange's Mill (?) conglomerate is a fairly sharp contact. However, the upper contact is gradational with the overlying siltstone unit and is chosen at the last occurrence of sand-size particles. This sand-silt contact was determined in the field and would not necessarily meet laboratory criteria for sand and silt sizes.

In the southeast corner of the area, one of the Tertiary or Quaternary conglomerates was deposited on the eroded sandstone and siltstone unit. Here there is a definite contact between the sandstone and siltstone unit and the overlying conglomerate.

Siltstone Unit

Definition and Thickness: The siltstone unit is defined as those beds overlying the sandstone and siltstone unit and underlying the hill-capping limestone unit. The siltstone unit is the first Cretaceous unit that was deposited on a relatively uniform surface in this area. This unit is approximately 50 feet thick.

Lithology: This unit is fairly uniform in its character. It predominantly consists of massive and thick-bedded, light-yellow to-buff, generally porous siltstones. Near the base of the unit a yellow, vertically-jointed, sandy-clay occurs. A zone of gastropods similar to *Turritella* occurs near the center of the unit.

Topography: The siltstone unit is more resistant than the underlying sandstone and siltstone unit. Therefore it forms the steep slopes of the hills. A heavy growth of scrub oak is characteristic of the siltstone unit. This vegetation grows on outcrops of the less resistant beds and appears as distinct bands on the aerial photographs.

Stratigraphic Relation: The lower and upper contacts of this unit are both gradational. The upper contact was placed at the first occurrence of the thick-bedded limestones that form the distinctive ledges that cap the hills.

Limestone Unit

Definition and Thickness: The limestone unit consists of those limestone beds that overlie the siltstone unit. These beds cap the hills and form a plateau on the south of the area. Their thickness varies from 15 to 35 feet because of erosion of their upper surface.

Lithology: The limestone unit consists predominantly of thick-bedded limestone with alternating thin-bedded calcareous siltstones. The limestone is whitish-gray in color and is sublithographic to finely crystalline in texture. It contains an abundance of odd-shaped, dark-gray flint or chert nodules.

Topography: The limestone unit forms the resistant ledges and flat tops of the hills and has very little vegetation except grasses. This appears on the aerial photographs in sharp contrast to the dense vegetation of the underlying siltstone unit.

Stratigraphic Relation: The lower contact of this unit with the siltstone unit is gradational and has been discussed previously. The limestone unit is the topographic high of the area and has no upper contact.

CENOZOIC SYSTEMS

Tertiary or Quaternary Conglomerates

Three small deposits of loosely consolidated caliche conglomerate occur in the area. Two of these deposits, in the west and northwest part of the area, are almost identical in character and are considered to belong to the same stratigraphic unit. They consist of cobbles and small boulders of San Saba limestone that have been partially, and in some cases completely, replaced by the caliche cementing material.

The map symbol for this unit is T-Qsc. This unit occurs on slopes of the San Saba limestone. It was deposited as terraces adjacent to present-day stream valleys, and therefore must have been deposited after the beginning of the present erosion cycle.

The other conglomerate, whose map symbol is T-Qkc, was deposited closely parallel to the west branch of Panther Creek in the southeast corner of the thesis area. It occurs as a terrace deposit along the stream and consists of loosely cemented pebbles, cobbles, and small boulders of limestone and odd-shaped pieces of chert. It can readily be seen that the limestone and chert was derived from the Cretaceous limestone unit and was deposited on a post-Cretaceous erosion surface.

There is little similarity between these two types of conglomerates because of their different lithology, and they also differ from the lithology of the Lange's Mill (?) conglomerate. Therefore the appearance of these conglomerates is different and they can easily be differentiated in the field.

Recent Sediments

Recent sediments occur along some of the stream valleys of the Upper Schep Creek area. In general, these deposits are uncommon and those that occur have a maximum thickness of less than 5 feet.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The structural features of the Upper Schep Creek area are relatively simple and they consist of a series of northeast-southwest trending normal faults of small stratigraphic throw that affect only the Paleozoic rocks. However it must be brought out that these local structural features are a component of the regional structure and that they reflect the structural trends of the Llano uplift.

REGIONAL STRUCTURE

The Llano uplift is a structural dome whose core consists of Precambrian and Paleozoic rocks. However this area is a topographic basin that is almost completely rimmed by nearly horizontal beds of Cretaceous age. According to Cheney and Goss (1952, p. 2237) the Llano uplift is approximately 10,000 feet structurally higher than the flanking Fort Worth and Kerr basins to the northeast and southwest, respectively.

The Llano region has undergone two major periods of deformation. The first of these deformations involved only the Precambrian rocks. According to Sellards (1932, p. 34), Precambrian sediments were intruded, metamorphosed, and folded into broad northwest-southeast trending folds that plunge to the southeast. This period of intense regional compression was followed by uplift and erosion that occurred prior to Late Cambrian deposition.

The second major deformation, that occurred during Pennsylvanian time, was responsible for the uplift of the Llano region. Strata of Precambrian and Paleozoic age now occur from 5000 to 10000 feet above their occurrence in nearby sedimentary basins. This structural uplift is traversed by predominantly northeast-southwest trending normal faults, a majority of which are downthrown to the northwest.

LOCAL STRUCTURE

General Statement

The major structural features of the Upper Schep Creek area consist of a great number of normal faults of small stratigraphic throw which form a series of horsts, grabens, and step faults.

Faulting

The faults of the Upper Schep Creek area are normal faults that have a general northeast-southwest trend and seem to have predominantly steep dips. This is in agreement with the regional trend of faults, as they also have a general northeast-southwest strike.

The best single criterion for detecting faults in this area was a close examination of the aerial photographs, on which the majority of the faults appear as distinct vegetational lineations. Of course this method must be combined with field examination, using anomalous dips and strikes, omission or repetition of key beds, abrupt termination of beds, and brecciated zones as the chief criteria for establishing the presence of faults.

Plate V

FAULTS EXPOSED ALONG THE WEST BRANCH OF PANTHER CREEK

Figure 1

Key beds show four small faults downthrown to the right (northwest).

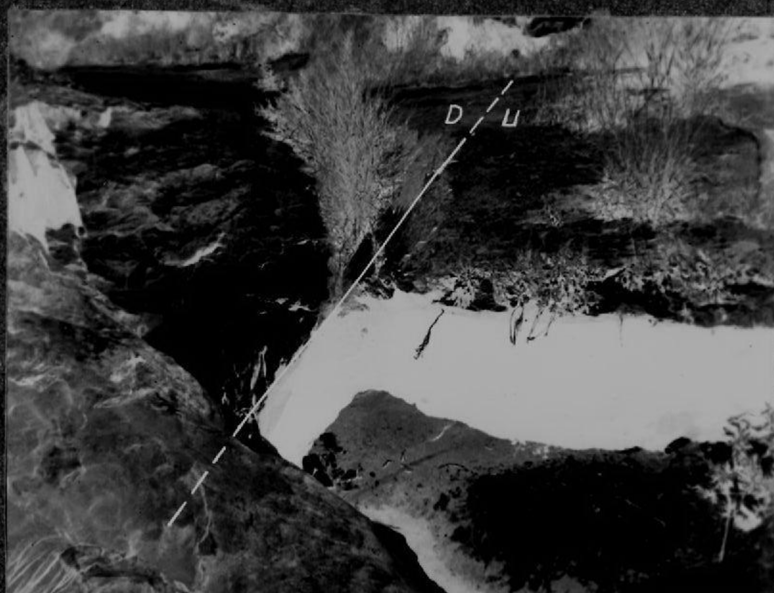


Figure 2

Small fault between the Morgan Creek member (downthrown) and the Welge member (upthrown).

Although the individual faults in this area are not particularly large, it is the faulting that actually controls the geologic structure of the Upper Schep Creek area. Most of these faults have a stratigraphic throw of less than 100 feet. As a result, the outcrops of the Paleozoic beds are offset only for short distances, and the hilly topography, in general, actually has greater control of outcrop patterns than has the faulting. However it is the number of faults rather than their size that complicates the geologic structure of this area. This is illustrated by pl. V, fig. 1. In this photograph, basal Morgan Creek beds are cut by four small normal faults within approximately 50 yards. Displacement of the key bed indicates that all these faults are downthrown to the northwest and the total displacement is about 15 feet.

Another example of this type of faulting is illustrated by Plate VI, from near the same locality along the west branch of Panther Creek. Here the normal Welge sandstone-Morgan Creek limestone contact is at the top of this photograph (pl. VI). Upstream, or down dip, the Welge member is again encountered at four separate outcrops. An analysis of this situation reveals that the Welge member has been "faulted up", that is, a series of normal faults, downthrown to the northwest, has caused this repetition of strata. Using the average dip of beds and the map distance between outcrops, it was estimated by trigonometric computation that the six faults have approximately 100 feet of vertical displacement, which averages about 15 feet per fault.

Plate VI

TYPICAL FAULT PATTERN OF THE
UPPER SCHEP CREEK AREA

Aerial photograph showing repetition of the Welge outcrops due to faulting. (Welge outcrops are marked with light lines and the faults are marked with heavy lines.)

The foregoing examples were given as representative of the type of faulting that was encountered in the entire Upper Schep Creek area. With the exception of one small complicated area that will be discussed separately, the structural relations of the faults of this area are very simple and they have two effects. The first effect is merely to offset the contacts between the various formational members. This can readily be seen by tracing these contacts on the geologic map of the Upper Schep Creek area. The second effect is to widen the outcrops by a repetition of the beds. This is particularly apparent in the San Saba member where a series of faults causes the outcrop to be much too wide in proportion to its thickness. This repetition is caused by the majority of the faults being downthrown to the northwest whereas the dip of the beds is toward the southeast.

The exception to the relatively simple geologic structure of the Upper Schep Creek area is found in one small section that is located in the north-central portion. Here the geologic map shows complexly faulted blocks of Lion Mountain sandstone, Welge sandstone, Morgan Creek limestone, and Point Peak shale. This faulted area is located in the near vicinity of the junction of the Northwest and Southeast H G N faults. These two closely parallel faults trend northeast-southwest, are downthrown to the northwest, have a combined throw of over 250 feet, and are probably the largest faults in the Upper Schep Creek area. These two faults join and apparently die out to the northeast within a very short distance. A structurally complicated series of small wedged-shaped fault blocks occur right at the junction of the major faults. Just beyond these fault blocks, a series of at least three parallel faults continues in the same northeast-southwest trend of the parent major faults. Apparently this complexly faulted zone results from the dying out of the major faults.

The Northwest and Southeast H & N faults were named by this writer for a land survey where they are located.

Age of Faulting

The age of faulting cannot be determined accurately from the field evidence found in the Upper Schep Creek area. The youngest beds that are cut by faults are the limestones of the Ellenburger group, and the oldest beds not affected by faulting are the basal conglomerate of Cretaceous age. This evidence indicates that the age of faulting is post-early Ordovician and pre-Cretaceous. This long interval of time is in agreement with Cloud and Barnes (1948, p. 121), who date the regional faulting as Strawn or post-Strawn and pre-Canyon of Pennsylvanian age.

Cause of Faulting

Cloud and Barnes (1948, p. 118), using regional paleogeographic data as a basis, stated that the Llanoria geosyncline formed around the southern and eastern sides of the resistant mass of the Llano uplift.

These authors believed that the late Paleozoic folding of the sediments in this geosyncline is probably responsible for the faulting in the Llano uplift.

In the previous discussion on regional structure, it was assumed that the time of faulting probably closely followed the end of the period of uplift. This seems to suggest a common tectonic origin. Thus if the uplift is related to orogenic activity in the geosyncline, then the normal faulting of this relatively stable mass is probably related to it also.

The forces that caused faulting, and even the mechanisms that caused the forces, are not simple and are not well understood. This is apparent when the local structural features are closely examined.

Two apparent anomalies are noticed. The first of these is that the regional dip of the beds in the Upper Cherry Creek area is to the southeast even though the area is situated on the southwest flank of the structural uplift. One possible explanation is that a broad southwest-trending fold in the basement rocks would provide a southeast dipping flank. However, it is doubtful if this could be proven without subsurface data. Another possible explanation is that the dip of the beds, roughly perpendicular to the faults that are predominantly downthrown to the northwest, could possibly be caused by tilting of the fault blocks to the southeast.

The second apparent anomaly is that the majority of faults in the Upper Schep Creek area, as well as those on the northwest and southwest flanks of the Llano uplift, are downthrown to the northwest. This effect could occur if the faulting were independent of the uplift, but the evidence seems to indicate that faulting and uplift are not independent of each other.

A factor that should not be overlooked is the relation of these faults to pre-existing structural weaknesses that occurred as a result of the Precambrian deformation. Very little is known about faulting that accompanied the original deformation but it is known that there was a general northwest-southeast trend of the folds. According to structural analyses presented by Dr. W. L. Russell (1959, personal communication), the fault trends or structural weaknesses should occur parallel to the fold trends. From this it could be postulated that Precambrian fault trends were approximately northwest-southeast or north-south. This analysis leads us to believe that the existing fault trends do not follow the hypothetical Precambrian trends. However, it is possible that there were other structural weaknesses in the Precambrian rocks that did cause the later fault trends to be northeast-southwest. Even though very little is known about the Precambrian trends, it can be stated that any previous structural weaknesses must have had some effect on the resulting, or present, structures. So again it is emphasized that the faulting of this region is complex and not well understood.

Folding

The geologic data for determining large scale folding were absent in the Upper Schep Creek area. In the previous paragraph it is postulated that a very broad, gentle fold could occur in the basement rocks, but there is little evidence to support this. Although Grote (1954, pp. 25-27) found evidence of a small southwest-plunging fold in the Central Bluff Creek area south of Streeter, Texas, there do not seem to be any similar structures in the Upper Schep Creek area.

The only folding that was found in the Upper Schep Creek area was folding of a minor nature that was associated with differential compaction of the shale and limestone beds over the stromatolitic bioherms of the Point Peak shale.

SUMMARY OF GEOLOGIC HISTORY

GENERAL STATEMENT

The Upper Schep Creek area is an integral part of the Llano uplift, and a general discussion of the regional geologic history will also summarize the major events of local geologic history. It would be very unlikely that conditions would be the same in all parts of the Llano uplift area throughout geologic time. Therefore, geological evidence that seems to indicate variations in the local geologic history will be discussed and compared with the regional history.

REGIONAL GEOLOGIC HISTORY

The Precambrian history of this region was probably very long and varied. Intense deformation and alteration of the Precambrian rocks has obliterated and obscured most of the criteria that are used to determine geological environments.

According to Sellards (1932, p. 35), a great series of shales, sandstones and limestones was intruded, metamorphosed, and folded into broad northwest-southeast trending folds. Intrusive bodies that do not cut the Upper Cambrian rocks and their weathered fragments that are incorporated in these same rocks, are cited as evidence that these intrusives are Precambrian in age. Coarsely crystalline granites and metamorphosed sedimentary rocks indicate that these rocks were formed at great depths, but extensive erosion removed great thicknesses of rocks and exposed them at the surface prior to Early Paleozoic times.

The lack of Lower or Middle Cambrian rocks in the Llano region is caused either by nondeposition or by deposition and subsequent complete removal of sediments. Bridge, Barnes, and Cloud (1947, p. 113) stated that there may have been as much as 800 feet of relief on the Precambrian surface prior to the transgression of the Upper Cambrian sea. This probably indicates a long period of nondeposition and erosion.

The transgression of the Upper Cambrian sea caused the deposition of the Hickory sandstone on the Precambrian surface. Barnes and Parkinson (1939, p. 668) stated that in some localities the basal part of the Hickory consists of deposits of wind-blown sands. They also stated that wind-faceted quartz pebbles are commonly found in the lower part of the Hickory sandstone member. Later Barnes (1956, p. 8) stated that this indurated basal Hickory sandstone is of a different environment and may not be Late Cambrian in age. This environment may be contrasted with the shallow water environment that is common to the remainder of the Hickory sandstone as evidenced by ripple marks, cross-bedding, and marine fossils.

Near the end of Hickory deposition, decrease in sand grain-size and increase in carbonate content indicate changes in deposition of sand size particles which were possibly caused by movement of the strand line, or perhaps to changes in currents. The Hickory sandstone grades vertically into the Cap Mountain limestone through a sequence that includes calcareous sandstones and arenaceous limestones as intermediate rock types. The limestones of the Cap Mountain member contain varying amounts of glauconite and beds of fossil trilobites. This sequence was deposited in a relatively cool, shallow water environment, according to Cloud and Barnes (1948, p. 112).

These authors also stated that late Riley and early Wilberns deposition reflected a regressive-transgressive movement of the sea that was due to slight changes in land-sea relationship. Deposition of the Lion Mountain sandstone does indicate a renewed deposition of clastic quartz sands.

The overlying Welge sandstone is a massive, non-glauconitic, fairly uniform blanket-sand deposit. The absence of cross-bedding and ripple marks seems to indicate deposition under very uniform and quiet conditions. The absence of glauconite contrasts markedly with the underlying extremely glauconitic Lion Mountain sandstone. Perhaps this could be due to the occurrence of oxidizing conditions as Cloud (1955, p. 485) stated that glauconite never forms in waters of high oxygen content.

A decrease in quartz sand and the occurrence of granular, glauconitic limestones indicates further transgression of the sea, or a relative lowering of the clastic material source area during Morgan Creek time. Cloud and Barnes (1948, p. 112) stated that this deposition suggests a shallow water and rather cool environment, that would be similar to the environment of later Riley time.

These authors also stated that large quantities of argillaceous material, derived from a westward source, were deposited to form the

Point Peak shale member. This stratigraphic unit contains numerous thin, almost fissile, shaly or silty limestone beds. These beds indicate that deposition of calcium carbonate was still going on during clastic deposition. This influx of clastic material and the appearance of widespread bioherm zones could possibly indicate an uplift with regression or shallowing of the sea. Paige (1912, p. 79) stated that the presence of intraformational conglomerate and mud cracks suggests widespread tidal flats.

The source of clastic material was exhausted and again limestone deposition occurred through San Saba time until the end of the Cambrian Period. Local sand zones occur in the middle of the San Saba limestone beds. This indicates changes in deposition due to shifting currents, or to intermittently available clastic materials.

Deposition was continuous during Late Cambrian and Early Ordovician time in the western part of the Llano uplift, and the Upper San Saba sublithographic limestones are almost identical to Ellenburger limestones of the same type (pl. III, figs. 1 and 2). Cloud and Barnes (1948, p. 112) stated that the typical Cambrian arthropodan fauna was replaced with a dominant Ordovician molluscan fauna. These authors stated that a warm, shallow water environment persisted through Ellenburger time and that the region was probably similar to the Bahama Banks of today and that much of the newly deposited calcareous material was transported short distances prior to consolidation.

The absence of Middle and Upper Ordovician and Silurian rocks in this region indicates a period of non-deposition and erosion, or deposition and complete removal of these rocks by erosion.

Scattered remnants of Devonian rocks have been recognized by Barnes, Cloud, and Warren (1945, p. 163). These rocks occur in collapse structures in the Ellenburger limestones, which seems to indicate that Devonian deposition was probably minor and that pre-Mississippian erosion has almost entirely removed them. Cloud and Barnes (1948, p. 113) stated that maximum truncation of the Ellenburger rocks in the western part of the Llano region and the occurrence of younger Devonian rocks there indicate a pre-Devonian tilting of the region followed by the transgression of the Devonian sea from east to west.

Following the Devonian deposition and erosion, transgressing seas deposited sediments that compose the Chappel and Barnett formations that are Mississippian in age. The Barnett shale thins as it approaches the Llano uplift which suggests that the first movements of uplift occurred during Late Mississippian time. Cloud and Barnes (1948, p. 111) stated that widespread truncation and locally complete removal of the Barnett shale was accomplished in pre-Pennsylvanian time.

Transgression of the Lower Pennsylvanian seas over the region resulted in deposition of sediments of Bend age. The major uplift of the region occurred during Middle Pennsylvanian time as Cloud and Barnes (1948, p. 116) stated that Pennsylvanian deformation probably occurred simultaneously with deformation in the Llanorian geosyncline. These authors also stated that unfaulted beds of Canyon age overlie faulted beds of Ellenburger age. This indicates that regional faulting occurred prior to Canyon time.

Following the major uplift during Pennsylvanian time, the Llano region must have remained above sea level until the Early Cretaceous, as there are no Permian, Triassic, or Jurassic rocks present in the region.

The final transgression of the sea occurred during Early Cretaceous time when a series of conglomerates, sandstones, clays, siltstones, and limestones were deposited on the truncated Precambrian and Paleozoic rocks. Subsequent uplift and erosion has removed the Cretaceous beds from the crest of the uplift, and a topographic basin has been formed. During this last erosion cycle caliche conglomerates of Tertiary or Quaternary age were formed, and they occur as terrace deposits along stream valleys.

LOCAL GEOLOGIC DEPOSITIONAL HISTORY

Introduction

The depositional units that are found in the local area will be discussed in the following paragraphs. The principal emphasis is given to the depositional history of the Paleozoic rocks with minor consideration given to the Mesozoic rocks of the area.

Paleozoic Era

In the local area the oldest rocks exposed are the limestones of the Cap Mountain member of the Riley formation. These beds are underlain by the Hickory sandstone member that was the basal deposit of the transgressing Late Cambrian sea. The absence of a shale unit, that overlies the basal sand in the ideal case, must be due to the absence of fine clastic material. Perhaps the finer material had already been transported away leaving only the sandy material as mantle on the land area. Deposition of the Cap Mountain limestones indicates that relatively clear shallow seas probably existed at this time.

The Lion Mountain sandstone consists of extremely glauconitic quartz sands and lenses and beds of fossiliferous limestone. According to Cloud (1955, p. 484), the formation of glauconite requires marine waters of normal salinity, reducing conditions, and appropriate source materials. High organic content of bottom sediments, slow sedimentation, and water depths from 10 to 400 fathoms are also considered necessary for its formation. Cloud (1955, p. 190) further stated that the decomposition products of crystalline rocks were probably the most abundant source materials for forming glauconite. The above criteria list the most favorable conditions for the formation of glauconite. These are not the conditions that are expected for deposition of sands, so it is possible that the glauconite was not formed in place. However, if very long periods of quiet, reducing conditions were separated by short periods of storm-agitated conditions then it would be possible for the formation of glauconite and the deposition of sands to occur together. Local crustal movements probably account for renewed clastic deposition and for regressive movements of the sea. Uplift of this area would provide clastic materials for sand deposition and also silt and clay decomposition products of the crystalline rocks for glauconite formation.

Another peculiar depositional feature of the Lion Mountain member is the occurrence of lenses of limestone that are almost a trilobite coquina. The problem is to determine the most probable way that these "trilobite lenses" have been formed. Did the arthropods live in these waters with their remains accumulating over long periods of time, or were their remains brought in by currents and deposited? If these are simple accumulations, then how are the lens-shaped deposits explained? Information obtained from Dr. H. R. Blank (1958, personal communication) may be used to solve these problems. It has been noted that these "trilobite hash lenses" occur at slight angles with the horizontal in cross-bedded sandstones. Under these circumstances it seems that the extremely abundant remains of these arthropods, as well as other animal remains, were laid down with other detrital materials as cross-bedded deposits. The shape and inclined position of fore-set beds would suggest that the "hash" lenses originated in this manner.

According to Daugherty (1958, personal communication), who made a sedimentation study of these members, the upper 3-5 feet of the Lion Mountain beds contain very coarse sand and granule-sized quartz grains, whereas the lower part of the Welge sandstone contains less coarse fractions. Perhaps this marks the lowest occurrence of the strand line which resulted in stronger currents that could rework and deposit coarser sediments. In the local area there does not seem to be any appreciable erosion of the top of the Lion Mountain member. However, minor regression of the sea could have left this area near base level which would preclude extensive erosion. The above evidence is cited to substantiate the fact that an unconformity exists between these two members.

The well sorted sands of the Welge member occur as a thin blanket deposit over the entire region. The absence of cross-bedding, ripple marks, and glauconite seem to indicate deposition under very uniform, quiet, oxidizing conditions.

The Welge sandstones grade vertically into the Morgan Creek limestones. This seems to indicate further transgression of the sea or a wearing down of the low land area and decreased amounts of clastic material being deposited. The middle part of the Morgan Creek member contains relatively pure limestones, which indicate shallow sea deposition of calcium carbonate with little or no deposition of clastic materials. In the local area the upper part of the Morgan Creek member contains a 10 foot calcareous shale zone, shaly partings between limestone beds, and several small bioherm zones. Since these features are found just below the Point Peak member, it seems that these effects are probably caused by a shallowing of the sea and minor influx of clastic materials prior to the major influx of these materials in the Point Peak time.

A gradual influx of clastic materials and growth of the bioherm zones suggest slow changes in conditions of deposition and gradual spread of algal colonies.

Cloud and Barnes (1948, p. 112) stated that large quantities of argillaceous material were derived from a westward source and were deposited to form the Point Peak member. The shale beds of this member are separated by thin beds of shaly or silty limestones throughout. The occurrence of shale, limestone, and several bioherm zones in the Point Peak probably indicates a slow influx of argillaceous material with alternating deposition of muds and calcium carbonate at shallow depths. Intraformational conglomerates, mud cracks, and ripple marks are further proof of deposition at shallow depths or perhaps on tidal flats.

The occurrence of vertically thin and laterally intermittent bioherm zones at the top of the Point Peak member is in contrast with the thick, extensive zones that are found in the adjoining areas. This variation follows the observations of Barnes and Bell (1954, p. 53) who stated that the top of the bioherms is very irregular, and that their thickness is variable. On the northern flank of the Llano uplift the major bioherm zones occur within the San Saba limestone, and on the southern flank they occur within the Point Peak shale. According to Scaife (1957, p. 45) the development of the algae that formed these reefs is controlled by the zone of photosynthesis, which is determined by water depth and clarity. The occurrence of these organisms in zones of clastic and carbonate deposition seems to suggest that water depth must have the greater effect.

It was noted that the algal colonies grew on the intraformational conglomerates. This can be indirectly related to shallow water depths as the intraformational conglomerates were formed on tidal flats.

Cloud and Barnes (1948, p. 113) stated that soft bottom muds and muddy water conditions could possibly inhibit the development of bottom-dwelling fauna. The very nature of Point Peak deposition with its alternating muds and calcium carbonate sediments could explain the absence of firm bottom conditions. The absence of firm foundations could be used to explain the intermittent nature of algal growth in the local area.

Following the deposition of the clastic Point Peak shale, thick limestones of the San Saba member were deposited. The boundary between the Point Peak and San Saba is gradational, which seems to indicate that the clastic source area had been slowly worn down until no more clastic materials were available for deposition. Since there is a gradual decrease in clastic deposition and there is a tendency for the bioherms to die out, it is probable that the seas became relatively deeper and the source area was exhausted of its clastic sediments. As the seas became clearer again the deposition of calcium carbonate was predominant.

Small, pea-size bodies of algal origin, called Girvanella, occur in the lower beds of the San Saba member. In the local area the Girvanella are not very abundant, however, in the area of Scaife (1957, p. 50) this algal growth occurs in a 70 foot interval within the thick

(110 foot) bioherm zone. The *Girvanella* in the local area also occur near the bioherm zone. The absence of this algal growth in the middle and upper parts of the San Saba probably indicates that deeper waters occur that would inhibit algal growth. Whether or not this could be used as an indication of water depth would require further study within the Llano region.

The middle and upper parts of the San Saba consist of relatively pure limestones. Glauconite becomes scarce to absent in the very upper part of the San Saba and is also absent in the overlying Ellenburger limestones. Sublithographic, very pure limestones occur within this interval. The conditions of deposition seem to have changed and very clear shallow seas probably occurred. These conditions favor calcium carbonate deposition and restrict glauconite formation.

In the local area there must have been continuous deposition through Late Cambrian and Early Ordovician time. This is not true throughout the region as Cloud, Barnes, and Bridge (1945, p. 133) placed the Cambro-Ordovician boundary at an erosional and faunal break that occurs in the eastern part of the uplift. The lower beds of the Ellenburger limestones are the youngest known Paleozoic rocks within the local area.

It is not known whether there was additional Paleozoic deposition in this area prior to the uplift of the region that occurred in Middle Pennsylvanian. If there was, the deposits have been removed by subsequent erosion.

Mesozoic Era

Following the long period of uplift and erosion the Early Cretaceous sea encroached upon this region and a thick sequence of sediments was deposited. The Cretaceous deposits in the area represent the ideal case of a transgressing sea as they consist of a basal conglomerate, followed by sandstone, siltstone, and limestone units. These represent conditions of deposition where the source area supplies a range of coarse-to-fine clastic materials and as the supply of clastic materials is exhausted the waters clear and calcium carbonate is precipitated.

The basal, or Lange's Mill (?), conglomerate has been described as a valley-fill conglomerate by Barnes (1948, p. 189). This conglomerate is not limited to valley-fill type deposits in the Upper Schep Creek area. It is possible that the conglomerate is a continental deposit, but because of its lateral extent and because of its decrease in coarseness from bottom to top, it is felt that this unit is probably marine in nature.

The transgression of the Cretaceous seas was responsible for the last marine deposition in this area. Since that time the area has been above base level and erosion and very minor continental deposition has occurred.

ECONOMIC GEOLOGY

The Upper Schep Creek area consists predominantly of pasture land that can be used only for grazing purposes. The principal source of income for this area is derived from the raising of sheep, goats, and cattle. There are two small, abandoned fields that are located on the outcrop of the Cretaceous sand and silt unit. It is possible that further dry-land farming on this geologic unit would prove partially successful, but since the area is uninhabited, it is unlikely that this will occur.

Ground water is another resource of this area. The only water requirements of this area are for livestock; earthen tanks, windmills, and the intermittent streams furnish the required water. The Lion Mountain sandstone, the Welge sandstone, and the Cretaceous sands seem to be the principal aquifers. These units do not now furnish large quantities of water, since there is not a large demand. The Hickory sandstone would probably provide fairly large quantities of ground water, but this zone is too deep to be economically feasible.

Two caliche pits in the area have furnished the base material for the county road that traverses the area. However, these pits have no further economic application. The limestones of this area would be a good source of crushed rock, but again the distance to points of use would be an economic disadvantage.

This area has no prospects for other mineral development.

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A P P E N D I X

A composite section, composed of (1) part of the Morgan Creek limestone and the Welge sandstone, and (2) the Lion Mountain sandstone, was measured in the Upper Schep Creek area. The location of these sections is marked on the geologic map accompanying this report.

	Thickness in feet
Wilberns formation	
Morgan Creek limestone member	
10. Limestone, gray with orange spots, finely crystalline, glauconitic. The _Eoorthis texana_ zone occurs in this interval 2 feet below the top of the measured section or 54 feet above the base of the Morgan Creek limestone	6
9. Concealed, soil covered bench	4
8. Limestone, gray, thin bedded, glauconitic	3
7. Limestone, gray, alternating thin-and thick-bedded, glauconitic. Lenses of almost friable trilobite coquina occur throughout this section	10
6. Concealed, soil covered slope.	2
5. Limestone, blue-gray, finely crsytalline, glauconitic, contains lenses of cystoids	3
4. Limestone, light-purple, thick- to thin-bedded, finely crystalline, sandy, glauconitc	1
3. Limestone, light-gray, thick-bedded and dense, with light-red, thin-bedded arenaceous limestone	7

		Thickness in feet
2.	Limestone, light-purple, thick-bedded, crystal-line, glauconitic, slightly arenaceous	5
1.	Limestone, maroon, massive, sandy, glauconitic that grades to maroon, massive, calcareous sand-stone.	5
	Subtotal	56
	Welge sandstone member	
2.	Sandstone, yellow-brown, massive, fine-to medium-grained, sub-rounded to rounded, non-calcareous and non-glauconitic	14
1.	Sandstone, yellow-brown, massive, medium-to coarse-grained, sub-rounded to rounded, slightly glauconitic.	1
	Subtotal	15

The section consisting of the Lion Mountain member was measured in the bed of the west branch of Panther Creek on the Ernest Geistweidt property.

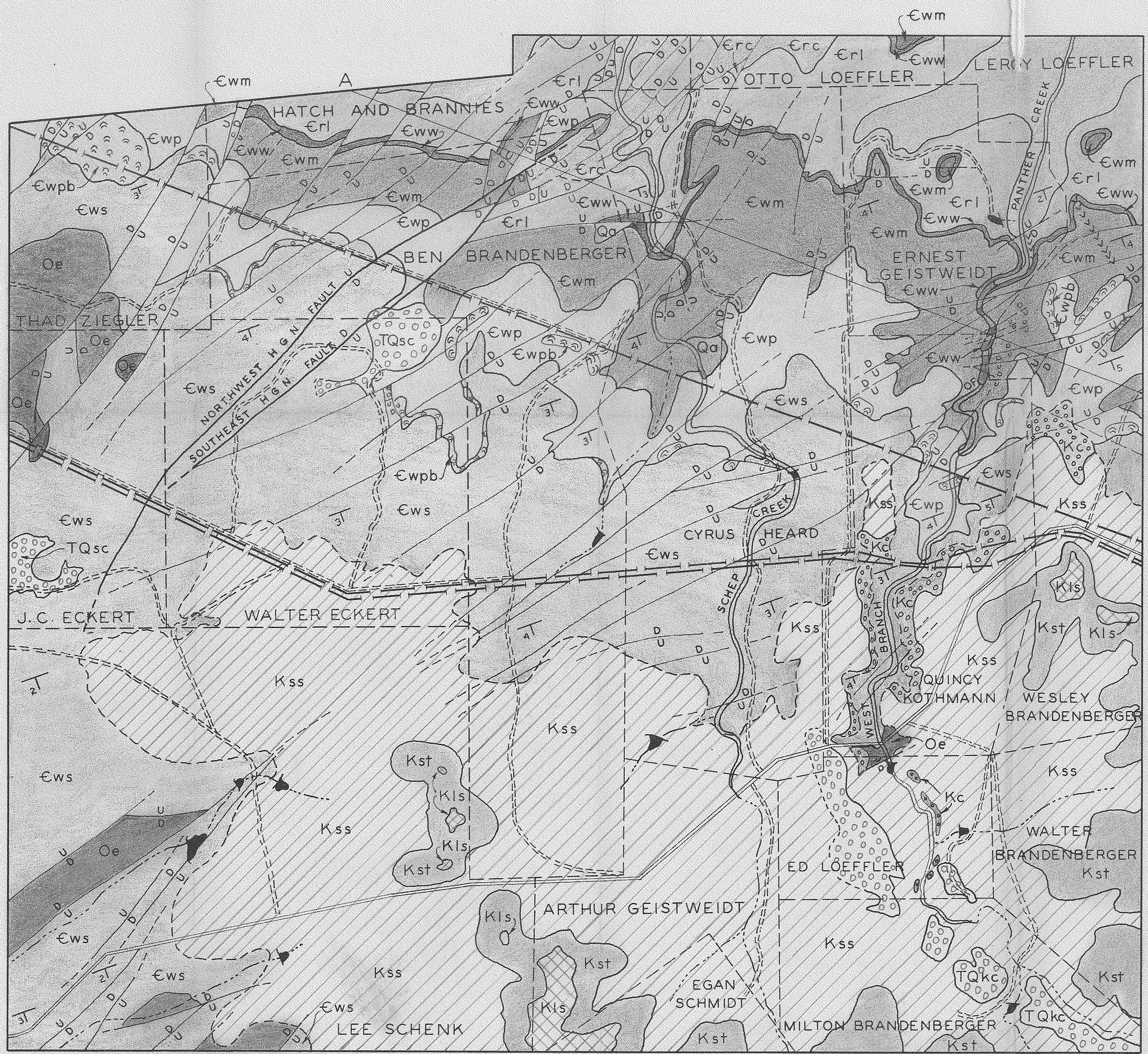
Riley formation

Lion Mountain sandstone member

15.	Siltstone, red-brown, thin-bedded, fissile, contains abundant large, angular quartz grains	2
14.	Sandstone, dark-green, thin-bedded, friable, abundantly glauconitic, non-calcareous	2

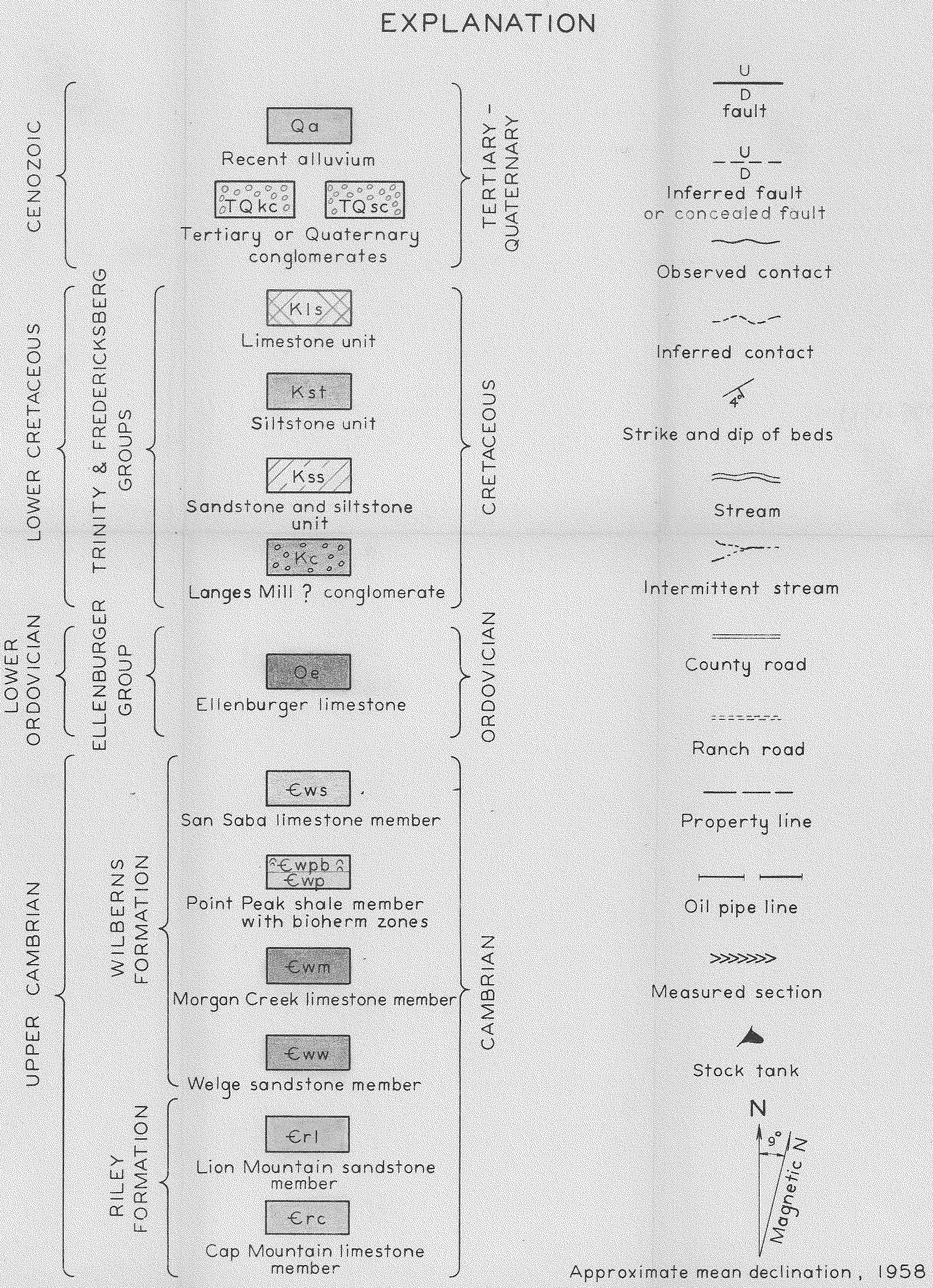
	Thickness in feet
13. Sandstone, green-gray, fine- to coarse-grained, rounded to sub-rounded quartz grains, glauconitic. Lenses of "trilobite hash" occur throughout this interval.	8
12. Limestone, white-gray, thin-bedded, arenaceous, glauconitic. Grades laterally into facies of whitish-green, massive, glauconitic sandstone	4.5
11. Sandstone, olive-tan, thin-bedded, fine-grained, glauconitic	2.5
10. Limestone, white-gray, dense, glauconitic	1.0
9. Sandstone, dark-brown, thin-bedded, glauconitic	9.5
8. Limestone, brown with small orange spots, calcite veined, finely crystalline, glauconitic	1.0
7. Sandstone, light-brown, massive, very fine-grained, glauconitic.	7.0
6. Limestone, slightly glauconitic, light brown, massive, arenaceous	2.5
5. Sandstone, dark-gray, fine-grained, occasional concentrations of calcite crystals, glauconitic, calcareous.	8
4. Limestone, light-tan, massive and dense with scattered oolitic type structure, slightly arenaceous and glauconitic	1.5

		Thickness in feet
3.	Sandstone, gray, massive, fine-grained, glauconitic, with streaks of limonite and calcite veins disseminated throughout	2.5
2.	Limestone, gray, massive, finely-crystalline, glauconitic	1.5
1.	Sandstone, massive, fine-grained, glauconitic	1.5
	Subtotal	50.0
	Total Thickness of Section	121.0 ft.

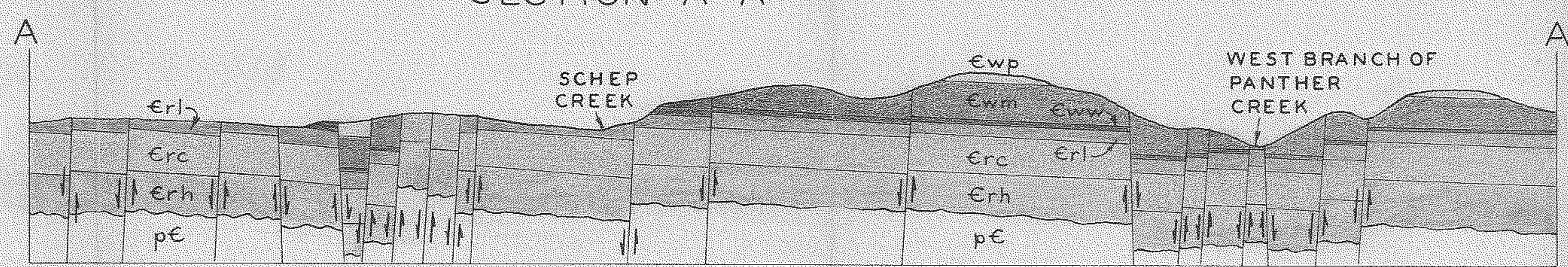


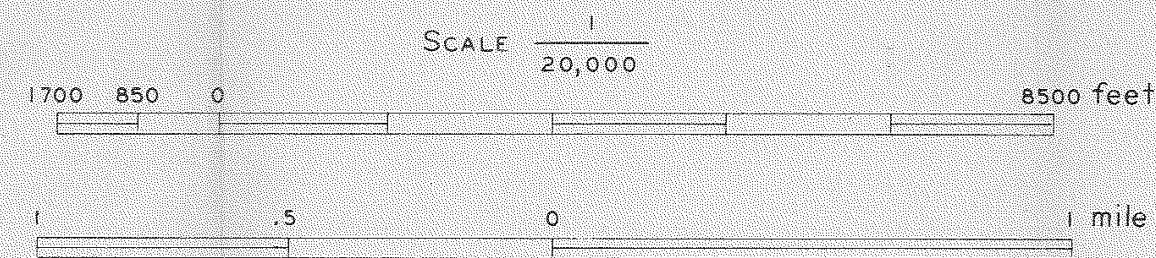
Base map from U. S. Department of Agriculture,
Commodity Stabilization Service, aerial photograph, 1955

Geology by H. D. Marshall, 1958



SECTION A-A'





GEOLOGIC MAP AND SECTION OF THE UPPER SCHEP CREEK AREA, MASON COUNTY, TEXAS