GEOLOGY OF THE SIGNAL HILL QUADRANGLE,

HAYS AND TRAVIS COUNTIES, TEXAS

APPROVED:

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R. A. K.

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ABSTRACT

The Signal Hill Quadrangle is located astride the Balcones Escarpment southwest of Austin. Cretaceous rocks (Albian and Cenomanian) cropping out in the area include the upper two members of the Glen Rose Formation, the Bull Creek and Bee Cave Members of the Walnut Formation, the Kainer and Person Formations of the Edwards Group, and the Georgetown, Del Rio, and Buda Formations. Deposition represented by these formations ranges from supertidal to tidal-flat to open-shelf marine environments. At one location there is a basalt plug, probably of Senonian age. The youngest deposits in the quadrangle are those associated with Quaternary terraces and alluvial sands and gravels.

The faults mapped are part of the Balcones Fault Zone, a system of <u>en echelon</u>, northeast-trending, predominantly normal, dip-slip faults. This system was probably active in the middle Tertiary. The Mt. Bonnell Fault is the most important fault in the quadrangle. It is one of the major faults of the Balcones Fault System, having been downthrown 170-350 feet to the southeast. The total displacement of all faulting in the map area is about 800 feet.

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I. INTRODUCTION

Objectives

The objectives of this project are twofold. First, this thesis is part of Dr. Keith Young's continuing study of the Balcones Fault Zone. During his tenure at The University of Texas, Dr. Young has supervised students who mapped the geology of the Balcones System between Austin and San Antonio (e.g. De Cook, 1956; Noyes, 1957; Davis, 1962; Abbott, 1966; Grimshaw, 1970; Smith, 1978). Second, I wanted to become more familiar with the stratigraphy and structural geology of the Austin area. This study also expanded my knowledge of carbonate geology and of the problems of mapping an area with few stratigraphic controls and poorly-exposed outcrops.

Location

The Signal Hill Quadrangle is a U.S. Geological Survey, 7½-minute quadrangle, which lies astride the border of Hays and Travis counties in south-central Texas (Figure 1). It is bounded on the north and south by parallels of latitude 30°15'N and 30°07'30"N, respectively, and on the

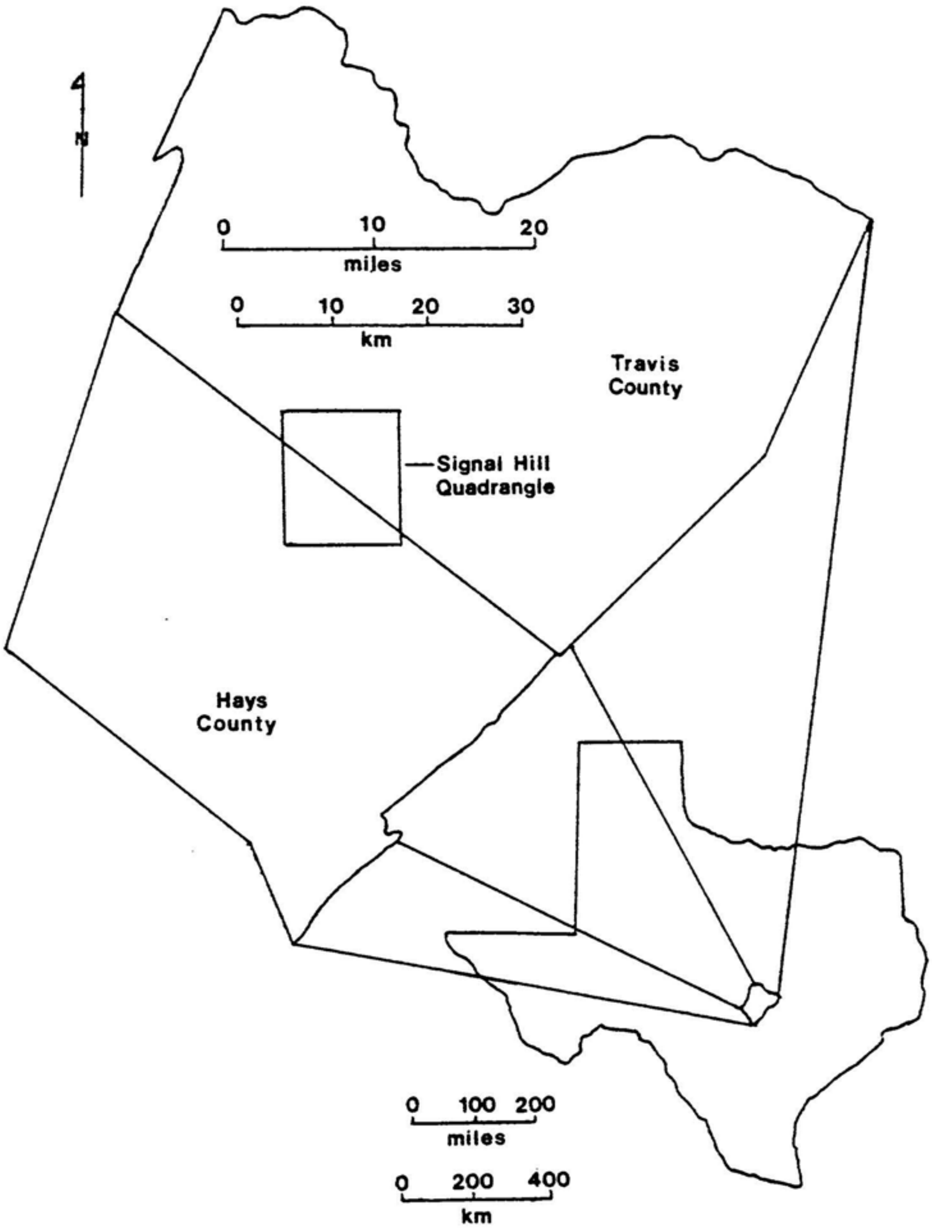

Figure 1: Location of the Signal Hill Quadrangle.

east and west by meridians of longitude 97°52'30"W and 98°00'W, respectively (Figure 2). The center of the quadrangle is approximately 13 air miles southwest of the Texas State Capitol Building in Austin.

Accessibility

The Signal Hill Quadrangle is easily accessible by several public highways (Plate 1). U.S. Highway 290 provides access to the northern part of the quadrangle, F.M. 1826 and Nutty Brown Road provide access to the central and southwestern parts of the quadrangle, and Bliss Spillar Road provides access to the southeastern part.

Rapid development is occurring along U.S. 290 and F.M. 1826. Old ranches are being converted to new housing developments. As these conversions occur, access to land is hindered because there are so many more landowners from which to ask permission for access.

In the southern one-third of the quadrangle, much of the land remains as large ranch-holdings, although some are for sale. Access to these lands is much simpler because there are fewer landowners.

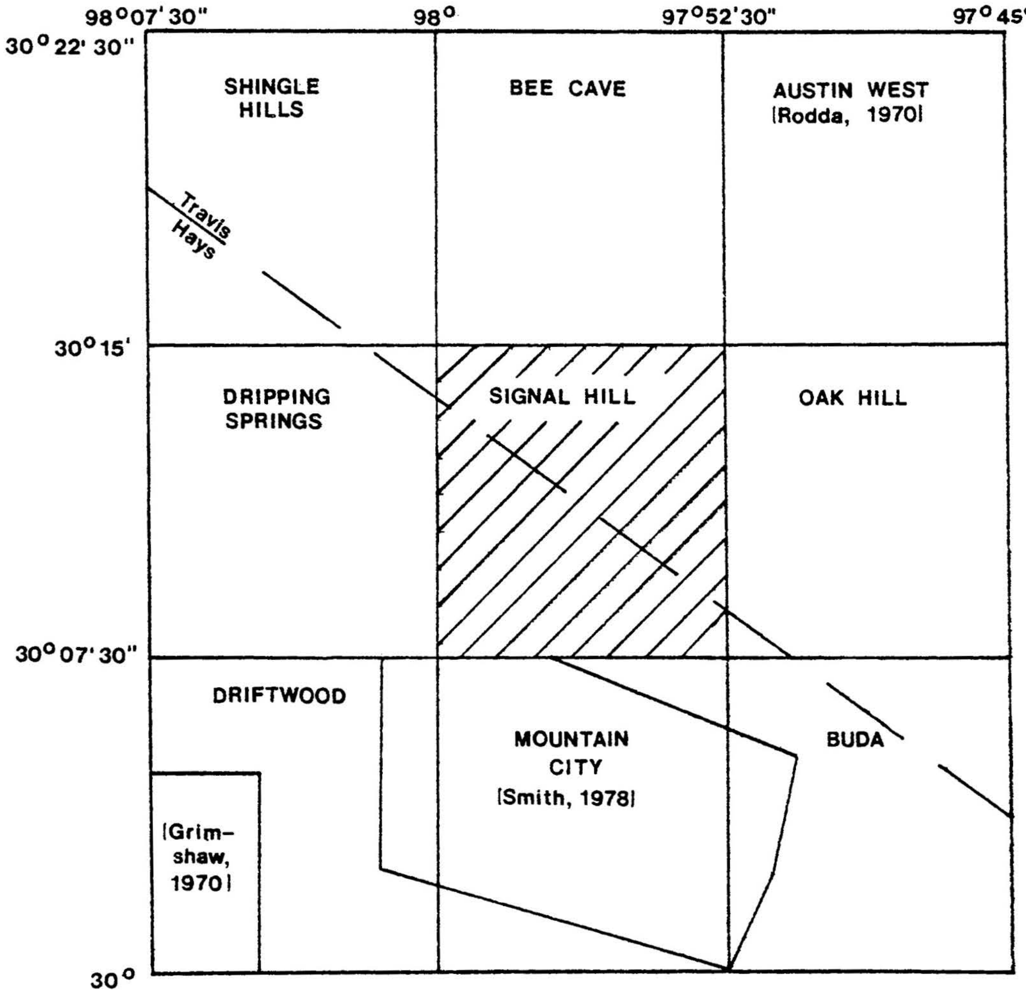

Figure 2: Adjacent quadrangles and previous work.

History of Settlement

The early history of the map-area is discussed extensively in Dobie (1932). Most of this early settlement consisted of ranching and farming.

In the last 20 years land-use has been changing from farmland and ranchland to residential tracts for housing. The rapid growth of Austin has driven up prices of land, enticing some residents of the area to sell their land to developers. This change started along U.S. 290, and in the last 10 years has extended to F.M. 1826, Nutty Brown Road, and Bliss Spillar Road.

As Austin grows and access to the downtown area improves, growth will accelerate and increase pressure on the limited water-resources of this area. Already there are problems in supplying water to some of the newer residents. Ultimately, the city will have to solve these problems when the area comes under its jurisdiction. It is probable that some of the present landowners will be dissatisfied with the final solutions.

Previous Work

Ferdinand Römer was the first explorer to study the Cretaceous geology in central Texas (1846; 1848). Hill and

Vaughan (1897) and Hill (1901) also studied the geology of central Texas, including the map-area.

More recently, Grimshaw (1970), Rodda (1970), and Smith (1978) mapped and discussed the geology of areas near the Signal Hill Quadrangle. Garner and Young (1976) mapped part of the quadrangle as part of their study of the environmental geology of the Austin area.

Several students at the University of Texas studied the regional, Cretaceous stratigraphy of central Texas. They include Hixon (1959), Moore (1959; 1961), Martin (1961), Winter (1962), Wilbert (1963), and Rose (1972). These studies were invaluable aids for analyzing the stratigraphy of the area.

Methods of Investigation

I mapped the geology of the Signal Hill Quadrangle on aerial photographs and on a U.S. Geological Survey, 7½-minute, topographic map during the summer and fall of 1980.

I used aerial photographs, flown by the Department of Agriculture in 1951 and printed at a scale of 1:20,000, primarily to map the faults and the Glen Rose Formation. The faults are often accentuated as linears on the topography; the Glen Rose stands out because its high relief and alternating members of limestone and dolomite are easily discerned on aerial photographs.

I used the topographic map primarily to map the geology southeast of the Mt. Bonnell Fault, in the fault zone. This area of low relief and thick vegetative cover required extensive field checking of formational contacts and traces of faults. Consequently, I walked over virtually all of this half of the quadrangle.

I measured five sections of strata using a five-foot Jacob's staff and a hand lens (Appendix). Measureable sections of each formation do not crop out in the quadrangle. Therefore, I was able to measure sections of only the Glen Rose Formation, the Bull Creek Member of the Walnut Formation, and the Kainer, Person, and Georgetown Formations.

II. PHYSICAL GEOGRAPHY

Topography

The maximum relief in the Signal Hill Quadrangle is 520 feet. The highest elevation is 1235 feet on top of a hill on the western edge of the map area, just south of U.S. 290. The lowest elevation is 715 feet in a tributary of Little Bear Creek in the southeastern corner of the quadrangle.

Based on slope intensity, the topography of this area can be divided into two physiographic provinces (Garner and Young, 1976), separated by the Mt. Bonnell Fault. Northwest of that fault lies the Edwards Plateau province, with slopes generally from 5 to 15 percent; adjacent to major creeks, slopes may be nearly vertical. Topography in this province is highly dissected. Southeast of the Mt. Bonnell Fault, in the Balcones Fault Zone, is the Rolling Prairie province, with slopes of generally less than 5 percent; adjacent to Bear Creek, slopes may be nearly vertical. Topography in this province is moderately dissected.

Drainage

The quadrangle lies within the Colorado River Basin. Local drainage is accomplished by numerous small tributaries which flow into the major creeks--Bear Creek, Slaughter Creek, and Williamson Creek. All three of these creeks ultimately drain into Onion Creek, which enters the Colorado River just east of Austin. All the creeks in the quadrangle are ephemeral.

Climate

The climate of the area is similar to that of Austin--subtropical, warm, and humid. The summer of 1980 was one of the hottest and driest on record and did not facilitate geologic mapping. Smith (1978) extensively discusses the climate of the area.

Vegetation

Slowly-weathering limestone produces only a thin soil which cannot sustain a wide variety of vegetation. The most common flora are juniper "bushes", a variety of oak trees, prickly pear cacti, and short and bunch grasses. Woody plants are usually restricted to the alluvial soils along major creeks.

The most effective competitor among the vegetation is juniper. Man has extinguished the fires that previously had kept the spread of juniper under control; juniper is now the dominant plant on lands not cultivated or grazed. At times, these trees grow so densely it is impossible to walk through them.

Oak trees are the only tall shade trees in the quadrangle that grow well on limestone. The live oak is the most common variety. It grows slowly; 50-foot trees are generally more than 100 years old. The oaks and prickly pear cacti prefer to grow on the Edwards Limestone.

Cuyler (1931) noted that vegetation can be used to determine lithology of the bedrock. This method works well with formations of different lithologies, but when lithologies are similar, as in the map-area, this method cannot be used reliably.

III. STRATIGRAPHY

The geologic units that crop out in the Signal Hill Quadrangle are composed of Cretaceous rocks and two minor deposits of sand and gravel, as shown in the stratigraphic column (Figure 3). The Cretaceous, sedimentary rocks range from Albian (Upper Glen Rose) to Cenomanian (Buda). These units are predominantly limestone, dolomite, and marl, with a combined thickness of 850 feet. A Senonian (Cretaceous), basaltic plug crops out at one location; its vertical extent is unknown. The Quaternary units in the map-area consist of thin, unconsolidated alluvial deposits.

Pre-Cretaceous Rocks

Rocks of the Ouachita Foldbelt form the basement for the younger units of the quadrangle. These Paleozoic rocks were deposited in a geosyncline in front of the exposed Texas Craton (Sellards, 1931, p. 820), and were later thrust to the west and northwest, against the craton (Flawn, *et al.*, 1961, p. 187).

Rocks of the foldbelt do not crop out in the quadrangle. The Mann #1 Reeder well, located at the central-

<table>
<tr><th>SYSTEM</th><th>LOCAL SERIES</th><th>SERIES</th><th>STAGE</th><th>GROUP</th><th>FORMATION</th><th>MEMBER</th><th>THICKNESS FEET</th></tr>
<tr><td colspan="7">QUATERNARY TERRACES AND ALLUVIAL DEPOSITS</td><td>20</td></tr>
<tr><td rowspan="9">CRETACEOUS</td><td rowspan="9">COMANCHE</td><td rowspan="3">UPPER CRETACEOUS</td><td rowspan="3">CENOMANIAN</td><td rowspan="3"></td><td>BUDA</td><td></td><td>50</td></tr>
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<tr><td rowspan="2">GLEN ROSE</td><td>MEMBER 5</td><td>100</td></tr>
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Figure 3: Stratigraphic column of the Signal Hill Quadrangle.

western edge of the quadrangle, penetrates the Ouachita facies at a depth of 699 feet, where the rocks consist of slightly metamorphosed, flysch-like sands and shales (Flawn, *et al*., 1961, p. 271).

Cretaceous System

Hill (1887) divided the Cretaceous of Texas into the Comanche and Gulf Series. Only units of the Comanche Series crop out in stratigraphic continuity in the quadrangle. The Gulf Series is represented only by the Senonian basalt, which cuts across the older Comanche units; all Gulfian, sedimentary units have been removed by erosion.

All the sediments comprising the rocks of the Comanche Series were deposited on the Central Texas Platform (Figure 4). This shelf was the area of calcareous deposition, more than 150 miles wide, separated from the ancestral Gulf of Mexico Basin by the Stuart City Reef Trend. Slightly deeper basins, such as the Maverick and Tyler, embayed upon the shelf. The sediments deposited on the shelf range from supertidal to shallow subtidal. These environments varied little over hundreds of square miles, resulting in the deposition of nearly flat, widespread calcareous beds on the entire shelf as it subsided. Deposition of limestone was

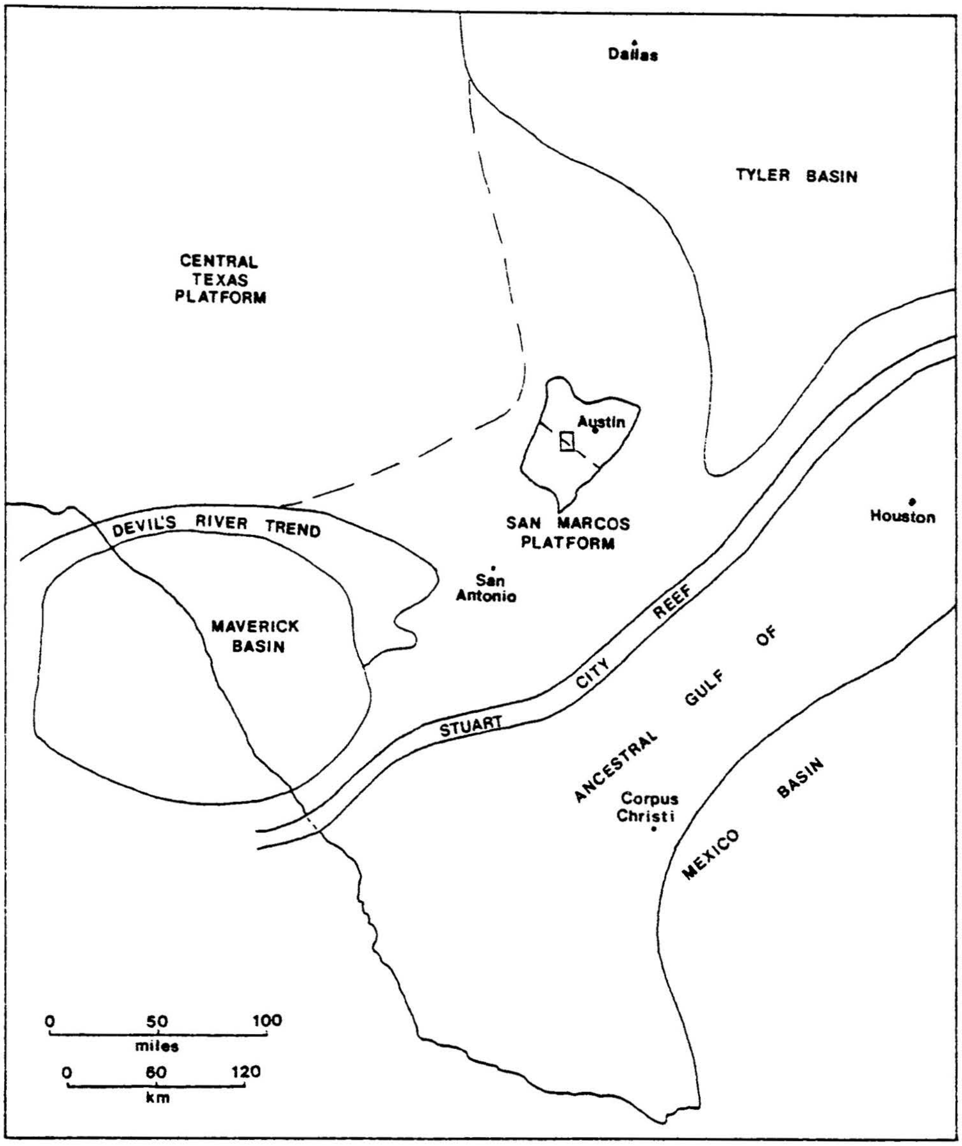


Figure 4: Regional elements of Texas during the Cretaceous (after Rose, 1972, p. 4).

occasionally interrupted as minor falls in sea level or excessive evaporation resulted in dolomitization. Influx of terrigenous clays resulted in the deposition of marly units or clay.

The Signal Hill Quadrangle lies wholly within that part of the Comanche Shelf affected by the San Marcos Platform. This platform is a broad, stratigraphic nose plunging southeast, away from the Llano Uplift, towards San Antonio. It is an area which subsided more slowly than the rest of the Comanche Shelf, and resulted in a thinning of the units across the platform.

Each of the geologic units which crop out in the quadrangle is described in the following section. Measured sections for the thicker units are shown in the Appendix. A detailed description of thin sections for most of the units is available in Smith (1978). A list of the fossils which occur in the Cretaceous, sedimentary units is available in Davis (1962) and Young (1977).

Comanche Series

Glen Rose Formation - Shumard (1860) named this unit the *Caprotina* Limestone. Hill (1891, p. 504) renamed it the Glen Rose Limestone after exposures along the Paluxy

River near the town of Glen Rose, Somervell County, Texas. In the Austin area Rodda (1970) divided the Glen Rose into five members, based on the content of dolomite.

Member 4 of the Glen Rose is at least 125 feet thick. It consists primarily of beds of hard, gray wackestone alternating with beds of soft, white or light-tan marl and marly limestone. The wackestone beds are generally less than three feet thick, are often burrowed, and usually contain some fragments of fossils. The marly beds are generally less than four feet thick, contain varying, minor amounts of clay, and only rarely contain fossils. These marly beds weather more easily than the hard limestone beds and form receding profiles, resulting in the formation of stairstepped topography characteristics of the Glen Rose (Figure 5).

The upper 50 feet of this member contains occasional beds of porous, sugary-textured, tan dolomite up to three feet thick. These dolomitic beds typically become more common higher in the unit.

The contact between members 4 and 5 of the Glen Rose Formation is gradational. In measured section 1 the contact is placed above the last one-foot bed of wackestone. Above this unit the beds of limestone are usually less than one foot thick and dolomite is the most common lithology.

Figure 5: Stairstepped topography characteristic of the Glen Rose Formation. Photo taken along Bear Creek, west of Nutty Brown Road. View is looking northeast.

Member 5 of the Glen Rose is 90-100 feet thick. It consists primarily of porous, sugary beds of dolomite less than eight feet thick and of occasional thin beds of grayish-tan, dolomitic limestone. The dolomite characteristically weathers dark gray and forms a more gradual slope than the limestones and marls of Member 4. Dolomitization has destroyed most remains of fossils, although some burrows still remain (Figure 6).

Deposition of sediments which comprise the Glen Rose Formation took place on the broad, shallow Comanche Shelf, behind the Stuart City Reef. The shelf floor was frequently exposed subaerially as supratidal deposits prograded back across the back-reef area. Evidence of this depositional environment is reflected in the extensive lateral continuity of individual beds, by the occurrence of cavities in beds which at one time probably contained nodules of evaporite, and by the occurrence of dolomite.

The contact between the Glen Rose Formation and the overlying Walnut Formation is an iron-stained and pitted horizon, which possibly represents an unconformity. This contact is poorly exposed in the quadrangle.

Figure 6: Burrowed horizon of Member 5 of the Glen Rose Formation. Note the discharge of groundwater from porous beds of dolomite. Photo taken along Bear Creek, east of Bear Creek Estates Road. View is looking southeast.

Walnut Formation - Hill (1891) named the Walnut Formation for outcrops of clay and limestone at Walnut Springs, in Bosque County, Texas. Moore (1959) divided the Walnut Formation into two members, the Bull Creek below and the Bee Cave above, based on lithologic differences.

The Bull Creek Member is approximately 40 feet thick. It consists of medium-thick beds of gray-weathering wackestone and miliolid grainstone, occasionally marly or nodular (Figure 7), and dolomite. On a fresh surface these beds are light tan to light gray and contain scattered fragments of fossils. The contact with the overlying Bee Cave Member is not exposed in the area. Moore (1959) reports that the contact is an iron-stained, bored and pitted horizon.

The Bee Cave Member is approximately 20 feet thick. It consists of tan-weathering marl and gray, nodular wackestone. On a fresh surface these beds are light gray and white. Fossils are abundant, especially the oyster *Ceratostreon texana* (Römer). The Bee Cave Marl weathers easily, forming a recessed slope above the Bull Creek Member which is often covered with shells of *C. texana* (Figure 8).

Figure 7: Typical outcrop of the Bull Creek Member of the Walnut Formation, above Bear Creek, on the Word Ranch, south of F.M. 1826. View is looking east.

Figure 8: Typical outcrop of well-weathered Bee Cave Marl, at the end of Bear Creek Estates Road. Note the abundant shells of _Ceratostreon texana_ (Römer). View is looking east.

The depositional environment of the Walnut Formation was on a shallow-water, marine shelf. Introduction of terrigenous clay behind the Stuart City Reef resulted in deposition of the Bee Cave Marl (Tucker, 1962, p. 197). Moore (1961, p. 53) believes the Bee Cave was deposited in a mud flat which supported an abundance of organisms.

The contact of the Bee Cave Member with the overlying Edwards Group is sharp, with an abrupt change of lithology from a marl to a hard, fossiliferous limestone. This contact is conformable (Young, in Barnes, *et al.*, 1963, p. 43).

Edwards Group - Shumard (1860, p. 583) originally named this group of strata the *Caprina* Limestone. Hill (1889a, p. 5) called it the Barton Creek Limestone, and later Hill and Vaughan (1897, p. 193) replaced both names with the Edwards Formation. The type-section is along Barton Creek in Travis County, Texas (Adkins, in Sellards, *et al.*, 1933, p. 332). Rose (1972, p. 18) elevated the Edwards of this area to group status and named two new formations, the Kainer below and the Person above, from cores taken from the Person oil field in Karnes County, Texas.

The Kainer Formation and younger Cretaceous units in the Signal Hill Quadrangle have been extensively faulted and are poorly exposed. Therefore, the thicknesses of these units are estimates, based on the isopachous maps of Rose (1972).

Kainer Formation - The Kainer Formation is approximately 310 feet thick. Rose (1972, p. 18) divided the Kainer into two informal members, a dolomitic member below and a grainstone member above. Both crop out in the quadrangle.

The dolomitic member consists of massive beds of dark gray-weathering dolomite and dolomitic limestone up to ten feet thick, and of beds of hard, rudist-bearing, gray-weathering wackestone and packstone up to three feet thick. On a fresh surface the beds of dolomite are tan and highly porous; the beds of limestone are light gray to white and contain abundant fragments of fossils. The dolomitic beds contain numerous nodules of chert, which range from gray to dark blue to black (Figure 9). These nodules have a spherical or elliptical shape and an average longest dimension of five inches. Nodules of chert are less common in Kainer limestones. Iron-stained nodules of chert often occur as float

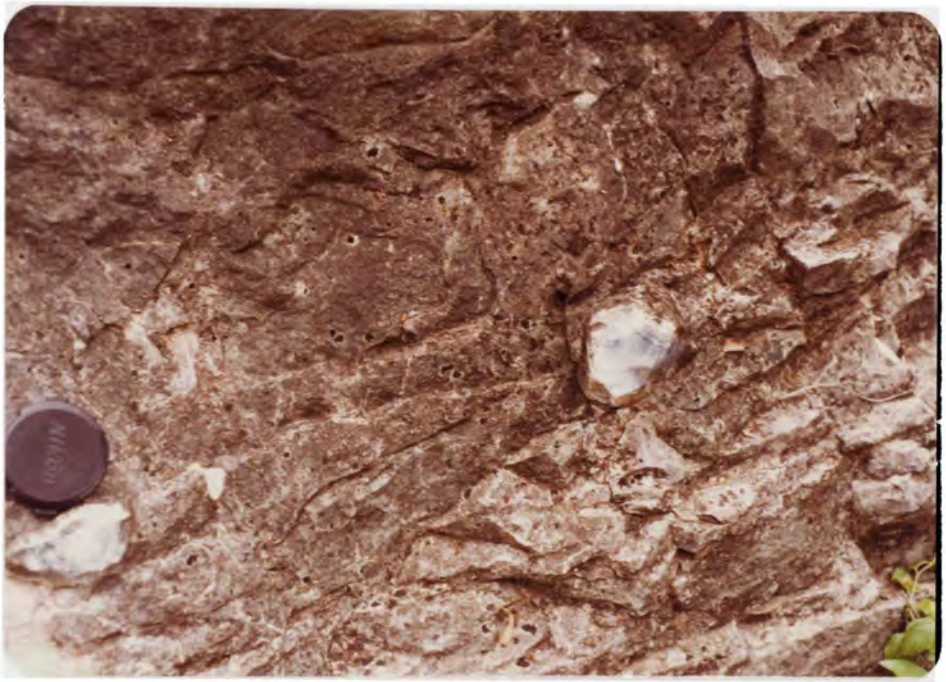


Figure 9: Nodules of chert in the Kainer dolomite, along Bear Creek near measured section 3. View is looking north.

on weathered surfaces of the Kainer Formation (Figure 10). Collapse zones, usually less than three feet thick, also occur in the dolomitic member. These zones consist of coarse, crystalline calcite and result from dissolution by groundwater of beds of evaporite and limestone. Subsequently, the overlying beds collapse and the resulting rubble is cemented by calcium carbonate.

The grainstone member consists of hard beds of grainstone which weather medium gray and contain abundant miliolid foraminifers and fragments of fossils. These beds are generally less than one foot thick and contain little chert.

Rose (1972, pp. 52, 53) believes the depositional environment of the limestones which later became the dolomitic member represents open to restricted, shallow-marine and tidal-flat deposition. Dolomitization of the limestone probably occurred through mixing of magnesium-enriched brines and meteoric water in a supratidal environment. The grainstone member represents open-shelf to shallow-marine to supertidal deposition.

The contact between the Kainer Formation and overlying Person Formation is not exposed in the quadrangle.

Figure 10: Float of iron-stained nodules of chert on a weathered surface of the Kainer Formation on the Spillar Ranch. View is looking east.

According to Rose (1972, p. 25) the contact is sharp and probably conformable.

Person Formation - The Person Formation is approximately 75 feet thick. Rose (1972, p. 19) divided the Person into five informal members, but due to faulting and vegetative cover, only three members crop out in the quadrangle. In ascending order these are (1) a marly unit, (2) a unit of coarse, cave-filling calcite, and (3) a fossiliferous wackestone and mudstone.

The lower, marly unit is equivalent to the Regional Dense Member in the subsurface (Rose, 1972, p. 19) and to the upper part of the Burt Ranch Member of the Edwards Plateau (Rose, 1972, p. 35). In the quadrangle it consists of 15 feet of gray-weathering, nodular limestone and marl which contain few fossils (Figure 11). On a fresh surface these beds are light gray to white and contain a small amount of clay; this is the only unit in the Edwards group which contains clay, and it is therefore an important marker bed. Unfortunately, this unit crops out only at two locations in the quadrangle (Plate 1).

Above the marly unit lie various carbonaceous units. Sparry, cave-filling calcite and hard, gray-weathering, fossiliferous wackestone are the two most common lithologies.

Figure 11: The marly unit of the lower Person Formation, along Bear Creek at the site of measured section 4. Thickness is approximately six feet. View is looking south.

The sparry calcite is often stained red and occurs as coarse, crystalline calcite or radiating crystals which fill collapse-zones. The wackestones are light gray on a fresh surface and contain abundant fragments of rudists.

Throughout the limestones of the Edwards Group weathered surfaces often exhibit a characteristic texture called microkarst (Figure 12). These textures result from solutional activity of rainwater on the surfaces of limestone which are nearly pure calcium carbonate (Young, personal communication).

The depositional environment of the Person Formation was a restricted, shallow-marine shelf (Rose, 1972, p. 52). An influx of a small amount of clay produced the marly beds. An eventual return to quieter, restricted, shallow-marine conditions enabled deposition of the fossiliferous wacke-stones.

The contact of the Person Formation and overlying Georgetown Formation is not exposed in the quadrangle. In Hays County and in the Austin area Wilbert (1963, p. 20) found the contact to be a bored and corroded zone.

<u>Georgetown Formation</u> - Shumard (1860, p. 583) named this unit the Washita Limestone. Hill (1901, p. 262) named

Figure 12: Microkarst resulting from solutional activity of Edwards Limestone. Photo taken on the Spillar Ranch, south of Bear Creek. View is looking southwest.

it the Georgetown Formation for its occurrence along the San Gabriel River at Georgetown, Williamson County, Texas. The Georgetown Formation includes all strata above the Edwards Group and below the Del Rio Clay (Wilbert, 1963, p. 13).

The Georgetown Formation is approximately 50 feet thick in the quadrangle. It consists primarily of hard, massive beds of light gray-weathering, nodular limestone (Figure 13). Bed thickness is less than eight feet; beds are often separated by a one-inch thick bed of marl. On a fresh surface the Georgetown is light gray and occasionally contains abundant fragments of fossils.

The Georgetown contains the most abundant and varied fauna of all the formations studied. The most common megafossils include Neithea sp., Plesioturrilites brazoensis (Römer), Arctostrea sp. cf. carinata (Lamarck), Texigryphaea washitaensis (Hill), and Scabrotrigona sp.

The depositional environment of the Georgetown was a shallow-water, marine shelf, as reflected by its fauna. The muddy rocks suggest an environment of low energy.

The contact of the Georgetown Formation with the overlying Del Rio Formation is not exposed due to faulting.

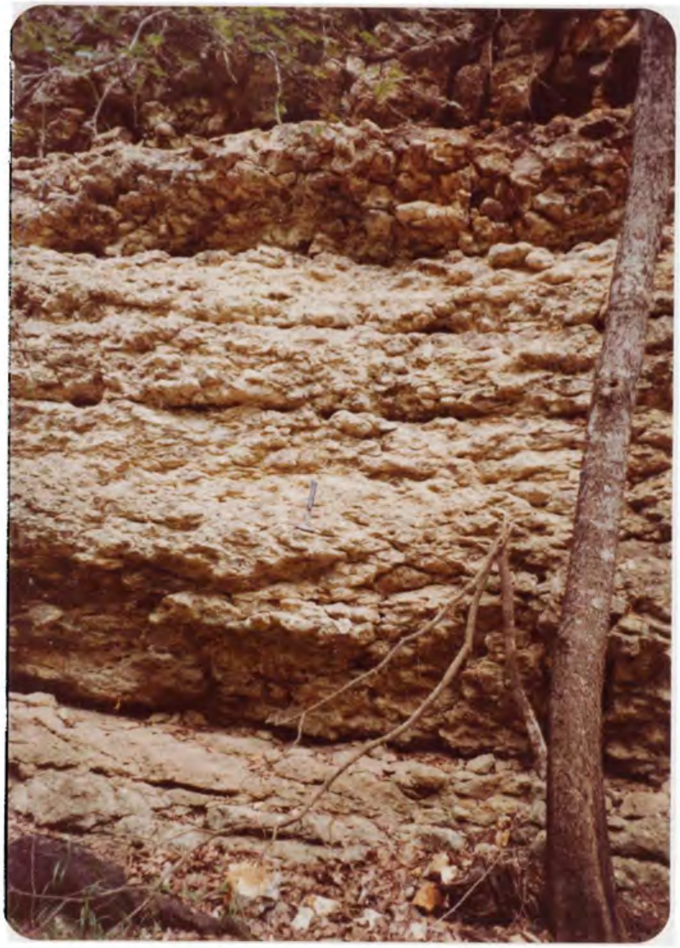


Figure 13: Nodular limestone of the Georgetown Formation, at the site of measured section 5. View is looking south.

Wilbert (1963, p. 33) considers it to be conformable, gradational, and possibly interfingering.

Del Rio Formation - Shumard (1860, p. 583) originally named this unit the *Exogyra arietina* Marl. Cragin (1894, p. 40) applied the name Grayson Marl to outcrops in Grayson County in north Texas. Hill and Vaughan (1897, p. 236) named the equivalent strata in southeast Texas the Del Rio Clay, with the type-section being a conical hill two miles southeast of Del Rio, Val Verde County, Texas (Adkins, in Sellards, *et al.*, 1933, p. 387).

The Del Rio Clay is approximately 60 feet thick, but only cultivated, surficial exposures occur in the quadrangle. The predominant lithology is a claystone, composed of kaolinite and illite (Grimshaw, 1976, p. 220) and weathering grayish-tan. Thin, calcite-cemented slabs occur in the quadrangle, randomly scattered as float on surfaces of the Del Rio. The surfaces of these slabs contain abundant, pyritized specimens of the most common fossil in the Del Rio, *Ilymatogyra arietina* Römer (Figure 14).

Nodules of ironstone occur randomly on surfaces of Del Rio and in creeks draining the Del Rio. These nodules have many shapes; the maximum longest dimension is two inches.

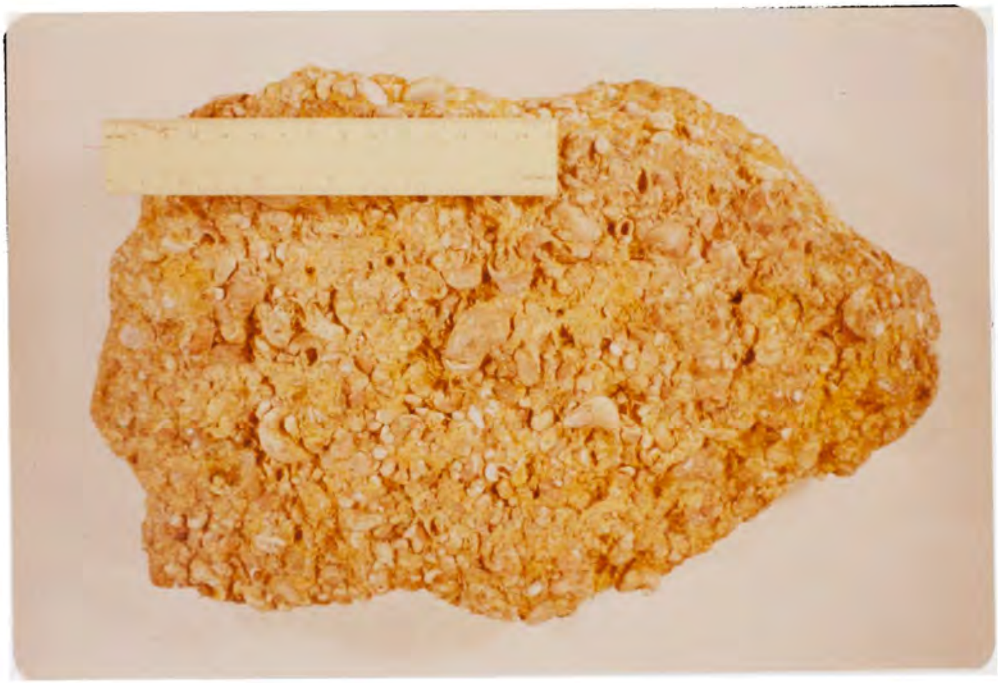


Figure 14: Slab of calcite-cemented Del Rio Clay with abundant Ilymatogyra arietina Römer, found as float on a Del Rio outcrop in the southeastern corner of the quadrangle.

The occurrence of these nodules indicates the Del Rio was deposited in an environment of very low energy, possibly near shore in a lagoon.

Because the Del Rio occurs only as surficial exposures, the contact with the overlying Buda Formation is not exposed. This contact is gradational (Martin, 1961, p. 36).

Buda Formation - Hill (1889b, p. 289) named this unit the Vola Limestone. Vaughan (1900, p. 18) renamed the formation the Buda Limestone, with the type-section along Shoal Creek, in Austin, Travis County, Texas.

The Buda Formation is approximately 50 feet thick, but only 35 feet crop out in the quadrangle in scattered, poorly-exposed outcrops on one fault block (Figure 15).

The Buda consists of two informal members (Hixon, 1959), (1) glauconitic wackestone and micrite below, and (2) intraclast-bearing wackestone and packstone above.

The lower member weathers to a yellowish-gray; on a fresh surface, it is medium gray and contains many fragments of fossils. Blue-green splotches of glauconite occur throughout the member; these are characteristic of the lower Buda.

The upper member weathers light gray to tan; on a fresh surface, it is light yellowish-orange and contains

Figure 15: Typical, poorly-exposed outcrop of Buda Limestone. View is looking west.

well-rounded, elliptical intraclasts of lower Buda. These intraclasts are characteristic of the upper Buda.

Buda sediments were deposited in a shallow, moderate- to high-energy, open-marine environment. Wave-energy had to be sufficient to deposit fragments as intraclasts in the upper Buda.

The unconformity at the top of the Buda is not exposed in the quadrangle. This unconformity marks the end of deposition of the Comanche Series and the beginning of the Gulf Series.

Gulf Series

Basalt - A small, reddish-brown-weathering outcrop of basalt occurs on the Spillar Ranch (Figure 16). This outcrop is seven feet in diameter; basalt float lies on slopes adjacent to it. The basalt is similar in composition to the Pilot Knob basalt of Travis County (D. L. Barker, personal communication; Barker and Young, 1979), rich in clinopyroxenes, olivine, plagioclase, and zeolites. On a fresh surface the basalt exhibits a black, glassy groundmass with occasional one-tenth-inch splotches of white zeolites.

Figure 16: Outcrop of basalt on the Spillar Ranch. View is looking south.

The age of this basalt is approximately 79 million years (Senonian), assuming it was intruded contemporaneously with Pilot Knob. This outcrop is probably the remnant of a volcanic neck, hence its limited lateral extent. The vertical extent of the outcrop is unknown; it probably extends to a great depth, as reflected by its basaltic composition. Basaltic outcrops of the late Cretaceous occur extensively throughout the Austin area in the Balcones Fault Zone (Lonsdale, 1927).

Quaternary System

Deposits Associated with Terraces - These unconsolidated deposits are poorly developed in the quadrangle, occurring only adjacent to the major creeks and consisting of coarse cobbles of gray limestone, nodules of chert, and small amounts of carbonate sand and mud. The total thickness of these deposits cannot be accurately determined due to the paucity of good exposures. In areas adjacent to the Signal Hill Quadrangle these deposits are up to 20 feet thick (Smith, 1978, p. 48; Rodda, 1970, p. 7).

Alluvial Deposits - Creek beds generally consist of bedrock of limestone covered with caliche (Figure 17). Unconsolidated alluvial deposits occur locally and are

Figure 17: Caliche-covered bedrock on the floor of Bear Creek east of the Spillar Ranch.

thickest where creeks drain marly units, such as the Glen Rose and Walnut formations. Here these deposits are up to 20 feet thick and consist of carbonate gravel, sand, silt and clay.

IV. STRUCTURAL GEOLOGY

Regional Structural Features

Balcones Fault Zone - The southeastern half of the Signal Hill Quadrangle lies within the Balcones Fault Zone. This zone consists of northeast-trending, predominantly normal, dip-slip, *en echelon* faults which mark the boundary between the Edwards Plateau and the Gulf Coastal Plain throughout central Texas.

The Texas Craton and Ouachita Foldbelt controlled the position of the Balcones Fault Zone. The stable edge of the craton acted as a hinge, and the thick shale sequences of the Ouachita facies acted as zones of weakness for slippage during subsidence of the ancestral Gulf of Mexico. This subsidence caused extension of the crust and resulted in Balcones faulting (Foley, 1926, p. 1263). This crustal extension also resulted in normal faulting to the southeast in the Luling-Mexia Fault Zone. Together, these two fault zones form the boundaries of a 30-mile-wide graben (Foley, 1926, p. 1261).

Balcones faulting had begun by the Miocene, as indicated by the occurrence of Cretaceous fossils in the Oakville Formation (Miocene) southeast of the fault zone (Weeks, 1945, p. 1736; Ely, 1957).

In the quadrangle faulting is difficult to detect because of vegetative cover and the lack of marker beds, especially in the Edwards, in which most of the faults occur. Most faults trend from N35E to N60E (Plate 1). Most of these faults are normal, dip-slip faults, downthrown to the southeast. The reverse faults may be antithetic faults, related to the major faults in the quadrangle. Fault planes are also obscure and attitudes are difficult to determine. In the Austin area dips of fault planes are nearly vertical except for the planes of small antithetic faults, which dip less than 90 degrees.

The one major fault in the map area is the Mt. Bonnell Fault (Plate 1). It strikes approximately N40E; the dip could not be ascertained. It is a normal, dip-slip fault, downthrown to the southeast. Total throw decreases from 350 feet in the northeast part of the quadrangle to 170 feet in the southwest part. Most Balcones faulting occurs southeast of this major fault.

Most faults in the quadrangle have a displacement of less than 75 feet. Lack of marker beds creates difficulties in determining the exact amount of net slip along these minor faults. Total displacement across the fault zone in the Signal Hill Quadrangle is approximately 800 feet, of which an unknown part is due to regional dip.

Jointing - Two sets of joints occur extensively throughout the quadrangle. The predominant joint set trends approximately N60E, parallel to Balcones faulting. These joints are found in the Edwards Limestone and the Glen Rose Limestone in the fault zone. A secondary joint set trends approximately N25W. Usually these joints are found northwest of the Mt. Bonnell fault, in the Glen Rose Limestone. Both sets are tension fractures, associated with Balcones faulting (Rodda, 1970, p. 8).

Regional Dip - Regional dip varies with location in the Quadrangle. Northwest of the Mt. Bonnell fault, regional dip is to the northeast. Near that fault dip is to the east. Southeast of the Mt. Bonnell Fault, regional dip is generally to the southeast.

The upthrown block northwest of the Mt. Bonnell Fault dips up to 25 feet per mile to the northeast. This is in spite of the fact that displacement increases in that direction. This dip is produced by the decline of Glen Rose units into the Round Rock Syncline, northeast of the San Marcos Platform.

Near the Mt. Bonnell Fault the regional dip is up to 150 feet per mile to the east (Figure 18). The dip probably varies with displacement across the fault.

The downthrown fault-blocks in the fault zone southeast of the Mt. Bonnell Fault generally dip to the southeast. This dip results from (1) late Mesozoic and Cenozoic subsidence of the Gulf Basin, (2) uplift of the Edwards Plateau, and (3) initial dip towards the Gulf of Mexico (Muehlberger and Kurie, 1956, p. 43). Measuring regional dip in the fault zone is difficult because of extensive faulting. Dips on individual blocks may be as great as twenty degrees but are generally less than five degrees. In central Travis County Dunaway (1962, p. 13) notes a regional dip in the fault zone of 100-125 feet per mile to the southeast.

Local Structural Features

Doming - Groundwater selectively dissolves beds of limestone and evaporite of the Kainer Formation, resulting in collapse of the overlying beds. When exposed by erosion,

Figure 18: Glen Rose Limestone exhibiting regional dip to the east, adjacent to the Mt. Bonnell Fault. Pond is on Bear Creek, on the grounds of Friday Mountain Camp. View is looking southeast.

these beds exhibit undulating, low-relief topography, with apices of the undulations forming domed structures up to thirty feet in diameter (Figure 19). Although the limbs of these domes may dip up to 30 degrees (Figure 20), relief is generally less than four feet. These structures appear in the creek beds crossing the Kainer Formation, southeast of the Mt. Bonnell Fault.

Although these structures appear similar to granitic exfoliation domes, the process by which these blocks are produced is totally different. The bedding planes of the undulating beds of limestone are already weakened by fracturing and dissolution by groundwater. When exposed to surficial erosion, cement is completely dissolved. The torrential flow of water through these ephemeral streams can then pluck individual blocks of limestone from the domes, leaving behind a structure which looks similar to an exfoliation dome.

Jointing on a local scale is associated with solutional-collapse domes. These joints appear to follow no trend.

Sinkholes - In the Edwards Group sinkholes occasionally occur due to the dissolution of underlying beds. All

Figure 19: Domed structure in the Kainer Formation in Bear Creek, at the eastern boundary of the quadrangle. The stake in the center of the structure is approximately 1½ feet long. View is looking southwest.

Figure 20: Steeply-dipping limb of a solutional-collapse dome on Bear Creek, at the eastern boundary of the quadrangle. View is looking north.

the sinkholes in the map area are less than ten feet in diameter, although to the south Davis (1962, p. 66) found sinkholes several hundred feet in diameter.

SUMMARY

The Signal Hill Quadrangle lies totally within the Colorado River Basin. It is divisible into two physiographic provinces, divided by the Mt. Bonnell Fault. Northwest of that fault is the Edwards Plateau; southeast of the fault is the Gulf Coastal Plain.

Cretaceous units exposed in the area range from the upper Glen Rose through the Buda Formations. Exposures are generally poor due to heavy vegetative growth and the abundance of faulting. Rock types represented by these formations are limestone, dolomite, marl and claystone. One small plug of basalt cuts across the Kainer Formation and is of only minor importance. Quaternary alluvial deposits occur only along major creeks.

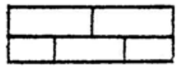
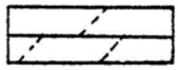
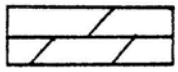
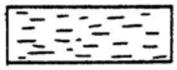
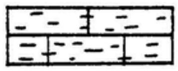
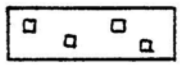
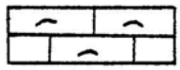
The southeastern half of the quadrangle lies within the Balcones Fault Zone. This zone consists of a series of *en echelon*, predominantly normal, northeast-trending faults which are probably Miocene. Total throw of these faults across the map area is approximately 800 feet.

APPENDIX

Measured Sections

SYMBOLS FOR MEASURED SECTIONS

Lithologic

Limestone	
Dolomitic limestone	
Dolomite	
Marl	
Marly limestone	
Collapse zone, calcite-filled	
Shell fragments	

Paleontologic

Gastropod	
Pelecypod	

Figure 21

Profile for measured section 1 is in the pocket.

SECTION 1

Location: Section 1 is located on Friday Mountain campgrounds, at the base of Friday Mountain.

GLEN ROSE FORMATION

Member 5

Unit		Thickness feet
46	Dolomite: finely crystalline; light tan, weathers to dark gray; 1 massive bed, very soft.	0.5
45	Dolomitic limestone: light gray to light tan, weathers medium gray; heavily burrowed, bedding destroyed.	0.75
44	Dolomite: finely crystalline, very porous; light gray to light tan, weathers dark gray; massively bedded, very soft.	6.0
43	Dolomite: finely crystalline; light tan, weathers medium gray; thin to medium beds less than 7 inches thick.	8.0
42	Limestone: fine-grained carbonate mudstone; light gray to whitish-tan, weathers medium gray; 3 beds, each 2-3 inches thick, hard and resistant.	0.75
41	Limestone: coarse, sparry calcite with small, porous, dolomite-filled fractures; calcite is light gray, weathers medium-gray, dolomite is tan; no bedding; parts of outcrop stained steel blue.	3.0
40	Dolomite: finely crystalline and porous; light tan, weathers dark gray; beds 2-4 inches thick, soft.	4.0

Unit		Thickness feet
39	Dolomite: finely crystalline; tan, weathers dark gray; 1 massive bed, very soft.	1.0
	Covered interval	3.0
38	Dolomite: finely crystalline; tan, weathers medium gray; massively bedded; contains isolated packstone pods up to 9 inches long.	5.0
	Covered interval	8.0
37	Dolomite: finely crystalline and porous; tan, weathers medium gray; medium-thick beds, soft.	6.0
36	Limestone: finely-grained carbonate mudstone similar to Unit 42; light gray, weathers medium gray; hard and resistant.	0.25
35	Dolomite: finely crystalline; light tan, weathers medium gray; massively bedded, soft.	8.0
34	Dolomite: finely crystalline and porous; tan, weathers dark gray; massively bedded.	2.5
33	Limestone: coarse, sparry calcite and porous dolomite similar to Unit 41; calcite is light gray, weathers white, dolomite is tan and fills fractures; no bedding.	0.75
32	Limestone: fine-grained carbonate mudstone; light gray to white, weathers medium gray; contains northeast trending gractures which are filled with porous, tan dolomite.	0.75

Unit		Thickness feet
31	Dolomite: finely crystalline and porous; light tan, weathers dark gray; soft, 1 massive bed.	1.0
	Member 4	
30	Limestone: wackestone; light gray; weathers medium gray; contains some clay and fossil fragments.	1.0
	Covered interval	5.0
29	Limestone: grainstone; light gray; weathers medium gray; 1-2 inch thick beds, fragments of fossils and carbonate grains common.	2.5
28	Dolomite: finely crystalline and porous; tan, weathers dark gray; contains some clay, and vugs up to 1 inch in longest dimension.	2.0
27	Marl: dolomitic wackestone; light gray to whitish-tan, weathers light gray; contains some clay and iron-stained grains.	3.0
26	Limestone: wackestone; light gray, weathers light to medium gray; contains fossil fragments, many 1-2 inch thick beds.	3.0
25	Limestone: wackestone; light gray, weathers medium gray; contains some clay; massively bedded.	1.75
	Covered interval	4.0
24	Dolomite: finely crystalline and porous; tan, weathers black; contains vugs smaller than 1/2 inch.	2.75

Unit		Thickness feet
23	Limestone: wackestone; white to light gray, weathers medium gray; contains fossil fragments and some clay.	2.5
22	Limestone: wackestone; white to light gray, weathers light gray; nodular weathering, contains more clay than Unit 23.	2.5
21	Dolomite: finely crystalline, sugary, porous; tan, weathers black, forms a massive ledge.	3.0
20	Marl: wackestone; light gray to white; weathers light gray; nodular; receding profile, contains abundant clay.	6.0
19	Limestone: wackestone; light gray to tan, weathers medium gray; moderately-receding profile.	8.0
18	Dolomitic limestone: wackestone; light gray to tan, weathers medium gray; forms a ledge, contains little clay.	1.0
17	Marl: light gray to white, weathers light gray; slightly nodular, contains horizontal laminae in upper 1 foot.	5.0
16	Dolomitic limestone: wackestone; light gray to tan, weathers medium to dark gray; contains abundant fragments of fossils; weathers massively, hard.	1.5
15	Limestone: wackestone; light gray, weathers medium gray; contains fossil fragments; platey weathering.	2.0
14	Limestone: grainstone; reddish-gray, iron-stained horizon, sharp contact with unit below.	0.25

Unit		Thickness feet
13	Dolomitic limestone: packstone; medium gray to tan, weathers medium gray; contains abundant fossils and iron-stained grains; nodular; dolomitization incomplete.	1.5
12	Marly limestone: wackestone; light gray, weathers medium gray; lower 2 feet nodular, top 1 1/2 feet more resistant to weathering.	3.5
11	Dolomitic limestone: fine-grained wackestone; tan, weathers grayish-tan; iron-stained grains; contains 1/8-inch vugs filled with sparry calcite or carbonate mudstone.	0.75
10	Marl: medium gray, weathers light gray; contains abundant clay; weathers hard to soft.	2.0
	Covered interval	7.0
9	Marly limestone: packstone; gray to tan, weathers light gray; top 1 foot is burrowed, contains abundant grains; unit contains abundant clay.	7.0
8	Limestone: packstone; medium to dark gray, weathers dark gray; iron-stained grains; contains abundant fragments of fossils.	2.0
7	Marl: wackestone; medium gray, weathers light to medium gray; contains abundant clay; nodular.	1.0
6	Limestone: wackestone; medium gray, weathers medium gray; contains fragments of fossils.	2.0

Unit		Thickness feet
5	Marl: wackestone; medium gray, weathers light gray; contains abundant clay; nodular.	8.0
4	Limestone: packstone; light gray, weathers medium gray; hard and resistant.	1.25
3	Marl: wackestone; light gray, weathers light gray; contains iron-stained grains; unit not as soft as usual marl.	2.0
2	Limestone: packstone; light gray, weathers medium gray; hard and resistant, forms a ledge; some burrows weathering out; pulverulite at top of unit.	1.5
1	Marl: wackestone; light gray to white, weathers medium gray; somewhat nodular.	3.0
	Total section measured	158.5 feet

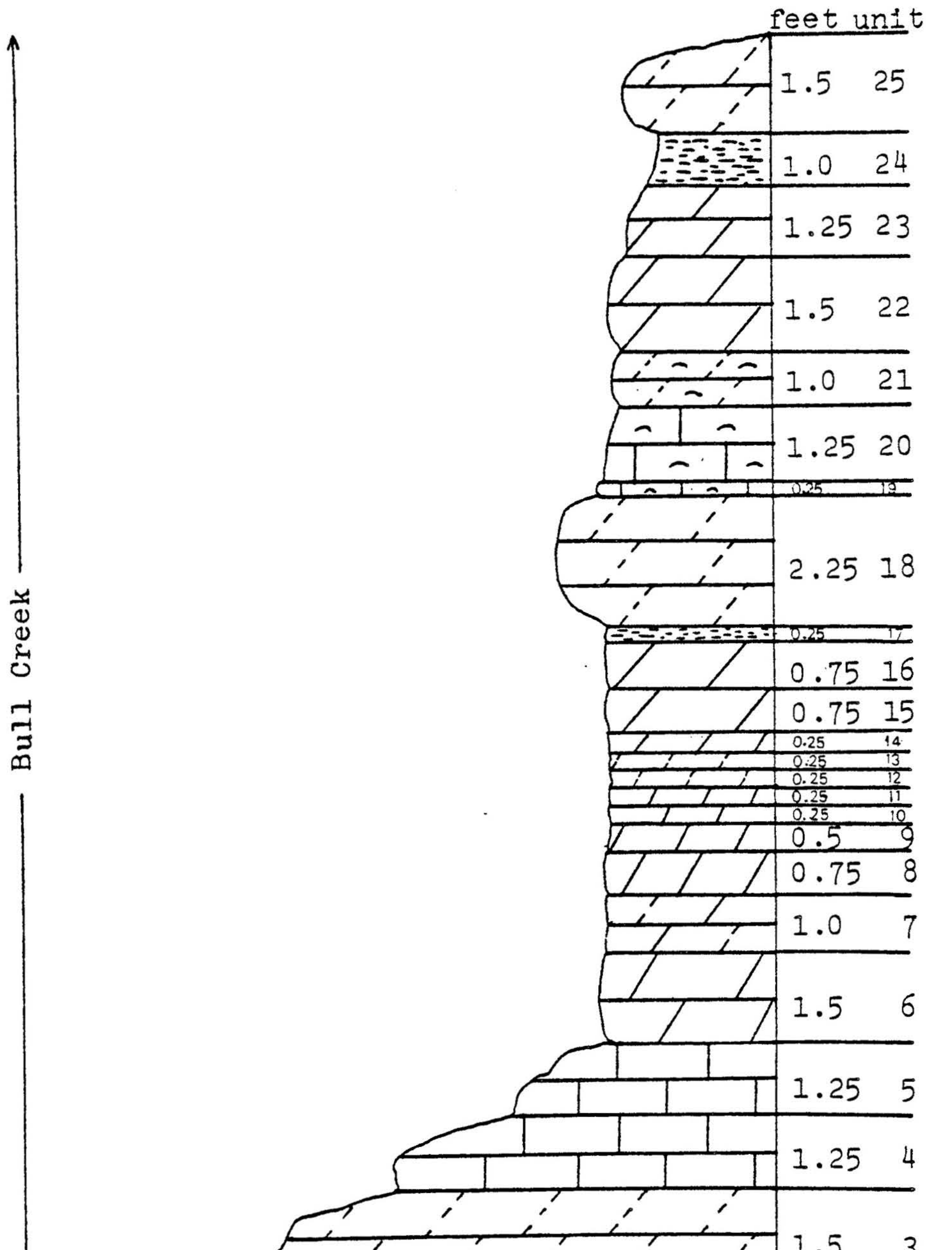


Figure 23: Measured section 2, Bull Creek member of the Walnut Formation

SECTION 2

Location: Section 2 is on the north side of Bear Creek, approximately 100 yards west of Dave Word's house, just off of F.M. 1826.

WALNUT FORMATION

Bull Creek Member

Unit		Thickness feet
25	Dolomitic limestone: light gray to tan, weathers medium gray; abundant fragments of fossils.	1.5
24	Marl: tan to white, weathers light gray; well-weathered, very soft; some sections better cemented than others.	1.0
23	Dolomite: tan, weathers dark gray; very porous, sugary, well-weathered; contains some pulverulite on a weathered surface.	1.25
22	Dolomite: dark tan, weathers dark gray; finely crystalline,sugary texture; porous, transmits groundwater.	1.5
21	Dolomitic limestone: packstone; medium gray, weathers black; contains fragments of fossils.	1.0
20	Limestone: packstone; medium gray to tan, weathers dark gray; slightly nodular; contains abundant fragments of fossils.	1.25
19	Limestone: wackestone; light gray, weathers medium gray; contains abundant clay and fragments of fossils.	0.25

Unit		Thickness feet
18	Dolomitic limestone; gray to tan, weathers dark gray; hard, massively bedded; iron-stained grains.	2.25
17	Marl: light gray, weathers medium gray; contains abundant clay, few fragments of fossils.	0.25
16	Dolomite: tan, weathers medium gray; finely crystalline and sugary; not porous; iron-stained grains.	0.75
15	Dolomite: gray to tan, weathers dark gray; finely crystalline, sugary texture; hard.	0.75
14	Dolomite: tan, weathers dark gray; finely crystalline and porous, sugary texture.	0.25
13	Dolomitic limestone: light gray to tan, weathers grayish-tan; porous, hard; not completely dolomitized.	0.25
12	Dolomitic limestone: light grayish-tan, weathers medium gray; not porous; fairly hard.	0.25
11	Dolomite: tan, weathers dark gray; finely crystalline, porous, sugary texture; iron-stained.	0.25
10	Dolomite: light gray to tan, weathers medium gray; finely crystalline, porous, sugary texture.	0.25
9	Dolomite: light tan, weathers medium gray; finely crystalline, porous; highly burrowed, burrows not destroyed.	0.5
8	Dolomite: tan, weathers medium gray; finely crystalline, porous, sugary texture.	0.75

Unit		Thickness feet
7	Dolomite and dolomitic limestone: light tan, weathers medium gray; slightly porous; some areas more completely dolomitized than others.	1.0
6	Dolomite: tan, weathers dark gray; finely crystalline, porous, sugary texture; iron-stained splotches.	1.5
5	Limestone: packstone; light gray, weathers grayish-tan; slightly nodular, marly; iron-stained grains.	1.25
4	Limestone: wackestone; light gray, weathers medium gray; nodular, some miliolids.	1.25
3	Dolomitic limestone: packstone; medium gray, weathers dark gray; streaks of dolomite throughout-- no pattern; 1/2 inch thick, iron-stained weathering rind.	1.5
2	Limestone: miliolid grainstone; light gray to white, weathers dark gray; abundant miliolids; sparry matrix; fractures on bedding surface trend northeast.	0.5
1	Limestone: wackestone; light gray with orange-stained matrix, weathers medium gray; slightly nodular; white grains stand out in matrix due to color differences.	0.5
	Total section measured	21.75 feet

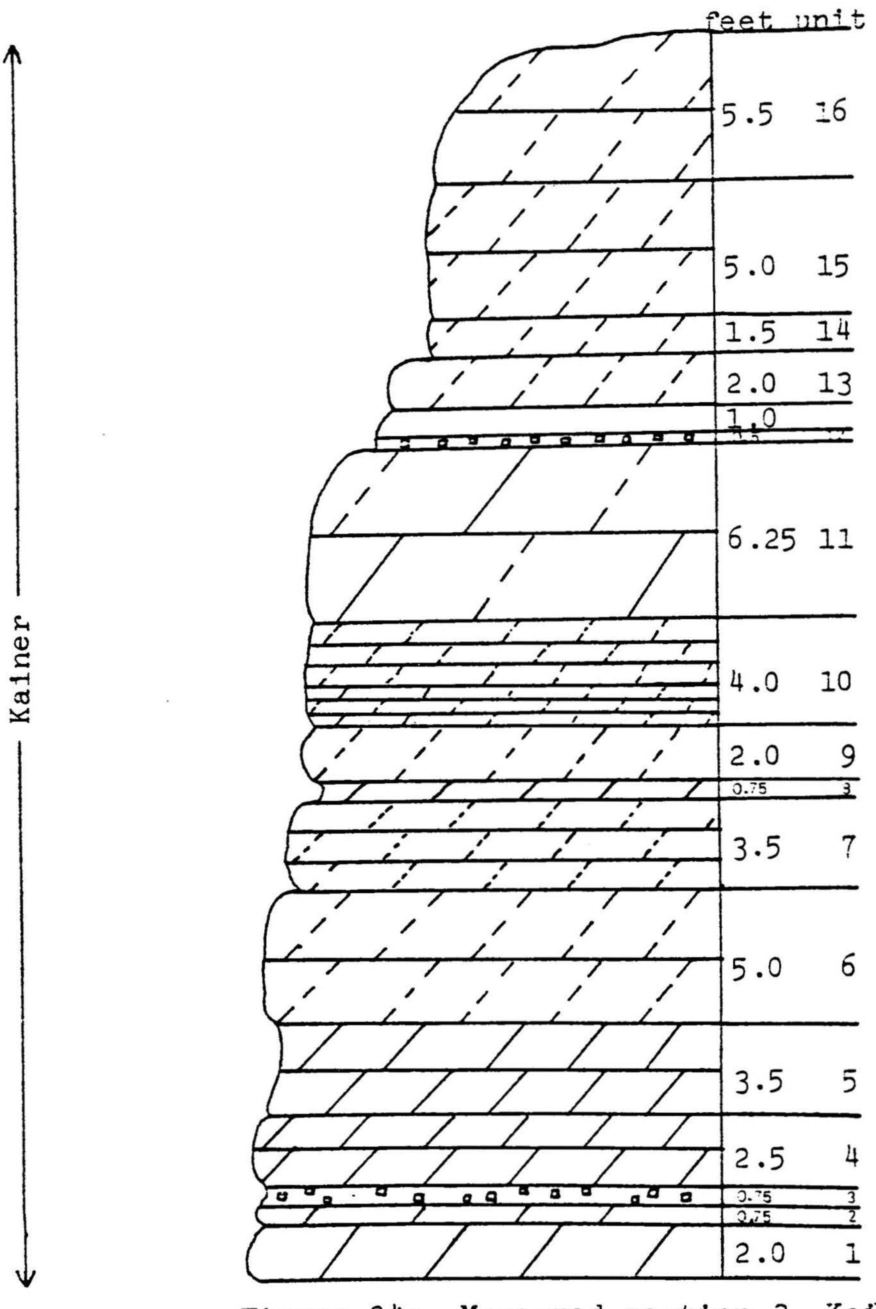


Figure 24: Measured section 3, Kainer Formation of the Edwards Group

SECTION 3

Location: Section 3 is located on the north side of Bear Creek, approximately 100 yards west of where the ranch driveway crosses Bear Creek.

EDWARDS GROUP

Kainer Formation

Unit		Thickness feet
16	Dolomitic limestone: wackestone; medium gray to tan; hard; weathers massively; some areas more dolomitic than others.	5.5
15	Dolomitic limestone: packstone; light gray to tan, weathers medium gray; grains of variable sizes; hard, massive beds; some areas more dolomitic than others.	5.0
14	Dolomitic limestone: hard wackestone; medium gray to white, weathers medium gray; vugs filled with sugary, tan dolomite.	1.5
13	Dolomitic limestone: hard wackestone; medium gray to tan, weathers medium gray; fractures filled with sparry calcite.	2.0
	Covered interval	1.0
12	Collapse zone: soft, very porous, pinkish-tan, masses of calcite; easily broken with a hammer; no bedding.	0.5
11	Dolomite and dolomitic limestone, intermixed: dolomite is medium gray to tan, weathers dark gray; dolomitic limestone is pinkish-gray, weathers light gray;	6.25

Unit		Thickness feet
11	1 massive bed with no pattern of intermixture.	
10	Dolomitic limestone: wackestone; light gray to tan, weathers dark gray; unit is vuggy and porous, weathers into flags 1/4-3 inches thick, thickening towards top of unit.	4.0
9	Dolomitic limestone: packstone; medium gray to reddish-tan, weathers medium- to dark gray; unit has distinct ring when struck by hammer.	2.0
8	Dolomite: finely crystalline and porous; light gray to tan, weathers dark gray; vugs often filled with sparry calcite; unit weathers to give mottled appearance.	0.75
7	Dolomitic limestone: wackestone; medium to dark grayish-tan, weathers dark gray; some unfilled vugs, some filled with sparry calcite.	3.5
6	Dolomitic limestone: hard packstone; light gray to tan, weathers medium gray; slightly porous, massively bedded, some fractures filled with sparry calcite; lower 3 inches contain flaggy beds.	5.0
5	Dolomite: finely crystalline and sugary; light gray to tan, weathers medium gray; unit corroded, with iron-stained strata.	3.5
4	Dolomite: finely crystalline and sugary; light gray to tan; porous and vuggy.	2.5
3	Collapse zone: coarse, crystalline calcite, medium gray to tan; lower 3 inches porous with vugs up to 1 inch across, iron-stained; upper 6 inches more tan, less porous, smaller vugs.	0.75

Unit		Thickness feet
2	Dolomite: finely crystalline and porous; light gray to tan, weathers dark gray; soft and vuggy.	0.75
1	Dolomite: massive, finely crystalline and porous; light gray to tan, weathers medium to dark gray; soft and vuggy.	2.0
	Total section measured	46.0 feet

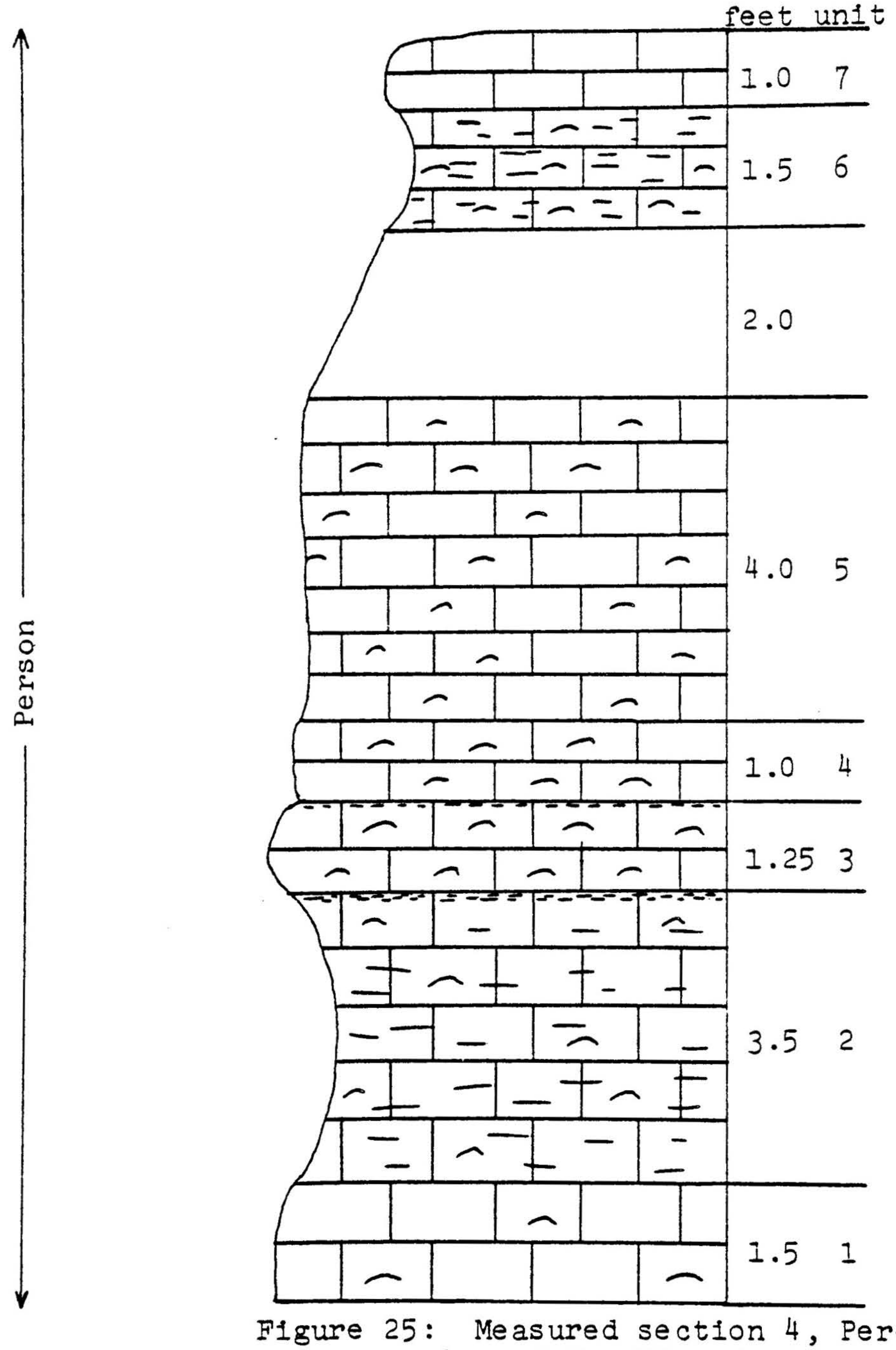


Figure 25: Measured section 4, Person Formation of the Edwards Group

SECTION 4

Location: Section 4 is located on the south wide of the ranch road which runs west along Bear Breek, behind the Spillar household, approximately 20 yards before the road crosses the creek.

EDWARDS GROUP

Person Formation

Unit		Thickness feet
7	Limestone: soft packstone; light tan to white, weathers light gray; nodular.	1.0
6	Marly limestone: wackestone; light gray, weathers light gray; contains abundant fragments of fossils and clay.	1.5
	Covered interval	2.0
5	Limestone: wackestone; tan, weathers medium gray; nodular; contains abundant fragments of fossils and clay.	4.0
4	Limestone: wackestone; light gray to tan, weathers light gray; massive, nodular bed; contains small fragments of fossils.	1.0
3	Limestone: hard packstone; light grayish-tan, weathers light gray; massively bedded; contains abundant fossil fragments; upper 1 inch is marly.	1.25
2	Marly limestone: wackestone; light gray to tan, weathers light gray; slightly nodular; contains a few fragments of fossils; base is slightly burrowed; upper 2 inches are marly.	3.5

Unit		Thickness feet
1	Limestone: hard mudstone; light tan, weathers grayish-tan; contains a few fragments of fossils.	1.5
	Total section measured	15.75 feet

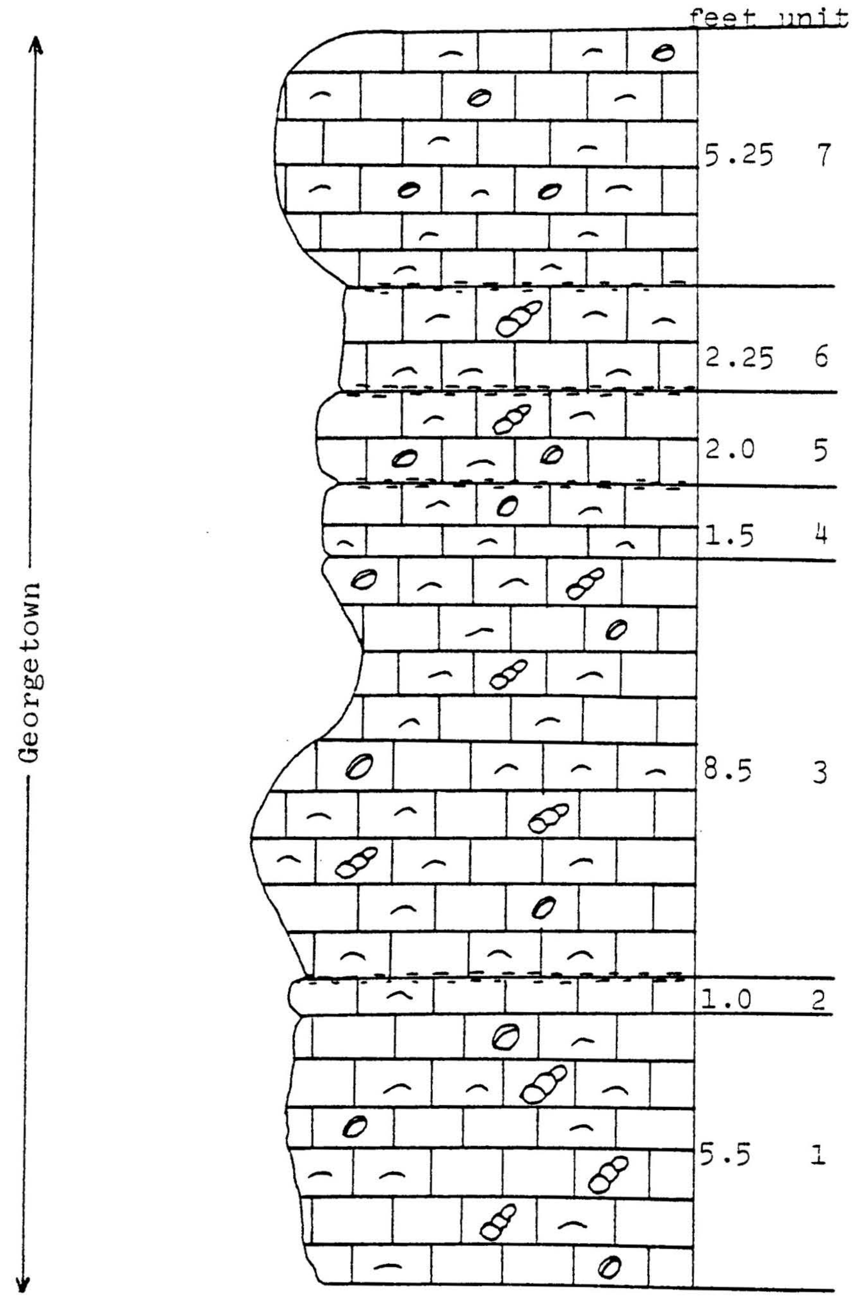


Figure 26: Measured section 5, Georgetown Formation

SECTION 5

Location: Section 5 is located on the south side of Little Bear Creek, on the eastern edge of the map area.

GEORGETOWN FORMATION

Unit		Thickness feet
7	Limestone: mudstone; tan to light gray, weathers medium gray; contains many whole fossils, especially *Texigryphaea* sp., and fragments of fossils.	5.25
6	Limestone: wackestone; light gray to tan, weathers light gray; some fragments of fossils; separated from Unit 7 by a 1-inch, marly horizon.	2.25
5	Limestone: wackestone; light grayish-tan, weathers light gray; nodular; fossiliferous; separated from Unit 6 by a 1-inch, marly horizon.	2.0
4	Limestone: hard wackestone; light grayish-tan, weathers light gray; nodular; contains abundant fossils, especially *Texigryphaea* sp.; separated from Unit 5 by a 1-inch, marly horizon.	1.5
3	Limestone: grainstone; light gray to white, weathers light gray; nodular; contains abundant fragments of fossils and whole fossils and is especially fossiliferous at base with *Plesioturrilites brazoensis* (Römer).	8.5
2	Limestone: wackestone; light gray, weathers medium gray; nodular; contains abundant fossils; separated from Unit 3 by a 1-inch, marly horizon.	1.0

Unit		Thickness feet
1	Limestone: packstone; light gray to tan, weathers medium gray, nodular; contains abundant fossils and fragments, including *Texigryphaea* sp. and *Plesioturrilites brazoensis* (Römer)	5.5
	Total section measured	26.0 feet

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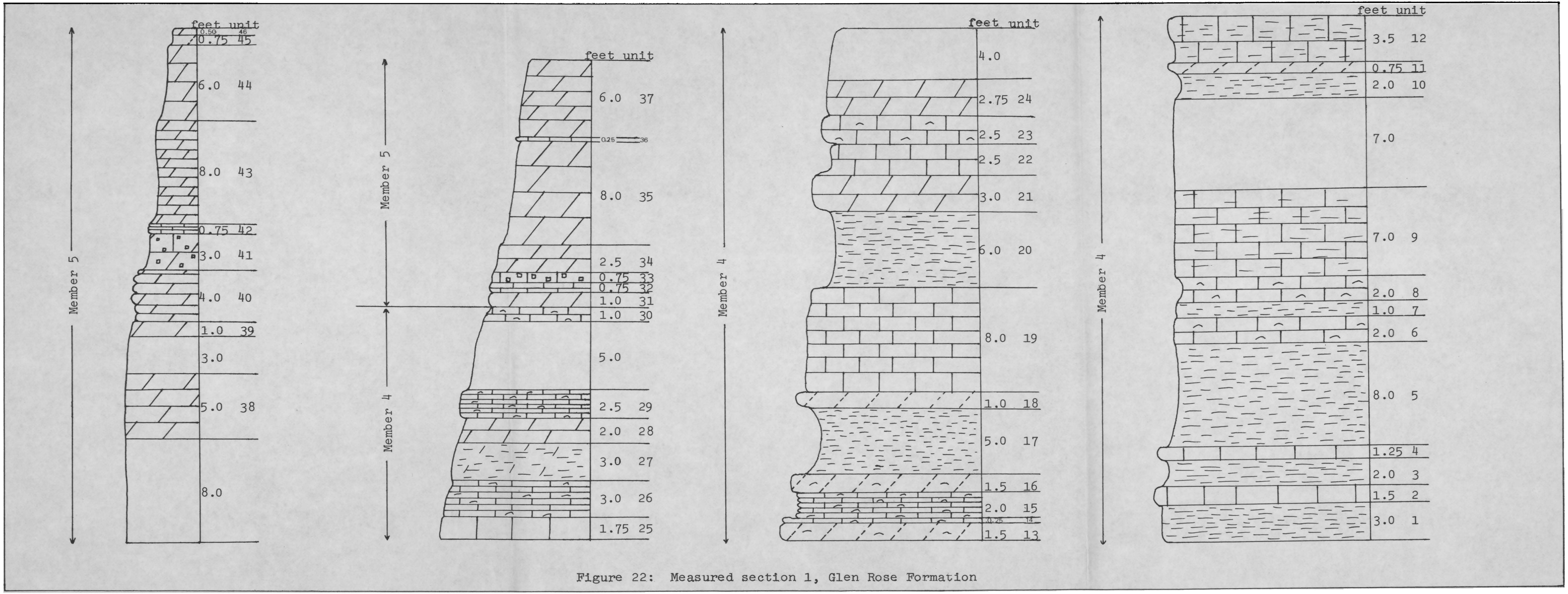

Figure 22: Measured section 1, Glen Rose Formation

Geology by Richard A. Kolb
Summer, Fall, 1980

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PLATE 1: GEOLOGIC MAP OF THE SIGNAL HILL QUADRANGLE, HAYS AND TRAVIS COUNTIES, TEXAS

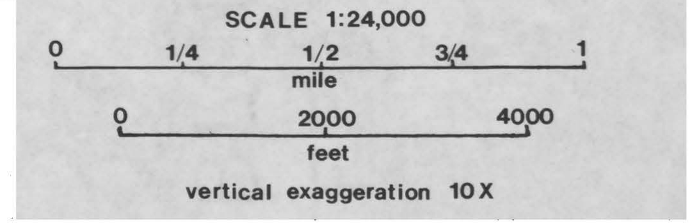

PLATE 2: GEOLOGIC CROSS-SECTION OF THE SIGNAL HILL QUADRANGLE, HAYS AND TRAVIS COUNTIES, TEXAS