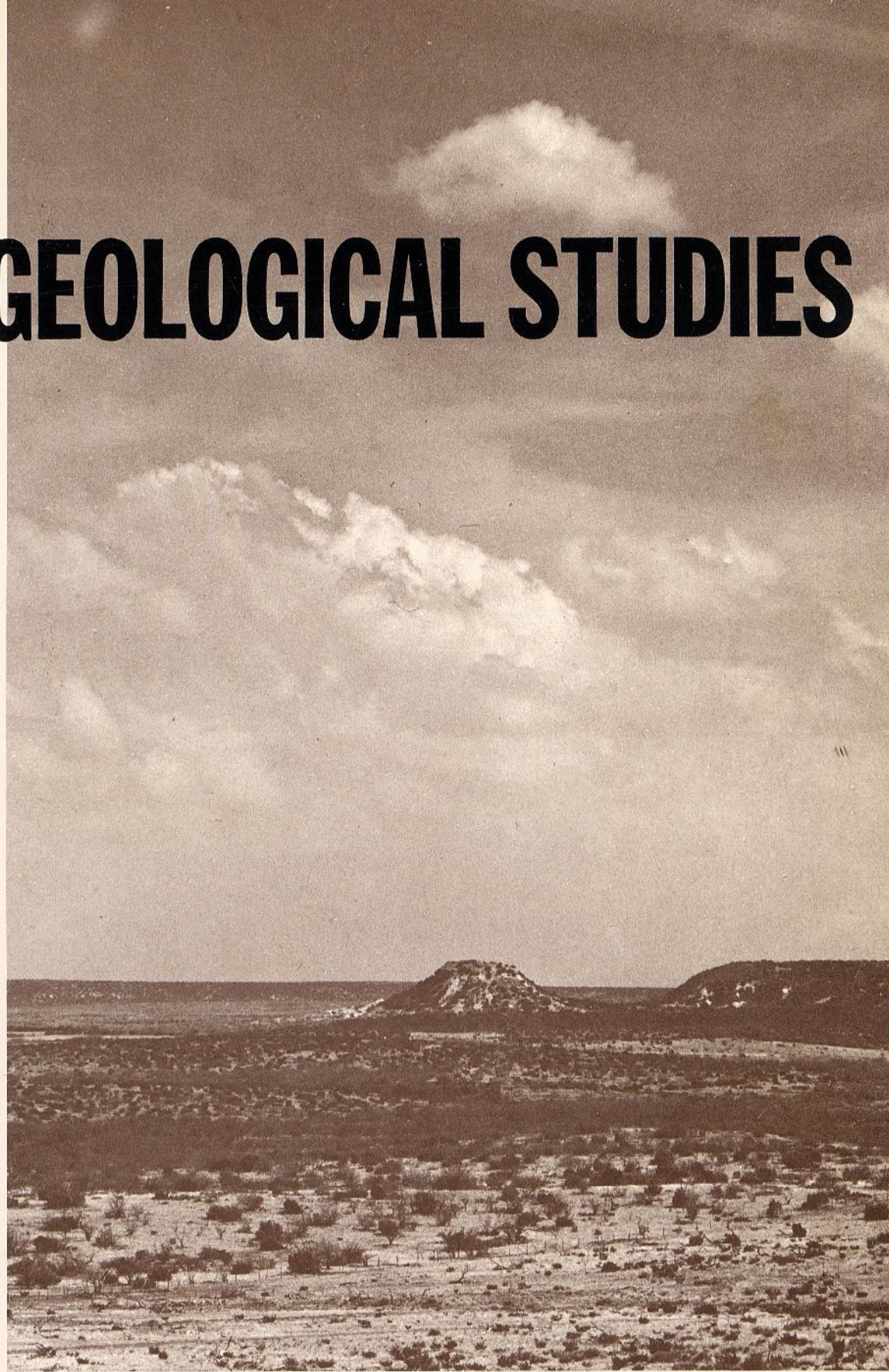
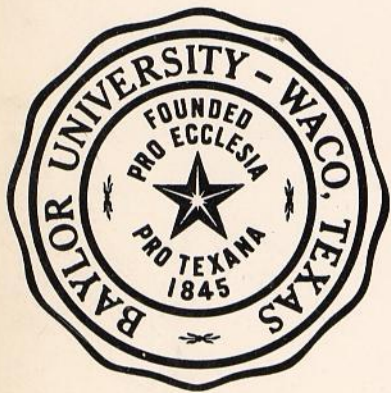


BAYLOR GEOLOGICAL STUDIES

FALL 1973
Bulletin No. 25



*The Nature of the Cretaceous-
PreCretaceous Contact, North-Central Texas*

JAMES S. BAIN

*"Creative thinking is more important
than elaborate equipment--"*

FRANK CARNEY, PH.D.
PROFESSOR OF GEOLOGY
BAYLOR UNIVERSITY
1929-1934

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BAYLOR GEOLOGICAL STUDIES

BULLETIN NO. 25

**The Nature of the Cretaceous-PreCretaceous Contact
North-Central Texas**

James S. Bain

BAYLOR UNIVERSITY
Department of Geology
Waco, Texas
Fall, 1973

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The Nature of the Cretaceous-PreCretaceous Contact North-Central Texas¹

James S. Bain

ABSTRACT

The initial Cretaceous deposits (first 10 to 20 feet of sediments above the Cretaceous-preCretaceous contact) of north-central Texas were deposited on, and, to an extensive degree, derived from the Wichita Paleoplain. The rocks and subsequent landforms of the Paleoplain controlled streams flowing across this surface and supplied the clastic sediments deposited by these streams. The initial Cretaceous sediments are mostly fluvial with some estuarine deposits. Fluvial deposits consist of overbank, point-bar, and channel mud, silt, sand, and conglomerate.

Three major and several minor drainage systems were developed on the Wichita Paleoplain. Outcrops of basal Cretaceous rocks in these ancient drainageways and their adjacent highlands document the fluvial processes in action at the time of their deposition. Basal Cretaceous estuarine mud, overbank laminar-bedded fine silt and mud, point-bar cross-bedded sand and gravel and channel deposits of imbricated or horizontally bedded sand and gravel may be observed across the entire study area. Their occurrence was predetermined by eastward-flowing streams at the dawn of Cretaceous time.

INTRODUCTION²

PURPOSE

Initial Cretaceous sediments of central Texas, apparently of fluvial origin, were deposited on an erosional surface of great age. The topography of that preCretaceous surface was of considerable relief, reflecting both structure and stratigraphy of the Paleozoic and Mesozoic rocks upon which the Cretaceous section rests. The relief of this surface controlled sedimentation of initial Cretaceous deposits. The geometry and composition of later deposits reflected this surface, perhaps to the end of Comanchean time. Hence, the nature of the contact is of considerable interest, not only in terms of initial Cretaceous sedimentation, but also for its effect on later deposition. The surface upon which Cretaceous deposition began is known as the Wichita Paleoplain (Hill, 1901, p. 363), and the present study describes the Wichita Paleoplain and its effect on Cretaceous deposition.

LOCATION

Basal Cretaceous rocks crop out over much of north-central Texas. The study area (approximately 212 miles long and 123 miles wide, at maximum width) encompasses all or parts of the following 18 counties: Parker, Palo Pinto, Stephens, Hood, Erath, Comanche, Eastland, Brown, Mills, Callahan, Coleman, Runnels, Taylor, Nolan, Mitchell, Coke, Sterling, and Howard (Fig. 1). The stratigraphic interval is narrow, however, and ranges from a few feet to 45 feet below the contact, to 40 or 50 feet above.

Cretaceous rocks of this region have formed three topographic provinces, discussed here as the eastern, central, and western sections. These sections generally correspond to the Pennsylvanian, Permian, and Triassic subcrops of the study area.

In the eastern section of the study area basal Cretaceous rocks crop out in a north-south trending belt, known as the Western Cross Timbers (Fig. 1). Here basal Cretaceous sand and mud have weathered to form low, rolling hills and prairies. Cretaceous rocks in the upper drainage of the Leon River have been removed by erosion. As a result of this removal, an extensive inlier consisting of Pennsylvanian rocks of the Strawn,

¹This bulletin is dedicated to the memory of Harold Deen Holloway (1928-1971).

²A thesis submitted in partial fulfillment of the requirements for the M.S. degree in Geology, Baylor University, 1973.

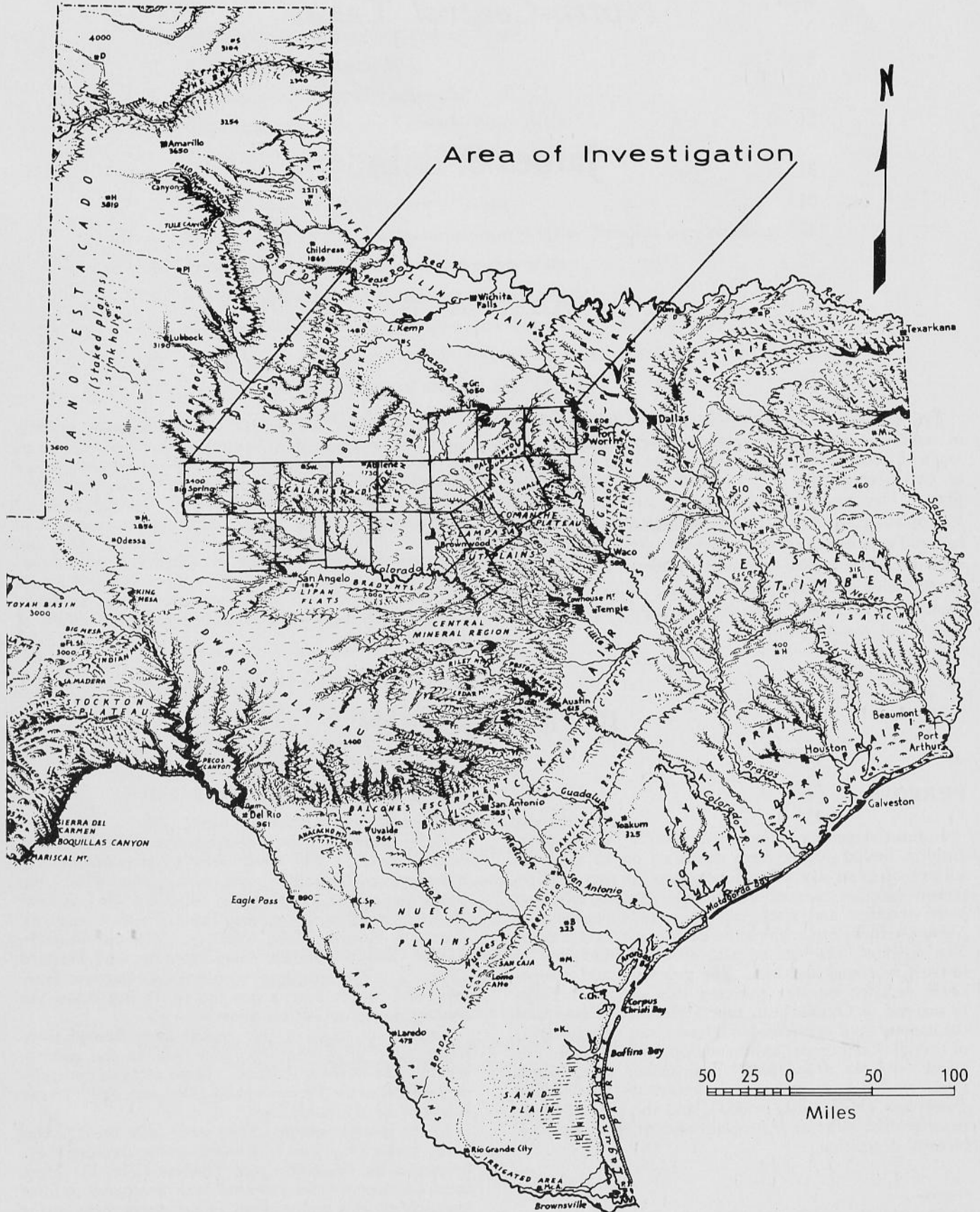


Fig. 1. Index Map. Area of investigation shows county outlines. Physiographic map of Texas. Reproduced from E. Raisz, 1957, Landforms of the United States.

Canyon, and Cisco Groups has been exposed in Eastland and Comanche Counties (Figs. 2, 3). The westernmost extension of basal Cretaceous sediments in the eastern section of the study area is approximately the center of Callahan County. The Western Cross Timbers is separated from the Callahan Divide by the upper Pecan Bayou drainage system and by an east-facing, north-south trending escarpment sometimes referred to as the "limestone belt" (Fig 1). This escarpment is formed by westward-dipping, resistant limestones of the Permian Wichita Group.

The Callahan Divide (Fig. 1) extends from western Callahan County through Nolan County and constitutes the central section of the study area. This topographic feature is formed by numerous outliers and mesas capped by resistant Fredericksburg limestone (Fig. 4), which also affords protection for the underlying, less resistant basal Cretaceous sand, conglomeratic sand, and mud. The Callahan Divide and western section of the study area are separated by the Colorado River valley.

In the western section of the study area (Howard, Sterling, and southwestern Coke Counties), the Lower Cretaceous beds emerge from beneath the younger sediments of the Llano Estacado. Here Fredericksburg limestone also caps mesas and series of long, low, flat-topped hills (cuestas). Basal Cretaceous sediments are exposed in the middle to lower portions of the steep-sided hills and river divides of the North Concho and Colorado Rivers. The basal Cretaceous sediments and underlying Triassic Dockum Group and Permian Double Mountain and Clear Fork Groups are exposed primarily in the Colorado River valley. The North Concho River valley is partially filled by Pliocene and younger deposits.

In the southern part of the eastern section of the study area (Mills and southern Brown Counties), basal Cretaceous sediments consist of a dense, sandy, pebble-to-cobble size conglomerate, the Sycamore Formation. This resistant conglomerate weathers to form rolling hills, observable on the western edge of the Lampasas Cut Plain (Fig. 1).

PREVIOUS INVESTIGATIONS

Roemer (1852), G. G. Shumard (1854), Jules Marcou (1856), and B. F. Shumard (1860) made reconnaissance studies of the Cretaceous rocks of Texas. These stratigraphic and paleontological works contributed knowledge about the Cretaceous section of Texas but were erroneous in recognition of overall stratigraphic sequence. It was not until 1887 that R. T. Hill correctly placed the rocks of the Lower Cretaceous System in their proper order and named the sequence the "Comanche series" (1887, p. 300).

In 1888, Hill assigned the name "Trinity formation" to the Cretaceous beds which underlie the Comanche Series and overlie Paleozoic strata. The next year he (Hill, 1889, p. 290) recognized three divisions in the Comanche Series: the Trinity (Basal), the Fredericksburg (Medial), and the Washita (Upper). At this time, he named the lowermost beds of the Trinity group the Trinity formation (Wilmarth, 1938, p. 2184-2185).

Hill (1889, p. 118) also applied the name Travis Peak sands to the sands of the Trinity Group. In 1901,

Hill further subdivided the Travis Peak Formation into Hensel sands, Cow Creek beds, and Sycamore sands in descending order (1901, p. 142-143). It was in this work of 1901 that Hill first discussed the Wichita Paleoplain. Hill (1901, p. 363-365) stated that the basal Cretaceous rocks of the Black and Grand Prairies rest unconformably upon the eroded Paleozoic surface. Hill's writings are most concerned with the regional aspects and configuration of the Paleoplain, but he apparently did not fully appreciate the amount of local relief on the eroded surface invaded by the earliest Cretaceous seas.

Hill (1901, p. 369) indicated the time transgressive nature of the basal Cretaceous deposits by stating:

"As indicated by their contact with the underlying Paleozoic floor, the shore line of the oldest layers of the Cretaceous rocks was near the present coast. As the sea progressively invaded the land, the successive beds, representing higher and higher horizons in the series, extended westward, their western margins resting upon the Paleozoic floor. Thus, the oldest Cretaceous rocks are found only to the east of the interior margin of the Central Province; the beds of the next horizons overlap these and extend farther west, . . . still later horizons represent the shore line contact between sediments of the advancing Cretaceous sea and the basement rocks upon which they were deposited."

J. A. Taff (1892) in his report on the Cretaceous area between the Colorado and Red Rivers discussed the basal Cretaceous contact at some length. Concerning the actual observation of the contact, he stated:

"In the valleys of larger streams crossing the Trinity sand toward the southeast, and where erosion is very rapid, the contact of the sand with the Paleozoic rocks is easily discerned; but where these conditions are not present, the sands spread out over the edge of the irregular base level in attenuated sheets and remnant areas obscuring actual contacts" (Taff, 1892, p. 282).

Taff (1892, p. 283) also stated that:

"On account of the irregular surface of the Paleozoic rocks, upon which the Trinity sand rests, and on account of the varied erosion of the many streams that pass across it with the dip of rocks, the contact line marks a very tortuous course."

This statement indicates that Taff was also aware of the complex topography on which the basal Cretaceous sediments were deposited. He also noted in commenting on the varying thickness of the Trinity sands:

"Thus it will be seen that the sand of the Trinity varies in thickness and different localities. In fact this difference in thickness is naturally to be expected, since a soft sand is laid down upon a hard, uneven surface" (1892, p. 287-288).

Figure 5 gives some indication of Taff's concept of the preCretaceous surface.

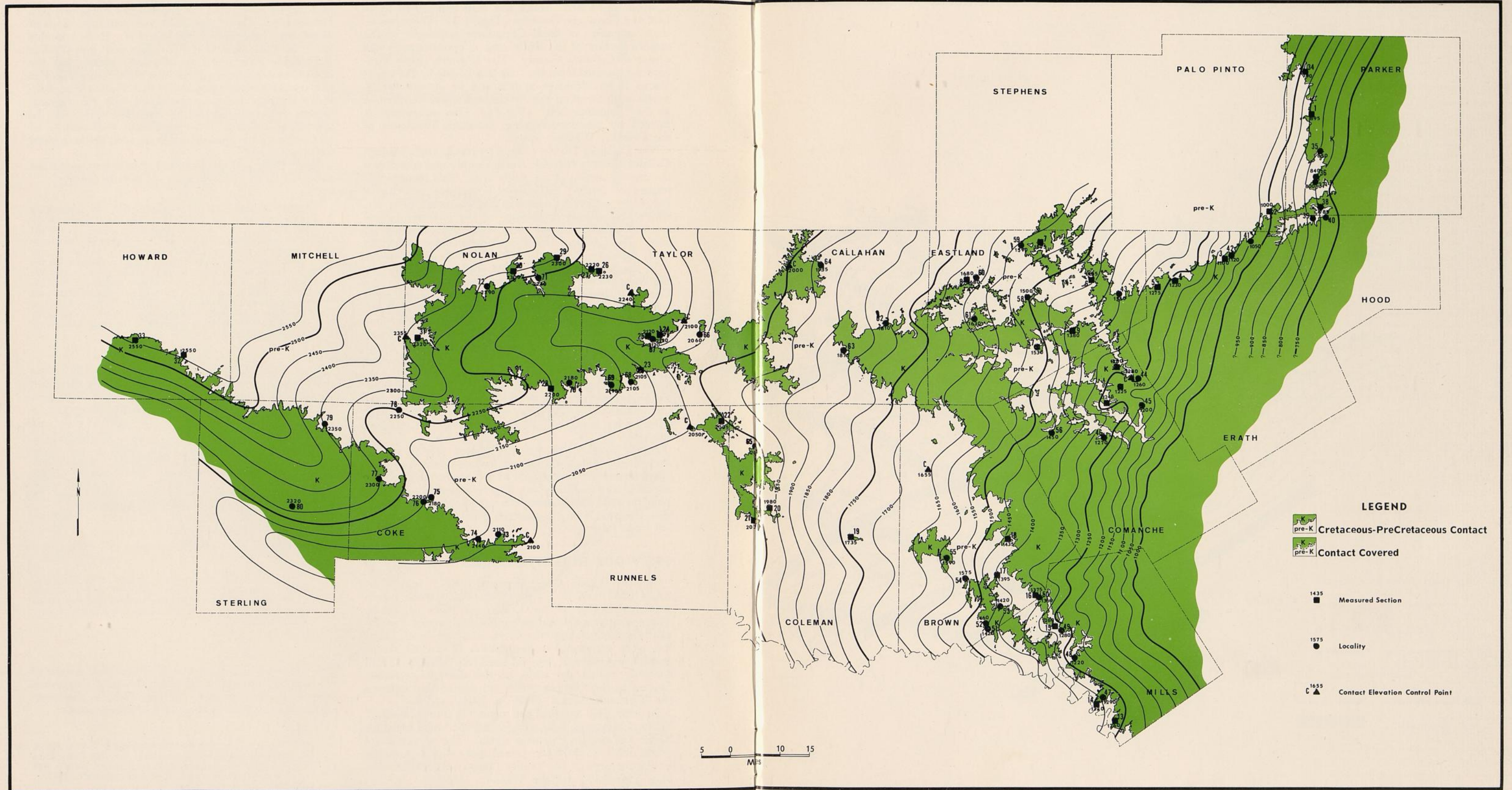


Fig. 2. PreCretaceous topography. Basal Cretaceous contact data compiled from: U. T. Bureau of Economic Geology Geologic Atlas of Texas, Abilene and Dallas sheets; Texas Water Development Board Reports 46, 50, 51, 57; Texas Water Commission Bulletins 6310, 6412; Texas Bureau of Water Engineers Bulletins 5103, 5411.

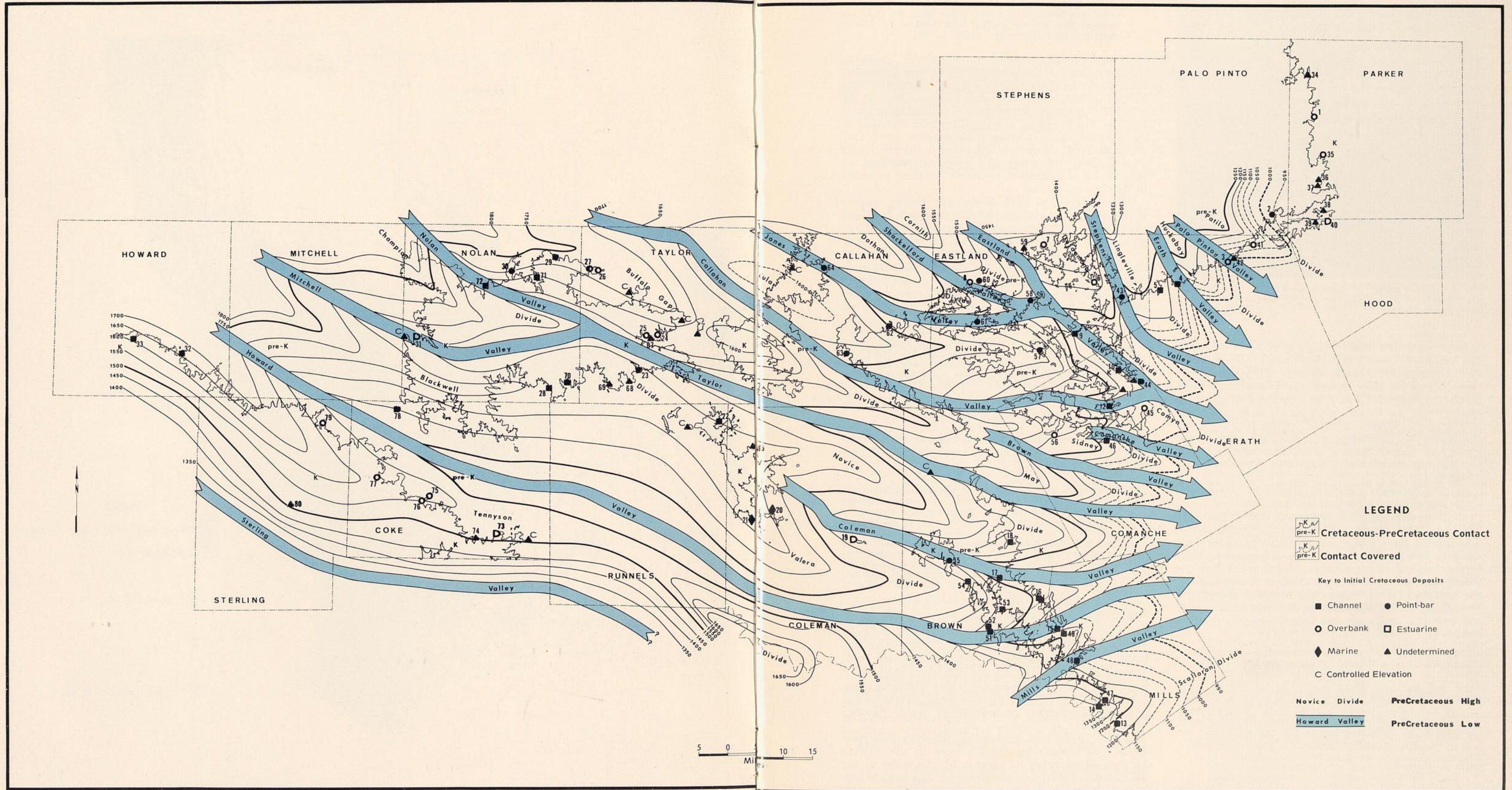


Fig. 3. Residual preCretaceous topography. Basal Cretaceous data compiled from U.S Bureau of Economic Geology Geologic Atlas of Texas, Abilene and Dallas sheets; Texas Water Development Board Reports 46, 50, 51, 57; Texas Water Commission Bulletins 6310, 6412; Texas Board of Water Engineers Bulletins 5103, 5411.



Fig. 4. Coke County. Cretaceous outliers in the Colorado River Basin, view northeast toward the southwestern end of the Callahan Divide.

Later work, but before 1932, was confined to county studies. J. W. Beede and V. V. Waite (1918) reported on the geology of Runnels County. They commented that, "Upon the Permian rest the Comanchean rocks in eastern Runnels County and the San Angelo conglomerate in the western part, which is in turn overlain by the Comanchean rocks" (1918, p. 9). J. W. Beede and W. P. Bentley, in a published work on the geology of Coke County (1918), concluded that the Comanchean rocks there rest upon Permian rocks (1918, p. 16).

G. G. Henderson (1928, p. 23-26) in a report on Tom Green County described the basal Trinity deposits as conglomerate, underlain by maroon shale or clay with white and pink streaks and layers, sometimes sandy. The colored clays and shales predominate in the base and yellowish to white clays are found higher up. Henderson believed this gradation offered proof that the Trinity sea laid down these strata after first reworking the red Permian sediments and observed that ". . . throughout the Trinity division, horizons of lenticular and quartzitic sandstones are found, generally three in number . . ." (1928, p. 24).

Gayle Scott (1930, p. 38), commenting on the Basement sands of the Trinity division, stated:

"In the valley of the Brazos near the Parker-Hood County line the Basement sands lie upon the eroded edges of the lower Strawn (Millsap) beds. Northwestward through the county they overlap successively higher levels and in the northwest corner of the county [Parker] are lying upon Pennsylvanian strata of lower Canyon age."

Scott also noted:

"An interesting feature is to be found in the red beds which occur at certain levels and localities. These are excellently exposed along the escarpment of the Glen Rose one mile northwest of Summit Filling Station, and at numerous other places. So far as the writer knows these red beds have not previously been recorded. They are

different from most so-called 'red beds', in that they are of a deep royal purple color. While these 'red beds' are unusual they are less striking than those of the Paluxy described on a later page" (1930, p. 39).

Adkins (1932) emended the Comanche Series as defined earlier by Hill to include the earliest Cretaceous (pre-Travis Peak) rocks. These are exposed in Malone Mountain, southern Quitman Mountains, and the Rio Conchos region. He stated, "The Comanche series and the Trinity group are therefore here emended to include also all Neocomian strata existent in Texas" (1932, p. 273). Therefore, even though the pre-Travis Peak rocks of this study area were not mentioned by Adkins, his classification provided for their inclusion in the Trinity Group.

Adkins (1932, p. 300) divided the Trinity outcrop in Texas into two classes: the marginal sediments and the offshore, neritic facies. The basal sands, conglomerates, and shales he described in the marginal facies.

L. D. Cartwright, in discussing regional structure of the Cretaceous System on the Edwards Plateau, made observations concerning the topography on which the basal Cretaceous rocks of southwest Texas were deposited. He stated:

"The Trinity division was deposited by a sea encroaching upon an upland plain, traversed by several broad south- and east-draining river valleys, and broken by ridges formed on outcropping resistant formations. Trinity deposits filled the lower areas of the floor of deposition, so that the succeeding Fredericksburg deposits were laid upon an almost level surface except for the tops of some ridges which were never submerged in Trinity time" (Cartwright, 1932, p. 691).

Cartwright also stated that the pre-Cretaceous topography was determined by the nature of the eroded Permian rock:

"Beneath the Cretaceous in the eastern Schleicher County topographically high area is a massive Permian limestone of Wichita-Clear Fork age, the outcrop of which the pre-Cretaceous surface forms the topographically high area. The rocks beneath the Cretaceous in the valleys flanking the high areas and on the marginal slopes are principally shales and sandstone, less resistant materials. Hence, the pre-Cretaceous topography is demonstrably controlled by the areal distribution of hard and soft formations on the old floor of deposition" (1932, p. 697).

In 1938, R. E. Peck described a new species of Charophyta for the Lower Cretaceous system of Texas. He gave the stratigraphic position of *Atopochara travovis* Peck as Glen Rose and reported the occurrence of these charophytes in one well (Eastland et al. no. 1, Schleicher Co., Texas) near the Lower Cretaceous base (Peck, 1938, p. 174). Peck also listed several species of Lower Cretaceous charophytes of North America (Peck, 1957).

Jager (1942) also investigated the subsurface pre-Cretaceous topography. In his work in the western portion of the Edwards plateau, he continued to use Hill's term of Wichita Paleoplain and attempted to present a more detailed regional picture of its surface (1942, p. 380-386).

Livingston and Bennett in a ground water report described the surface geology of the Big Spring, Texas area. This report gives the stratigraphy of the Trinity

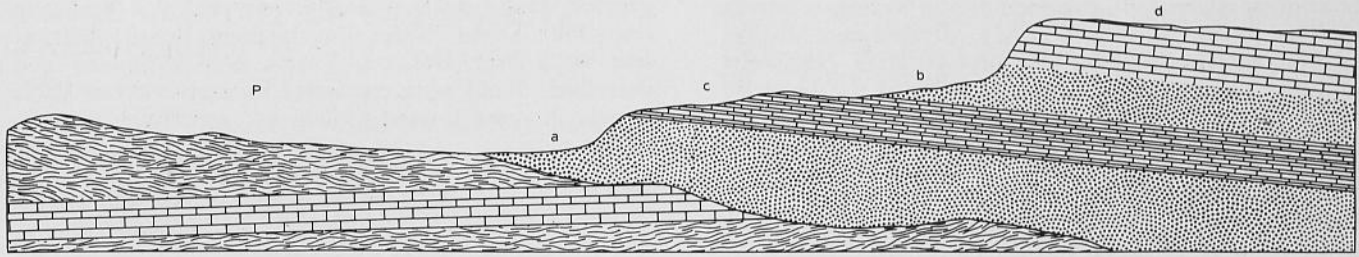


Fig. 5. Topographic phases of Trinity, Glen Rose and Paluxy rocks north of Leon river. P. Paleozoic. a. Trinity phase. b. Paluxy phase. c. Glen Rose phase. d. Comanche Peak phase. From Taff, 1892, p. 292.

formations and good lithologic descriptions (1944).

Sidwell gave a brief report on the size grading and heavy mineral content of Trinity rocks in north-central Texas (1947, p. 68-72).

F. M. Getzender (1956) discussed the stratigraphy and depositional environments of the Trinity rocks and posed several questions. In reference to the basal Trinity beds (Sycamore?) near the Central Mineral Region he stated:

"The shallow Trinity sea of itself was incompetent to tear loose and rework great quantities of coarse materials. At places around the Central Mineral region the Walnut overlaps onto the Paleozoic or older rocks and there is no marginal conglomerate present . . . These younger beds were laid down at a higher level than that of the piedmont [Sycamore] deposit, which already had been reworked and buried under the older Trinity sediments" (1956, p. 80.)

"The piedmont must have been developed at places to the north of the Central Mineral region, also. Along a line running northwest through Lampasas, Mills and Brown Counties the Trinity sands increase gradually in thickness, and grade from coarse to finer and finer materials, becoming restricted to purer quartz with the distance."

"But along the Brazos River in Parker County, . . . there is upward to 200 feet of much coarser material, many of the pebbles ranging in size up to 3 inches in diameter. Although they were deposited on a Pennsylvanian floor, there is no Pennsylvanian material in the conglomerate, all of the Trinity is pure quartz and all the pebbles and grains are well rounded" (1956, p. 80).

Hendricks, in his report on Parker County, discussed the Wichita Paleoplain (1957, p. 30). He reported that though there are topographic irregularities on the unconformity surface the relief on the buried topography does not exceed 50 feet. Thus the Paleoplain is less dissected than the present Pennsylvanian surface.

Hendricks described patches of discontinuous conglomerate that appear to be the oldest rocks found above the eroded Pennsylvanian surface. Above this the next beds are maroon clay containing a sand member that he mapped as a continuous bed (1957, p. 32).

The "red beds" were described by Hendricks as:

". . . massive, structureless units that offer little clue as to origin and type of deposition. They rest on Pennsylvanian or the above-described conglomerate in a sharp contact. The color is very predominantly maroon, but the lower clays have large, irregular green-colored portions. The green coloration apparently is due to differential oxidation or hydration of the iron compounds responsible for the colors of the clays, the green being less oxidized

than the maroon. The lower clays contain scattered pebbles of sandstone and chert and occasional rounded, frosted quartz grains. A thin zone containing hard irregular, calcareous masses is also a feature of the lower clays. . . . The sand member is near the middle of the red bed unit.

. . . The sand and maroon clays together average 30 feet in thickness, and the unit is represented everywhere along the basal Cretaceous contact except where it is overlapped by younger Cretaceous on the sides of old buried hills" (1957, p. 32-33).

In the Cross Plains Quadrangle Stafford (1960a, p. 65) reported up to 150 feet of relief on the surface that lies beneath the Cretaceous sandstones, conglomerates, siltstones and shales. In describing the basal Cretaceous sediments of this area Stafford stated:

"Conglomerate, interbedded with sandstone, is usually present in the basal 5-35 feet . . . At many localities it consists entirely of well-rounded quartz and quartzite granules and pebbles in a matrix of very fine to very coarse sand cemented with calcium carbonate. Rounded pebbles and cobbles of Pennsylvanian and Permian rocks, principally limestone, are common in few places. At one locality . . . however, about two-thirds of the conglomerate consists of reworked chert granules and pebbles from channel-fill deposits of the Permian.

"In some of the topographically lower areas of the pre-Cretaceous surface, as much as 35 feet of sandstone, siltstone, and shale of the Trinity lies between the basal conglomerate and the Paleozoic rocks" (1960a, p. 65-66).

The Grosvenor Quadrangle, south of the Cross Plains Quadrangle was also described in 1960. In this study, R. T. Terriere described the basal Trinity rocks:

"It is difficult to distinguish Cretaceous sandstone outliers from those formed by Pennsylvanian and Permian channel sandstones. They cannot be recognized on the basis of elevation because of relief on the unconformity at their base. One criterion that has been used for distinguishing Cretaceous sandstone from that of Pennsylvanian and Permian age is the presence of quartz pebbles in the Cretaceous rocks, whereas only chert pebbles are present in the sandstone of late Paleozoic age. Furthermore, the sand grains in many of the Cretaceous sandstone beds are more completely rounded than those of the Pennsylvanian and Permian sandstones. Where the base of a sandstone bed is exposed, the presence of caliche or of partly calichified shale or sandstone beneath it is also strongly suggestive of Cretaceous age" (1960, p. 30).

Watson (1964, p. 1726) identified the "basal Mesozoic" red beds of Parker and Hood Counties as Cretaceous on the basis of charophyte gyrogonites (*Atopochara triavolvris* Peck) found in the maroon shales. The

relation of charophyte gyrogonites and fluvial sediments is noted by Friend (1965, p. 52). Friend and Moody-Stuart partially attribute the deposition of calcareous material (caliche?) in fluvial deposits to the presence of charophytes (1970, p. 186-189).

Hendrick (1967) again described the oldest Comanchean rocks in north Texas as "patches of a discontinuous conglomerate observed in a few localities lying on eroded Pennsylvanian beds in Parker County" (1967, p. 52). He also described the "oldest laterally continuous unit" as maroon "red bed" clay containing a cross-bedded sand member in the middle of the succession with large irregular green areas in the maroon clay (1967, p. 53).

Hendricks (1967, p. 63) stated that the lithic unit designated as "basal red beds, sands, and conglomerates" has been named the Twin Mountain Formation by Fisher and Rodda (1966).

Boone (1968) discussed the Wichita Paleoplain in some detail. He noted that the relief of the topography exceeds 100 feet in some areas and reported that this buried land surface "resembles the topography of the Pennsylvanian and Permian outcrop area in North-Central Texas" (1968, p. 13). By using subsurface information downdip from the basal Cretaceous outcrops of north-central Texas, Boone (1968, p. 13-15) mapped and named several topographic features of the Wichita Paleoplain.

Font (1968), in a depositional environment study of the Lower Cretaceous deposits of Hood and Erath Counties, found two species of fossil charophytes and representatives of eight genera of foraminifera. These micro-fossils and few ostracods were found exclusively in the maroon shale sequence of the basal sediments.

PROCEDURES

Field work for this report was initiated during the summer of 1968. This work consisted primarily of measuring and sampling stratigraphic sections and describing localities. Locations and elevations were determined from United States Geological Survey Topo-

graphic Maps, scale 1:24,000 and 1:250,000. Cores from four Texas Water Development Board observation wells near DeLeon, Texas, were examined and described. Field work continued intermittently to 1971, largely directed toward "filling-in" significant gaps in earlier work.

Samples were collected for laboratory investigation. The shales and sandy shales were washed and examined for microfossils. Sands were studied under binocular microscope. Clays were analyzed by X-ray diffraction for clay mineral content (Appendix II). Plotted sections display the results of these laboratory investigations together with the lithology of the stratigraphic sections (Appendix I). The graphic sections were then used for correlation.

Library research, drafting, and writing continued intermittently throughout this period.

ACKNOWLEDGEMENTS

There are always several people to whom the writer of a thesis is indebted. This work is also a product of the labors, ideas, suggestions, and support of many individuals. The supervisor and prime-mover of this study was Dr. O. T. Hayward of Baylor University. Professors J. W. Dixon, Jr., Gustavo A. Morales, Walter T. Huang, and R. L. Bronaugh of the Baylor Geology Department also contributed time and advice during the preparation of this report. Dr. James L. McAtee, Jr. of the Baylor Chemistry Department contributed most generously of his extensive knowledge in clay mineralogy and clay identification.

The writer is also indebted to the Texas Bureau of Economic Geology, especially Dr. L. F. Brown, Jr., and to the Texas Water Development Board for ready access to maps, electrical logs, well cores, and other materials pertinent to this study.

Financial support for the field work and final preparation of this investigation came from the Union Oil Company of California and the Dallas Geological Society.

Dr. Peter A. Boone, Geological Survey of Alabama, kindly reviewed the manuscript before publication.

PRECRETACEOUS GEOLOGY AND PHYSIOGRAPHY

Preceding the deposition of Cretaceous sediments, a period of erosion produced an extensively weathered land surface in north-central Texas. The absence of Jurassic and Triassic rocks in the central and eastern portion of the study area indicates that this part of north-central Texas was positive throughout these periods or that later erosion stripped these rocks away before Cretaceous sediments were deposited. Even as the Cretaceous sea began to advance from the East Texas Embayment, initiating the deposition of Cretaceous sediments in central Texas, the Triassic, Permian, and Pennsylvanian rocks in the study area were being eroded by eastward-flowing streams.

The physiographic features of the erosional surface of the study area resulted from the action of running water on sedimentary rocks which range in lithologic type from shale and silt through sandstone and con-

glomerate to dolomite and limestone. Each of the lithologic units weathered into a distinctive topographic feature (Table 1).

As the land subsided in the path of the advancing Cretaceous sea (Hill, 1901, p. 110), fluvial sediments were deposited by the east and southeastward-flowing streams. These sediments, derived from eroding Triassic, Permian, and Pennsylvanian rocks of the area, were deposited in stream valleys incised into the pre-Cretaceous surface. The advancing Cretaceous sea then inundated the stream valleys, with their confined fluvial deposits and buried them beneath Cretaceous marine sands. The factor controlling the nature and distribution of the initial Cretaceous fluvial deposits was the topography of the pre-Cretaceous land surface which determined the paths of the depositing streams and the nature and amount of material deposited.

AREAL GEOLOGY OF THE WICHITA PALEOPLAIN

STRATIGRAPHY

The initial Cretaceous sediments were deposited on Paleozoic and Mesozoic rocks of three systems: Pennsylvanian, Permian, and Triassic. From east to west, the preCretaceous surface was marked by outcrops of: the Pennsylvanian Strawn, Canyon, and Cisco Groups; the Permian Wichita, Clear Fork, and Double Mountain Groups; and the Triassic Dockum Group. These rocks cover a wide span of sedimentary lithologies including shale, siltstone, sandstone, conglomerate, dolomite, and limestone.

Rocks of Pennsylvanian and Permian age in north-central Texas crop out in west-dipping north-northeast to south-southwest trending belts, exposing rocks of younger age in the west and progressively older rocks to the east. Triassic rocks, exposed only in the western portion of the study area, lie unconformably on Permian strata. Dip of the Triassic rocks is less than that of the Permian; therefore, their outcrop pattern is more erratic, reflecting the natural contour of the topography to a greater degree.

The Strawn Group is the easternmost exposed pre-Cretaceous group. Beds of this unit dip gently to the west, to and over the Bend Arch. Counties of the study area in which Strawn rocks occur are: Parker, Palo Pinto, Erath, Comanche, Brown, and Mills. The Strawn Group was divided by Sellards (1932, p. 108-110) into the Milsap Lake, Garner, and Mineral Wells Formations. The resistant, massive limestone, sandstone, and conglomerate of the Strawn Group and Palo Pinto Limestone of the overlying Canyon Group weather to form several parallel escarpments. Such features were apparently common in this region before the Wichita Paleoplain was buried. Inliers of resistant Pennsylvanian rock (i.e., Kickapoo Falls Limestone in Parker and Hood Counties) reflect topographic highs and their effect on initial Cretaceous deposition.

The Canyon Group also crops out in a northeast-southwest direction and dips westward. Within the study area, these rocks occur in Palo Pinto, Stephens, Eastland, Comanche, Brown, and Coleman Counties. Formations of the Canyon Group are the Palo Pinto, Grayford, Brad, and Caddo Creek (Plummer and Moore 1921, p. 90). Rocks of the upper Canyon Group and lower Cisco Group are less resistant and less massive than those of the Strawn and some of the Permian units. These rocks weathered into low, rolling hills and some ridges. It is in the area of subcrop of these rocks, beneath the Cretaceous section, that the contact is most difficult to delineate. Often the contact exists in an area where the Paleozoic rocks were eroded and transported only a short distance from their initial position to be deposited as Cretaceous fluvial deposits, similar to the Paleozoic provenance.

The outcrop pattern of the Cisco Group follows an almost north-south direction in the study area. The dip of these beds is somewhat steeper than that of the younger rocks to the west. Cisco rocks are exposed in Stephens, Eastland, Callahan, Brown, and Coleman Counties. Plummer and Moore (1921) divided the Cisco Group into the Graham, Thrifty, Harpersville,

Pueblo, Moran, and Putnam Formations. Sellards (1932) placed the Moran and Putnam Formations in the Wichita Group. The Pennsylvanian-Permian division was placed at the bottom of the Moran Formation by Sellards (1932, p. 172), based on the presence of the fusulinid *Schwagerina*.

Westward-dipping rocks of the Wichita Group crop out in a north-south trending belt through Stephens, Callahan, Taylor, Coleman, and Runnels Counties. The formations of the Wichita Group are: Moran, Putnam, Admiral, Belle Plains, Clyde, and Luders (Plummer and Moore, 1921). The resistant carbonate units of the Wichita Group have formed the physiographic feature referred to as the "limestone belt" (Fig. 1). Relief on the east-facing cuestas or ridges, observable in north-central Callahan County, is striking. When followed to the south, these ridges pass beneath Cretaceous sands at the eastern end of the Callahan Divide in the Denton-Oplin area. The features indicate the magnitude of relief of the Wichita Paleoplain buried by Cretaceous sediment in this area.

Three formations, the Arroyo, Vale, and Choza, form the Clear Fork Group of Permian age. These formations occur in north-south trending belts through Callahan, Taylor, Coleman, Runnels, and Coke Counties and have weathered to form the physiographic feature known as the Abilene Prairies (Fig. 1 and Table 1) with numerous outliers and escarpments of low relief. A similar topography probably occurs beneath Cretaceous sediments of the Callahan Divide.

The Double Mountain Group is the uppermost group of Permian aged rocks of north-central Texas. Rocks of this group crop out in a north to southwest-trending pattern in Taylor, Nolan, Mitchell, Runnels, Coke, and Sterling Counties. Sellards (1932, p. 177) divided the Double Mountain sediments into the San Angelo, Blaine, Whitehorse, Cloud Chief, and Quartermaster Formations. The Double Mountain Group and overlying Dockum Group have eroded to form the bad land type topography typical of red beds containing siltstones, sands, and conglomerates. Similar topography is also suggested by the contour patterns of the pre-Cretaceous surface developed on Dockum beds (Fig. 2).

Rocks of the Dockum Group are of the non-marine Santa Rosa Formation in the area of this study. They were laid down on the land surface as river and lake (?) deposits marginal to the eastern edge of the Triassic marine deposits of the western United States (Adkins, 1932, p. 244). These fluvial deposits appear to have been derived from mountains to the west and from the nearer, eroding Permian rocks of the Wichita Paleoplain, to the east (Adkins, 1932, p. 240-245).

STRUCTURE

The Wichita Paleoplain in the study area encompasses parts of a number of structural provinces. From west to east these are: the Midland basin portion of the Permian basin, the Concho (Eastern) shelf, the Bend arch, the Concho arch, the Fort Worth basin, and the Gulf Coastal Plain (Fig. 6). On a much smaller scale, faults in preCretaceous rocks were probably com-

TABLE 1 PreCretaceous Units of North-Central Texas

SYSTEM	GROUP	FORMATION	LITHOLOGIC DESCRIPTION	WEATHERING CHARACTERISTICS	THICKNESS RANGE	GENERALIZED WEATHERING CHARACTERISTICS BY GROUPS OR TYPES
TRIASSIC	DOCKUM	SANTA ROSA	Red clay, sandstone and conglomerate	Dense conglomerates hold up discontinuous ledges; clays and sandstones weather easily	100' to 400'	Red beds forming bad lands
		MOUNTAIN	WHITEHORSE-CLOUD CHIEF-QUARTERMASTER	Dolomites, red shales, thin gypsum beds and fine-grained sandstone	Rolling prairies or bad lands with some ledges and benches	
DOUBLE	BLAINE		Red and gray shales, massive gypsum beds, dolomite and some sandstone	Predominantly rolling prairies with the dolomites and gypsum beds forming escarpments, ledges and benches	300'	
SAN ANGELO	Chert, conglomerate, sandstones and some shales		Conglomerates and indurated sandstones form escarpments and benches; shales are less resistant	60' to 250'		
PERMIAN	CLEAR FORK	CHOZA	Red shales and some thin dolomites (Merkel Member)	Dolomite (Merkel) forms prominent escarpment; shales weather readily to rolling prairie	625' to 820'	Abilene rolling prairies with escarpments and outliers
		VALE	Shale and sandy shale with some sandstone and dolomite	Dolomite (Bullwagon) forms prominent escarpment; shales weather readily to rolling prairie	100' to 340'	
		ARROYO	Shales, limestones, marls and gypsum beds	Uppermost limestone (Standpipe) holds up an escarpment; other units are less resistant	75' to 260'	
	WICHITA	LUDERS	Limestone and shale	Limestone holds up ridges; shale less resistant	65' to 275'	Limestone belt with alternating thin, less resistant shales and sandstones
		CLYDE	Shale, marl and limestones	Limestones hold up ridges and escarpments; shales and marls are less resistant	200' to 475'	
		BELLE PLAINS	Shale, calcareous marl and limestone (limestone becoming thicker in upper portion)	Limestones in upper portion of Formation form escarpments; shale and marl are less resistant	200' to 300'	
		ADMIRAL	Shale and limestone	Limestone (20-50 feet) caps Formation and forms prominent escarpment; shale is less resistant	300' to 350'	
		PUTNAM	Shale with some sandstone overlain by limestone	Shale and sandstone weather easily; limestone (Coleman Junction) forms prominent escarpment to the south which thins and disappears to the north	140' to 190'	
		MORAN	Alternating shales, limestones, sandstones and sandy shales	Limestones form ridges and cap hills; shales and sandstones erode easily	200' to 350'	

Table 1. Continued

SYSTEM	GROUP	FORMATION	LITHOLOGIC DESCRIPTION	WEATHERING CHARACTERISTICS	THICKNESS RANGE	GENERALIZED WEATHERING CHARACTERISTICS BY GROUPS OR TYPES	
PENNSYLVANIAN	CISCO	PUEBLO	Shale with some sandstone and a massive limestone	Shale and sandstone weather easily; massive limestone forms an escarpment	190' to 230'	Alternating weak shale and sandstone with thin, resistant limestones and sandstones	
		HARPERSVILLE	Sandstone at base; shales including coal beds and some limestones and sandstones above	All units weather readily to form rolling prairie topography	240' to 300'		
		THRIFTY	Basal member is sandstone and locally a conglomerate; Shale, coal beds, sand, sandstone and limestone	Limestones hold up ridges and cap low hills; other units weather readily	200' to 230'		
		GRAHAM	Limestone, shale and sandstone	Limestone holds up low ridges; shales and sandstones weather easily	160' to 450'		
	CANYON	CADDO CREEK	Shale and limestone with some sandstones	Shale and sandstone weather easily; limestone holds up small ridges	125' to 350'		
		BRAD	Shales and limestones	Shales weather readily; limestones hold up small ridges	125' to 200'		
		GRAYFORD	Shales, limestones and some sandstones	Easily eroded into low, rolling, rounded hills	450' to 550'		
		PALO PINTO	Limestone	Forms prominent escarpment	50' to 100'		
	STRAWN	MINERAL WELLS	Shales with sandstones and conglomerates; some lenticular limestones	Massive sandstone (Lake Pinto Member) forms distinct escarpment; other units are less resistant	3,500' to 4,000'		Massive limestones, sandstone and conglomerates alternating with less resistant shales. Limestones and sandstones form outliers and escarpments.
		GARNER	Coal and thin limestones; sandy shale, sandstone and conglomerate	Weathers easily to form low, rolling hills and steep-banked creeks; sandstone and conglomerate (Brazos Beds) 25-30 feet thick form an escarpment	400' to 500'		
		MILGAP LAKE	Shale with some conglomerates and thin sandstones; limestones thin and lenticular	Limestones (ie. Kickapoo Falls and Dennis Bridge members) form benches or ledges; shales and sands are less resistant	1,600'+ (bottom not exposed)		

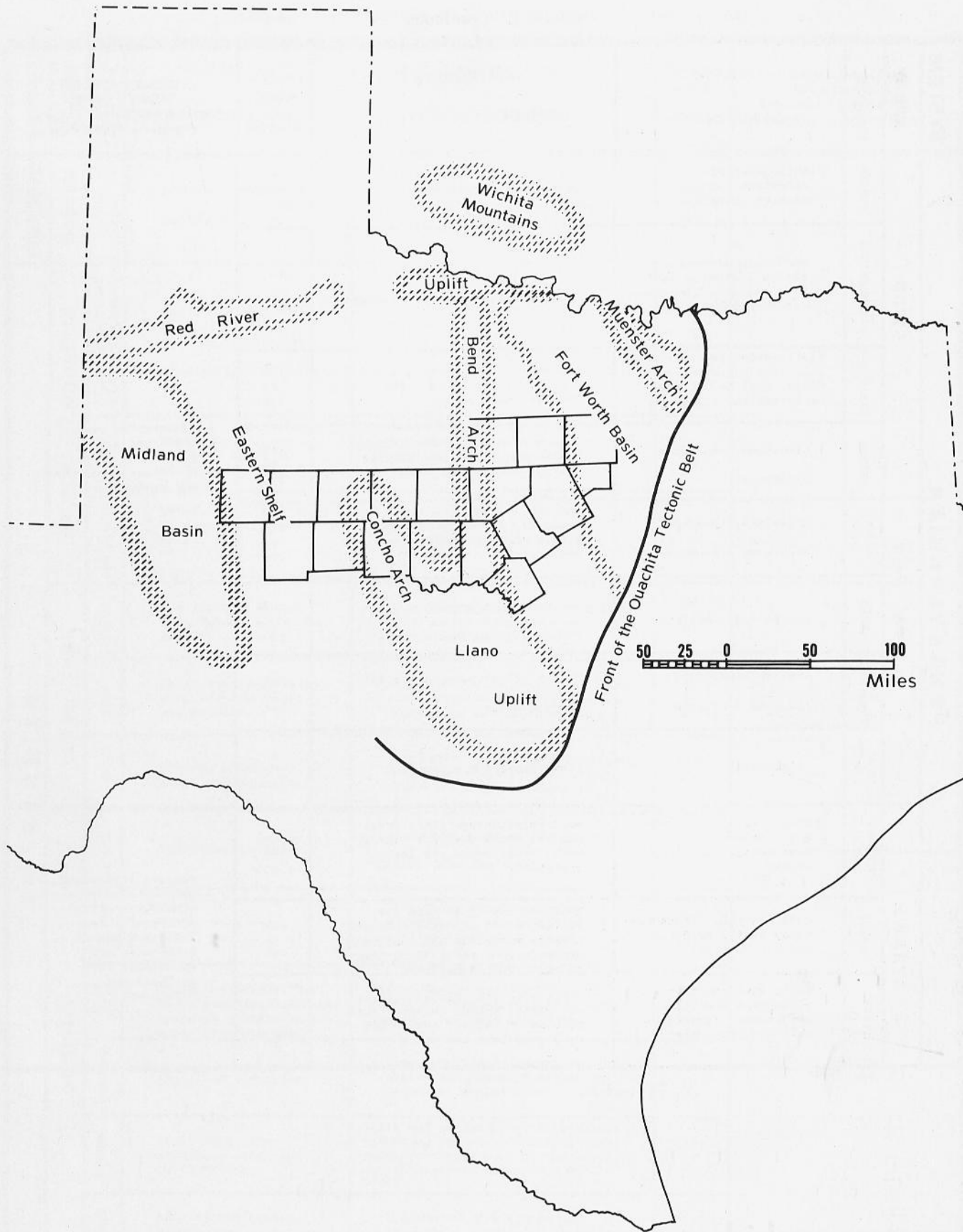


Fig. 6. Tectonic features of north-central Texas. From Eardley, 1951.

mon local structural features. Beyond the study area, major structures also contributed to development of the Paleoplain. These included the Llano uplift to the south-southeast, the Red River uplift and Wichita Mountains to the north, the Muenster arch to the northeast and, as Cretaceous deposition began, the down-to-the-coast faulting of the Gulf of Mexico to the east and

TOPOGRAPHY

Topographic features of the Wichita Paleoplain were determined by the weathering properties and structure of preCretaceous rocks. The more resistant units (i.e., limestones) capped hills, plateaus, and scarps whereas the softer units (i.e., shales) eroded to form valleys. Major streams crossed these lithologic units perpendicular to strike, as do present rivers, while minor tributaries tended to parallel strike.

The amount of local relief of the buried Wichita Paleoplain decreases east to west across the study area. Broad river basins separated by long, wide divides characterize the western portion of the study area, while numerous streams were working headward into the Pennsylvanian rocks in the eastern areas (Figs. 2, 3). The topographic features and relief are roughly equivalent to subcrops of the Triassic, Permian, and Pennsylvanian rocks.

Where basal Cretaceous sediments rest on more resistant preCretaceous rocks, the present landscape is gentle and of low relief. The contact is obscured by outwash and soil development. Where basal Cretaceous sediments overlie less resistant rocks, recent streams have cut deep, and steep-sided valleys exhibit better sections of the contact.

The preCretaceous topography was similar to the present physiography of north-central Texas. Broad river valleys transected the area in a predominantly west to east direction with prominent divides separating them (Fig. 3). Stream patterns of the study area were generally dendritic. Three major streams paralleled each other across the study area with several lesser stream and divide complexes apparent in the drainage systems of each.

In order to describe physiographic features on the preCretaceous surface, names have been given to these features. Valleys were named for the county in which they were first defined by the contours of Figure 3 (i.e., Howard Valley). Divides are named for a metropolitan area through which the axis of the divide passes (i.e., Tennyson Divide).

The southernmost prominent divide in the study area is the Tennyson Divide. This preCretaceous high trends generally southeastward through southeastern Howard County, across the southwest corner of Mitchell County into northeastern Sterling County, across Coke and Runnels Counties, then turns northeastward into and through Mills County. Separating the Tennyson Divide from the Scallorn Divide in southern Mills County is the Mills Valley. The Mills Valley was probably produced by a stream heading in the Llano uplift area. The Sterling Valley, also south of

southeast. Initial Cretaceous deposition in this area began with the gentle tilting and subsidence of the Texas foreland (Sellards, 1934, p. 27-31). With the consequent northwestward advance of the epicontinental sea, Cretaceous sediments buried the Paleozoic and early Mesozoic rocks.

the Tennyson Divide, trends southeastward across Sterling County, eastward across the northern portion of Tom Green County and into Runnels County where it turns south or southeastward. From southern Runnels County, this valley may trend southward around the western side of the Llano area or continue parallel with the Tennyson Divide and connect with the Mills Valley (Fig. 3).

The southernmost major stream valley of the study area is the Howard Valley. This valley may be traced from eastern Howard County through southern Mitchell, north-central Coke, across Runnels, southern Coleman and Brown Counties and northern Mills County (Fig. 3). Apparently the Howard Valley was deflected by the influence of the Llano uplift as it turns to the northeast near the Brown-Mills County line. The large stream which produced this valley probably had numerous tributaries that are not exhibited due to the scale and contour interval of Figures 2 and 3.

The northern flank of the Howard Valley, the Blackwell Divide, is another prominent divide in this area. This topographic high trends southeastward across Mitchell County, eastward through Nolan County into southern Taylor County, and turns southward in the northeastern corner of Runnels County. Here the divide is bisected by the Coleman Valley to form the Valera and Novice Divides. The Valera Divide swings through Coleman County into southern Brown County and thence into northern Mills County. The Novice Divide takes the northern route across Coleman County into central Brown County and into southern Comanche County (Fig. 3).

The Taylor Valley, second in magnitude to Howard Valley, was formed by the confluence of the Mitchell and Nolan Valleys in the east-central portion of Taylor County. The southeastward trend of this valley carries across southern Taylor County, northeastern Runnels County, northern Brown County and into southern Comanche County. The Mitchell Valley trends to the southeast across Mitchell County, and turns to the east in Nolan County as it nears the southeast trending Nolan Valley. These two valleys are separated by the Champion Divide (Fig. 3).

North of the Taylor Valley is the last major divide complex of the study area, the Buffalo Gap Divide. This topographic high trends across northern Nolan County, to the south across central Taylor County and southwestern Callahan County, and into northern Brown County. In Brown County, the first of three lesser divides is formed from the major body of the Buffalo Gap Divide. This is the May Divide which trends southeastward across Brown and Comanche Counties and is separated from the next offshoot, the

Sidney Divide, by Brown Valley. North of the Sidney Divide is Comanche Valley and the last high of the complex, the Comyn Divide (Fig. 3).

Off the northern flank of the Buffalo Gap Divide complex is an intricate system of dendritic valleys and their respective divides. From southwest to northeast they are Callahan Valley (which may or may not be equivalent to Boone's Callahan Valley), Eula Divide, Jones Valley, Dothan Divide, Shackelford Valley, Cornith Divide, and Eastland Valley. The Jones and Shackelford Valleys join at the termination of the Dothan Divide in northwestern Eastland County and in turn merge with Eastland Valley at the end of Cornith Divide near north-central Eastland County. Eastland Valley joins Callahan Valley as Eula Divide dies out in northeastern Comanche County (Fig. 3).

Eastland-Comanche Valley is separated from Stephens Valley to the east by the Desdemona Divide, which in turn is separated from Erath Valley by Lingleville Divide. Continuing to the northeast are a series of small valleys and divides. Huckabay Divide separates the Erath Valley from Palo Pinto Valley which is bounded to the northeast by Patilo Divide.

The preCretaceous topography can be generally described as a region of broad major valleys separated by even broader divides in the west, becoming dissected into numerous, less conspicuous valleys separated by

less prominent divides to the east. The many headward-working east-west trending streams of the eastern region and the fewer, much larger valleys of the western area apparently had numerous but small north-south trending tributary valleys.

The relationship of preCretaceous topography to type of bedrock is well illustrated in north-central Texas. In the eastern portion of the study area where the relatively thin, alternating, resistant and nonresistant Pennsylvanian terrigenous rocks were exposed, streams formed deeply incised dendritic drainage systems. Massive limestone units of early Permian age in Coleman and Callahan Counties tended to favor fewer and larger streams in wide valleys. The streams extended across the outcrop belt of relatively thicker shales, limestones and sandstones of the middle and upper Permian formations. Consequent streams shaped the major topographic features of the area. Subsequent tributaries, in shale valleys between the outcrop belts of more resistant limestone and sandstone, formed trellis drainage patterns. To the west, valleys became larger and less numerous across the Upper Permian rocks until they headed in the flat lying terrigenous units of the Dockum Group. Thus, it was topography, carved by fluvial processes, which controlled much of earliest Cretaceous deposition in central Texas.

INITIAL CRETACEOUS DEPOSITS

Deposition of Cretaceous sediments in the study area began with the slow subsidence of the Texas foreland. The Wichita Paleoplain was inundated by a transgressing sea which advanced to the west and northwest burying the Paleoplain with clastic sediments.

As the Cretaceous sea began its transgression from the East Texas Basin, southeastward-flowing streams were depositing the full spectrum of fluvial deposits on the Wichita Paleoplain.

The first deposits were fluvial sediments left by rivers and creeks as they crossed the Wichita Paleoplain. Over most of the study area these fluvial sediments are mud, silt, sand and small particle conglomerate derived from the underlying Paleozoic and Mesozoic (Triassic) rocks.

In western Mills, southern Brown and southeastern Coleman Counties, the initial Cretaceous deposits are pebble-to-cobble size conglomerates of the Sycamore Formation (Appendix I) deposited by high-gradient streams draining outcrops of Paleozoic rocks of the Central Mineral Region.

In some areas (measured sections 19, 31, locality 73), estuaries and bays developed as the Cretaceous seas advanced inland drowning river mouths and valleys (Figs. 7, 8). Advancing seas eventually covered the area burying fluvial and estuarine sediments beneath quartz sand. It was on this smooth, relatively level floor of marine sand that the carbonate units of the Cretaceous Comanche Series were deposited by transgressing seas.

INITIAL CRETACEOUS SEDIMENTS

Initial Cretaceous deposits are here defined as the lowermost 10 to 20 feet of Cretaceous rock resting on the Wichita Paleoplain. The initial Cretaceous sediments are fluvial, estuarine and marine. Although all these sediments are clastics, they vary considerably in type from mud to conglomerate.

Measured section 3 in Erath County (Appendix I) is typical of the mud found at the Cretaceous base in the northeastern portion of the study area. Initial Cretaceous mud, maroon with green and gray streaks, is almost without sedimentary structures. This overbank or still-water mud was probably reworked from Pennsylvanian sediments of similar appearance which cropped out in this area.

To the west, at measured section 5 (Appendix I) thick (up to 30 feet) accumulations of Pennsylvanian shales are separated from dark maroon, charophyte-bearing Cretaceous mud by loose sand and friable sandstone (Fig. 9). Sand and overlying sandy conglomerate suggest channel deposition by small streams (Fig. 10). To the northeast, at measured section 2 in Palo Pinto County, about 15 feet of dense Pennsylvanian limestone is overlain by Cretaceous point-bar deposits, consisting of red, cross-bedded, coarse-grained sandstone interbedded with white calcium carbonate-cemented pea-gravel conglomerate (Figs. 11, 12).

In Eastland County (measured section 9 and localities 43, 57, 58, 60, 61), the basal Cretaceous sediments

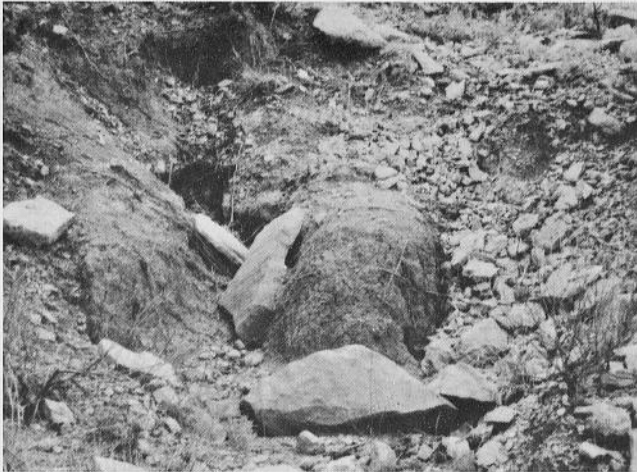


Fig. 7. Locality 73. Coke County. Basal Antlers Formation mud immediately above Permian conglomerate. Float is Fredericksburg limestone. This section indicates that much of the basal Cretaceous mud is reworked preCretaceous material.



Fig. 8. Locality 73. Coke County. Permian mud rock below massive conglomerate (seen as rubble on hillslope).

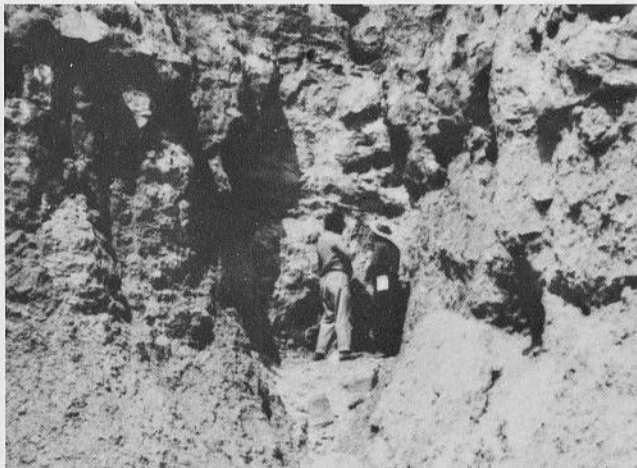


Fig. 9. Section 5. Erath County. Hosston sandstone overlying Pennsylvanian shale. Contact approximately at head level. Note dark (red) mud unit below top of bluff. This is probably reworked Pennsylvanian shale.



Fig. 10. Section 4. Erath County. Hosston sandstone overlying Pennsylvanian shale. These channel sands filled a valley in the subCretaceous surface.

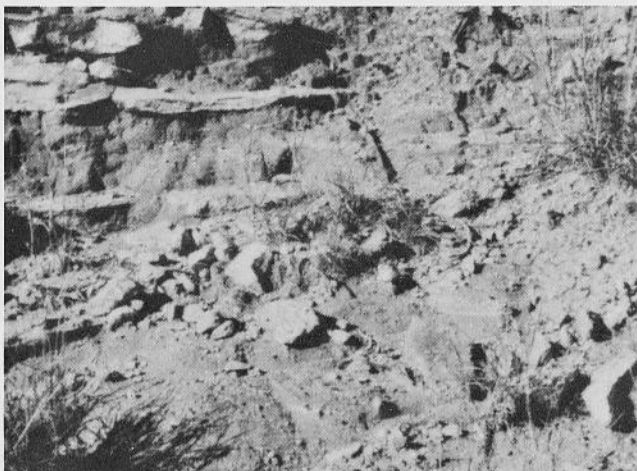


Fig. 11. Section 2. Palo Pinto County. Lower units of Hosston Formation overlying Pennsylvanian limestone (Fig. 12 for detail). The pea gravel accents the cross-bedded nature of these point-bar deposits.



Fig. 12. Section 2. Palo Pinto County. Detail view of unit 4 (Appendix 1, part 2). Note angularity of pebbles and coarseness of sand.



Fig. 13. Locality 43. Eastland County. Large blocks of cross-bedded, pea-gravel conglomerate capping small hill. These deposits commonly represent remnants or lag type material left after erosion of less resistant basal Cretaceous sand and mud.

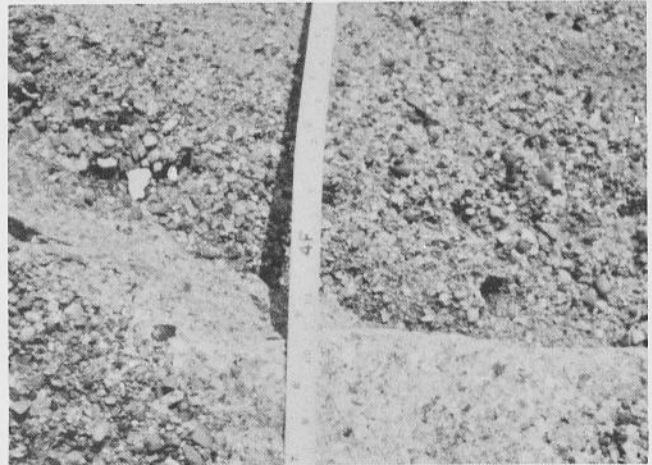


Fig. 14. Locality 57. Eastland County. Detail view of pea-gravel conglomerate in the lower Hensel Formation. This is a typical, dense, well cemented pea-gravel conglomerate. There is some upward fining or grading.

are typically point-bar and channel deposits. Massive, cross-bedded, opaline and calcium carbonate-cemented pea-gravel conglomerate with sand and sandstone is common. The conglomerate is usually discontinuous and lenticular, holding up small, rounded hills (Figs. 13, 14). These point-bar deposits are resistant to erosion when cemented. However, when weathered, they readily disaggregate leaving a residual pea-gravel veneer over large areas. Sandy tan mud overlain by opaline-cemented pea gravel is exposed at section 8 (Appendix I). The point-bar sand and gravel of measured section 9 are highly cross bedded and discontinuous with a wide size range of clastic materials, consisting of tan sand cemented by caliche, white sandy conglomerate, red-brown sandstone with pea gravel, and conglomerate. Overbank maroon mud and white-to-tan muddy sand are exposed in the basal Cretaceous deposits of measured sections 6 (Fig. 15) and 7. Both sections are capped by cross-bedded opaline-cemented pea-gravel conglomerate. The conglomerates are about 42 feet above the contact at section 6 and only 17 feet above it at section 7 (Appendix I).

Initial Cretaceous sediments exposed in Comanche County exhibit a close relationship to underlying topography. Channel and point-bar deposits described in measured sections 10 and 12 and at locality 46 (Appendix I) were deposited in valleys (Figs. 3, 16). The clean channel sand of measured sections 10 and 12 and locality 46 was deposited in Callahan, Eastland, and Comanche Valleys, respectively. Sidney and Comyn Divides were buried beneath thin overbank mud and sandy mud before opaline-cemented pea-gravel conglomerate was deposited over them by coalescing streams.

The Basal Cretaceous deposits of Mills and southern Brown Counties are of an entirely different regime than those of the rest of the study area. High gradient streams rising in the Llano Uplift carried quantities of large (pebble to cobble size) Paleozoic debris into the area of Mills and southern Brown Counties and created the massive piedmont deposits exposed in

measured sections 13, 14, 15, 16, 17, 18, and localities 48, 49, 51, 52, 53, 54, 55 (Appendix I and Figs. 17-19). These channel-fills are characterized by massive, indurated beds of conglomerate and coarse sandstone. The Sycamore Formation thins and the average grain size decreases generally to the northeast. Cretaceous sediments transported along Howard and Coleman Valleys served to dilute the coarse-grained Sycamore sediments with an influx of quartz sand.

In the Bangs area (west-central Brown County), above the thinning Sycamore Formation, later Cretaceous sediments consist of weakly consolidated sand in thin planar beds. This sand, which appears similar to the "blow sand" common to west Texas and the High Plains areas, has washed over and effectively concealed the Lower Cretaceous contact in this area. Similar basal Cretaceous deposits are also exposed near Carbon, Eastland County.

Initial Cretaceous deposits in Callahan County consist primarily of point-bar and channel sands and gravels. Cross-bedded pea-gravel conglomerate and conglomeratic sand, both indurated and unconsolidated were observed at localities 62, 63, and 64 (Fig. 20). In the eastern and central parts of the county, thick deposits of fluvial and marine clastic material form the Antlers Formation, equivalent to the Trinity Group. In contrast, the resistant Permian rocks forming the "limestone belt" are thinly covered by remnants of basal Cretaceous fluvial conglomerate and sand. These basal Cretaceous sediments thicken westward into eastern Taylor County.

The Cretaceous rocks of Coleman and Runnels Counties occur in erosional remnants and outliers forming buttes and mesas. The Trinity units in this area also tend to thicken to the west. The initial Cretaceous sediments exposed at measured section 19 are gray-yellow estuarine and overbank mud, silt, and white to tan sand. Overlying these are thick accumulations of fluvial sand and conglomeratic sand. In measured section 22 (Runnels County) and locality 65 (Coleman County), channel and point-bar sand and pea gravel are exposed



Fig. 15. Section 6. Eastland County. Large blocks of residual cross-bedded pea-gravel conglomerate capping small hill.



Fig. 16. Locality 46. Comanche County. Detail of pea-gravel conglomerate in the lower Hosston Formation. Note size, angularity, and random orientation.

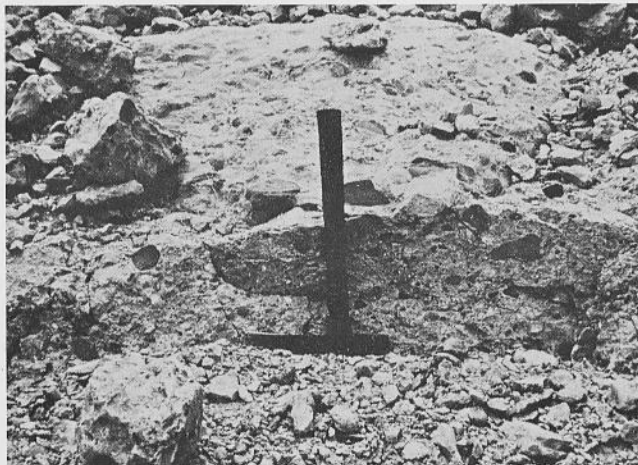


Fig. 17. Section 13. Mills County. The Sycamore Formation is a well cemented, large particle-sized conglomerate at this locality.

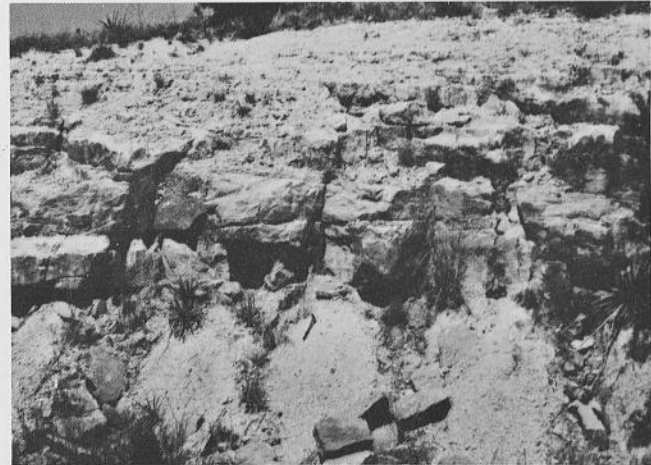


Fig. 18. Section 18. Brown County. Sycamore Formation overlying Pennsylvanian mud and sandstone. Contact at the color change in sand and mud just below the rock hammer. This locality displays the dilution of the conglomerate by coarse sand.



Fig. 19. Locality 49. Mills County. Sycamore Formation, note channel feature at rock hammer. Here the Sycamore is predominantly sandstone.



Fig. 20. Locality 62. Callahan County. Basal Cretaceous contact, Hensel Formation. Channel or point-bar sand and pea gravel.



Fig. 21. Section 20. Coleman County. Lower Antlers Formation marine sand. There are apparently no fluvial deposits present at this section.

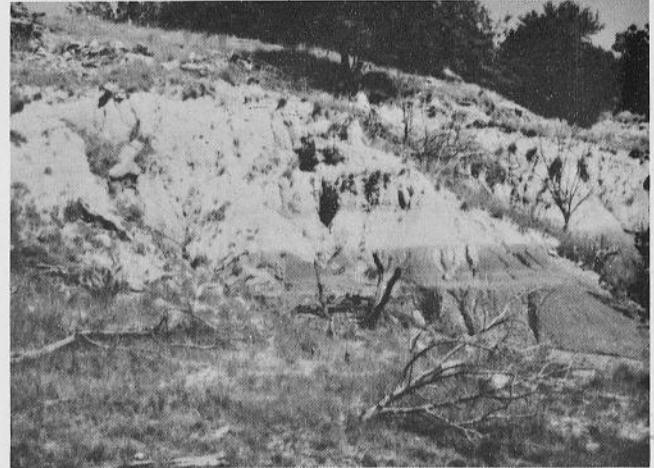


Fig. 22. Section 24. Taylor County. Typical example of the red Permian shale and white Cretaceous sand contact. Antlers Formation (pack sand and yellow mud) overlying maroon or red Permian shale.

(Appendix I). Measured sections 20 (Fig. 21) and 21 show initial Cretaceous sediments anomalous to any observed by the writer in the study area. Section 20 (Appendix I) is composed of white to tan marine sand (pack sand). Although the contact is not exposed, apparently no Cretaceous fluvial deposits occur between this sand and the underlying Permian limestone. This apparent preCretaceous high is further defined by surface exposures in the Talpa-Valera area and is reported to be traceable into the subsurface (Oral Communication, Loyd Walker, Texas Water Development Board, 1971). Measured section 21 (Fig. 2, Appendix I) exposes Cretaceous, Fredericksburg limestone resting on indurated white sandstone, tan to off-white caliche-cemented sand (Cretaceous?) and Permian shale.

Basal Cretaceous deposits exposed in Taylor, Nolan and northern Coke Counties (the Callahan Divide) display the most diverse sedimentary and depositional features in this study area. Estuarine and overbank mud and silty mud are prominent in measured sections 24, 25, 26, and 31 (Figs. 3, 22-26). These maroon and green-gray muds are overlain by white pack sand, conglomeratic sand and/or pea-gravel conglomerate (Appendix I). At measured section 27, maroon mud is thin (1-1.5 feet) and overlain by pea-gravel conglomerate and massive, cross-bedded, conglomeratic, point-bar pack sand (Appendix I). The high angle cross-bedding and conglomeratic sand with interbedded shale at measured section 30 are also indicative of the poorly sorted point-bar deposits common to the basal Trinity deposits of this area. Measured sections 23 and 29 and locality 78 (Fig. 27) display minor amounts of channel fill, although the initial Cretaceous sediments appear to be point-bar in origin. These sediments are thin and immediately overlain by the channel-fill sand. More characteristic, flat-bedded, somewhat indurated channel deposits are exposed at measured section 28 and localities 71 and 72 (Appendix I). The magnitude of relief created by the forming of Taylor Valley (Fig. 3) may be observed in the impressive thickness of lower

Trinity fluvial deposits and upper Trinity marine sand exposed in western Taylor County.

In Howard, Sterling, and Coke Counties along the northern extension of the Edwards Plateau, Fredericksburg and Trinity rocks are exposed at several localities. Locally, the Lower Cretaceous contact may be observed although debris from the Edwards Limestone and younger rocks has formed extensive talus slopes and outwash veneers (Fig. 2). Even bedded, gray-to-white, indurated channel sandstone is typical of initial Cretaceous deposits exposed at measured sections 32 and 33 (Figs. 28, 29) and locality 77, whereas overbank and estuarine mud is common at localities 73, 75, and 76 (Figs 7, 8).

EARLIEST CRETACEOUS DEPOSITIONAL ENVIRONMENTS

Interpretation of depositional environments active during initial Cretaceous sedimentation in the study area is graphically presented in Figure 3. The various environments depicted apply to the period of deposition of the lowest 10 to 20 feet of sediments above the Cretaceous-preCretaceous contact. These environments and their products were associated with streams as they crossed the Wichita Paleoplain and entered the transgressing Trinity sea.

It may be noted from Figures 2 and 3 that the stream valleys and divides were wider and less numerous to the west, becoming narrower and more numerous to the east. However, the streams to the west were neither larger nor of greater capacity than those to the east, as is suggested by the size of the larger clastic material (coarse sand and pea gravel) observed throughout the study area. These suggest mostly small streams of modest capacity but of substantial competence, not greatly different from present streams now draining the area.

In addition to the larger streams outlined in Figures 2 and 3, numerous smaller tributary streams controlled significant sedimentation during earliest Cretaceous

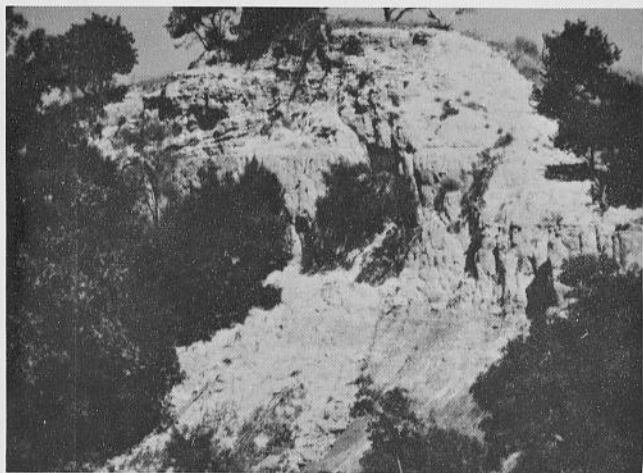


Fig. 23. Section 25. Taylor County. Antlers Formation (pack sand and yellow-green mud) overlying Permian shale. This photograph shows channel sand common to this area of Taylor County.

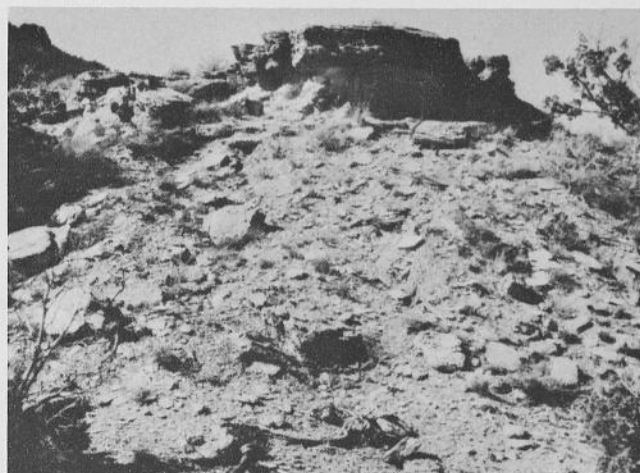


Fig. 24. Section 26. Taylor County. Antlers Formation (peagravel, conglomerate, sand, and mud) overlying Permian shale and siltstone. (Fig. 25 shows detail of upper units.)

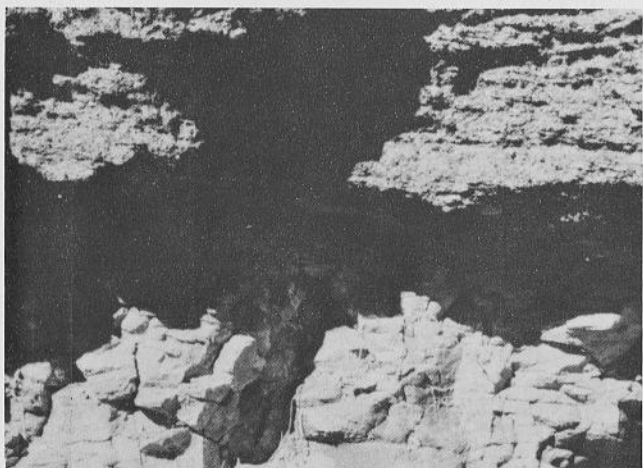


Fig. 25. Section 26. Taylor County. Closeup of units 4 and 5, lower Antlers Formation (Appendix I, part 2).

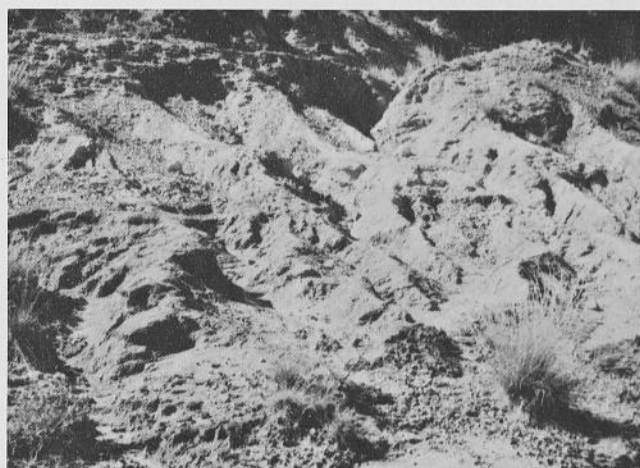


Fig. 26. Taylor County. Approximately 50 yards south of Section 26. Within 50 yards the dense peagravel conglomerate and sandstone are replaced by red siltstone and white sand at the same elevation.

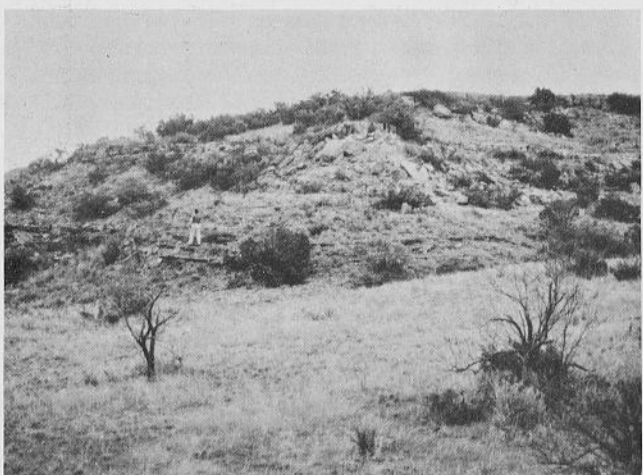


Fig. 27. Locality 78. Coke County. Antlers Formation above Triassic sandstone and conglomerate (geologist is standing at contact on Triassic ledge).

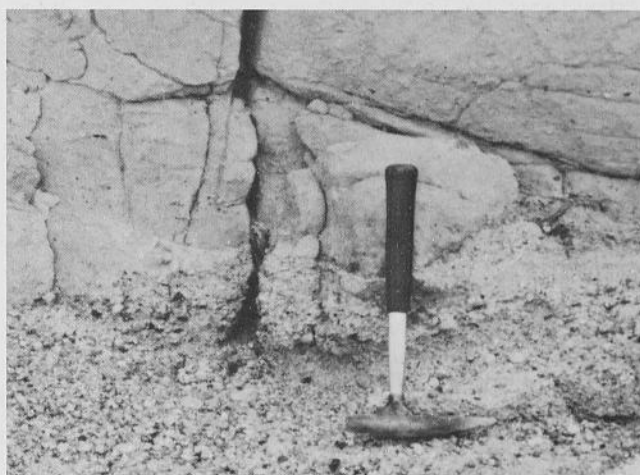


Fig. 28. Section 33. Howard County. Antlers sandstone and conglomerate. (Fig. 29 shows details.)



Fig. 29. Section 33. Howard County. Closeup of sand and pebbles in the lower Antlers Formation (Appendix I, part 2).



Fig. 30. Section 27, unit 4. Taylor County. Sedimentary structures in the lower Antlers Formation (Appendix I, part 2) above basal conglomerate. This section displays many fluvial sequences.

time. Many of the measured sections and localities observed during this study were not in the floors of major valleys or on crests of the divides. Instead, they represent points on valley walls of these ancient features.

Estuarine sediments, deposited in the drowned mouths of shallow early Cretaceous rivers and smaller streams consist mainly of pale yellow or gray-green mud and silty mud which occasionally contain fossil charophytes. These sediments usually are devoid of sedimentary structures such as cross-bedding or ripple marks. During this investigation, no coal or carbonaceous material (except Holocene plant roots) was observed in estuarine or overbank mud. This lack of carbonaceous material suggests an arid climate, such as that reflected in basal Cretaceous rocks in Trans-Pecos Texas (Allbritton and Smith, 1950, p. 1440).

Perhaps the estuarine clay (gray, green, and yellow) can be differentiated from the maroon and red clay of the overbank deposits by the color difference attributed to the oxidation state of iron pigments (Grim, 1951, p. 231). Ferrous iron pigments deposited in brackish or slightly saline water of estuaries may have been buried by later sediments and thus may have retained their predominantly green color, not too unlike those studied by Miller and Folk (1955, p. 340-341). Iron oxides deposited in overbank or flood-plain clay minerals were probably ferric oxides, typically yellow and red in color. However, muds derived from Paleozoic red beds may well have retained their red color, regardless of the restriction of the sedimentary environment (Van Houten, 1968, p. 404).

Overbank deposits are common throughout the study area. This mud and silt exhibits thin, even bedding without cross-bedding. The deposits themselves are usually thin, grading into overlying sand and conglomeratic sand within a few feet from the base of the section.

The most striking of initial Cretaceous sediments are point-bar deposits which contain cross-bedding accented by both pebble and clay layers. Point-bar deposits also

attained significant thicknesses in basal Cretaceous rocks (i.e., measured sections 27, 30, and 33; Figs. 28, 30). Opaline- and calcium carbonate-cemented pebbles conglomerates are also common to point-bar sediments in basal Cretaceous rocks. These also display prominent cross-bedding and, with the exception of the Sycamore Formation, are the most resistant basal Cretaceous sediments.

Channel-fill deposits of basal Cretaceous age differ from point-bar deposits primarily in their bedding. Channel-fill sand and conglomerate are even or flat bedded with little or no cross-bedding. Although mineralogically similar to point-bar deposits, channel-fill material tends to be more uniform in particle size. When conglomeratic sand is present, the pebbles are usually in bands representing restricted zones.

The Sycamore Formation is a heterogeneous accumulation of sand and pebble-to-cobble size conglomerate. Nearness of the Llano Uplift source area and grade size of the Sycamore sand and gravel indicate deposition by streams with high transport capacity and competence.

Clean, white-to-tan marine sand of varying thicknesses (measured sections 20 and 21) separates Permian rocks from the overlying Fredericksburg limestone. Fluvial deposits are thin or absent (Fig. 21). The relatively thin accumulations of marine sand and absence of fluvial deposits indicate a pre-Cretaceous high or positive area that was not inundated until late in Trinity time.

The size of clastic material in the fluvial deposits of the study area does not indicate depositing streams of large capacity or competence. In the western portion of this study area, streams flowing off Tennyson and Blackwell Divides deposited mud and sand in upper Howard Valley. To the east, lower Howard, Mills, and Coleman Valleys were receiving vast quantities of gravel and sand from the Llano Uplift. Mitchell and Nolan Valleys converged in western Taylor County at the end of the Champion Divide to form the Taylor Valley. The streams in these drainages were depositing

sand and conglomeratic sand of point-bar and channel-fill origin with occasional overbank mud. Northeast of Buffalo Gap Divide an extensive series of valleys and divides developed in Permian and Pennsylvanian rocks. Here opaline- and calcium carbonate-cemented, cross-bedded, pea-gravel conglomerate was extensively de-

posited in the point-bars of numerous streams. Stream patterns (Fig. 3) indicate the source of the pea gravel and much of the maroon mud underlying them to be from the north and northwest. Pea gravel in the western portion of the study area may have been derived by the reworking of Dockum conglomerate.

SUMMARY

The distribution and lithology of preCretaceous, Paleozoic, and Mesozoic rocks had a profound effect upon preCretaceous topography, and hence the deposition of initial and later Cretaceous sediments in the study area. Valleys in the Wichita Paleoplain of north-central Texas were sites of estuarine and fluvial deposition before the transgressing Trinity sea inundated the area. The source of the estuarine and fluvial sediments was the material from which the Paleoplain was constructed. Their final resting place was determined by erosion and transportation capacity of the depositing streams.

Figure 2 depicts the buried topography of the Wichita Paleoplain as it now exists and Figure 3 shows it at the time of initial deposition of Cretaceous rocks. These illustrations show only the larger valley and divide features, generally trending across the dip of the pre-Cretaceous rocks. Most initial Cretaceous sediments were deposited by smaller tributaries of these major drainage systems. Many of these unmapped tributaries flowed along strike in subsequent valleys somewhat perpendicular to major streams. In areas where pre-Cretaceous rocks were homogeneous, streams developed dendritic patterns. Areas of alternating beds of resistant and non-resistant preCretaceous rocks produced trellis drainage patterns. The streams of that time and place were probably of moderate capacity and competence.

Topographic features of the Wichita Paleoplain were dictated by the erosional characteristics of the exposed preCretaceous rocks. The more resistant limestones, sandstones, and conglomerates formed preCretaceous highs, whereas the less resistant shales and sands were eroded to form low areas. Knowledge of the underlying preCretaceous beds may be used to predict the

general contact topography and type of initial Cretaceous sediments found above the contact. Conversely, knowledge of preCretaceous topography permits prediction of type and thickness of earliest Cretaceous rocks and general character of rocks underlying the contact.

Generally, basal Cretaceous sediments deposited on resistant preCretaceous rocks have developed into a Holocene topography of low relief (i.e., locality 40, Hood County, where Cretaceous sediments overlie the Kickapoo Falls Limestone). Holocene topography developed in Cretaceous sediments resting on easily eroded preCretaceous rocks (i.e., Vale Formation at measured sections 24 and 25, Taylor County) has considerably more relief.

The use of fossil charophytes for identification of earliest Cretaceous sediments was found impractical in this study, due largely to the lack of fossils. Evidently conditions for preservation of fossils were not optimum in the somewhat arid continental environment of central Texas. Correlation by clay mineral composition of initial mud and muddy sand was found to be impractical because significant trends were not observed.

As in every investigation, during the course of this study a number of parallel problems were encountered but, because of time, had to be ignored. Obviously, significant and more detailed paleo-topographic studies of the Wichita Paleoplain can be made in peripheral areas. Mapping and stratigraphic investigations of specific fluvial units within the basal Cretaceous sediments may be effectively pursued to trace in detail individual river networks. Detailed mapping of buried paleoplain valleys should also provide geologic information on most available groundwater in parts of Taylor, Coleman, Callahan, Howard, Sterling, and especially Coke Counties.

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APPENDIX I, PART 1

SUMMARY OF MEASURED SECTION AND LOCALITY DATA

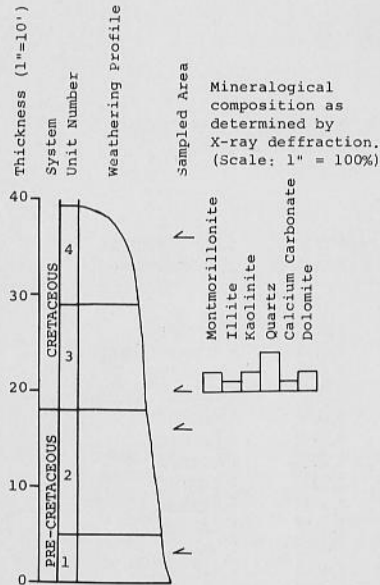
SECTION OR LOCALITY No.	CONTACT ELEVATION	DEPOSITIONAL ENVIRONMENT	COUNTY	SECTION OR LOCALITY No.	CONTACT ELEVATION	DEPOSITIONAL ENVIRONMENT	COUNTY
1	895'	Overbank	Parker	41	1,050'	Overbank	Erath
2	1,000'	Point-bar	Palo Pinto	42	1,120'	Undetermined	Erath
3	1,100'	Overbank	Erath	43	1,350'	Point-bar	Eastland
4	1,230'	Channel	Erath	44	1,260'	Channel or Point-bar	Comanche
5	1,275'	Channel	Erath	45	1,200'	Overbank	Comanche
6	1,465'	Overbank	Eastland	46	1,270'	Channel	Comanche
7	1,575'	Overbank	Eastland	47	1,290'	Channel	Mills
8	1,680'	Overbank	Eastland	48	1,220'	Channel	Mills
9	1,380'	Channel	Eastland	49	1,280'	Channel	Mills
10	1,280'	Channel	Comanche	50	1,360'	Channel	Brown
11	1,225'	Undetermined	Comanche	51	1,420'	Channel	Brown
12	1,245'	Channel	Comanche	52	1,460'	Channel	Brown
13	1,260'	Channel	Mills	53	1,420'	Channel	Brown
14	1,320'	Channel	Mills	54	1,575'	Channel	Brown
15	1,260'	Channel	Mills	55	1,590'	Point-bar	Brown
16	1,375'	Channel	Brown	56	1,450'	Overbank	Comanche
17	1,395'	Channel	Brown	57	1,530'	Point-bar	Eastland
18	1,435'	Channel	Brown	58	1,500'	Point-bar	Eastland
19	1,735'	Estuarine & Overbank	Coleman	59	1,590'	Undetermined	Eastland
20	1,980'	Marine	Coleman	60	1,680'	Point-bar	Eastland
21	2,030'	Marine	Coleman	61	1,630'	Channel	Eastland
22	2,005'	Channel	Runnels	62	1,810'	Channel & Point-bar	Callahan
23	2,105'	Channel or Point-bar	Taylor	63	1,875'	Point-bar	Callahan
24	2,120'	Overbank	Taylor	64	1,935'	Point-bar	Callahan
25	2,120'	Overbank	Taylor	65	2,015'	Undetermined	Coleman
26	2,230'	Overbank	Taylor	66	2,060'	Undetermined	Taylor
27	2,220'	Overbank or Point-bar	Taylor	67	2,120'	Undetermined	Taylor
28	2,200'	Channel	Nolan	68	2,105'	Undetermined	Taylor
29	2,300'	Channel or Point-bar	Nolan	69	2,190'	Undetermined	Taylor
30	2,300'	Point-bar	Nolan	70	2,180'	Channel or Point-bar	Nolan
31	2,320'	Estuarine or Overbank	Nolan	71	2,240'	Channel	Nolan
32	2,550'	Channel	Howard	72	2,290'	Channel	Nolan
33	2,550'	Channel	Howard	73	2,110'	Estuarine or Overbank	Coke
34	990'	Undetermined	Parker	74	2,140'	Undetermined	Coke
35	850'	Overbank	Parker	75	2,180'	Overbank	Coke
36	840'	Undetermined	Parker	76	2,200'	Overbank	Coke
37	800'	Undetermined	Parker	77	2,300'	Overbank or Channel	Coke
38	785'	Undetermined	Parker	78	2,250'	Channel or Point-bar	Coke
39	—	Paleozoic	Hood	79	2,350'	Overbank	Sterling
40	—	Estuarine or Overbank	Hood	80	2,320'	Undetermined	Sterling

APPENDIX I, PART 2

MEASURED SECTIONS

Key to form used in presentation of section data.
Section Number and Location.

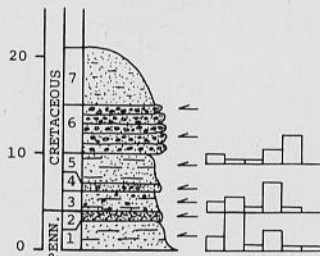
4. Lithologic description and thickness of individual units.
- 3.
- 2.
- 1.



SECTION 1. Parker County (lat 32°48'N; long 97°59'W)

In road cut along east side of Farm Road 113. Section on north side of Paterson Branch, runs from south to north and is approximately 0.3 mile from the intersection of Farm Road 113 and U.S. Highway 180. Contact elevation 895 feet.

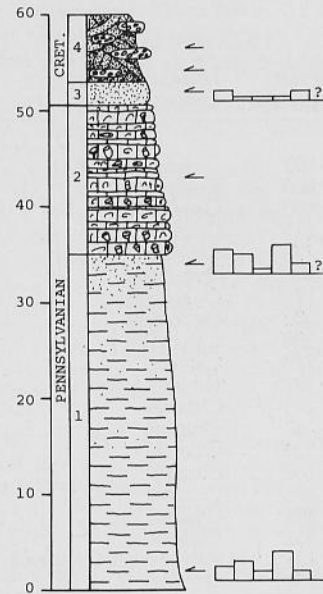
7. Sandy and muddy soil top of hill. 6.0'
6. Sandy pea-gravel conglomerate overlain by dense off-white, brown weathering sandstone: calcium carbonate cement. 5.0'
5. Mud: maroon with streaks of green sand; badly calichefied. 3.2'
4. Sandstone: gray, dense, calcium carbonate cement with some pea gravel. 0.8'
3. Mud: gray, weathers yellow, sandy, with pea gravel. 2.0'
2. Sandstone: gray-tan, dense, cross-bedded, calcium carbonate cement, laminated and ripple marked. 0.8'
1. Shale: maroon, yellow-green, weathers gray-tan, sandy, fissile. 3.0'



SECTION 2. Palo Pinto County (lat 32°34'N; long 98°07'W)

In road cut of county road east of U.S. Highway 281. Section begins at intersection and continues for approximately 0.3 mile to crest of hill. Contact elevation 1,000 feet.

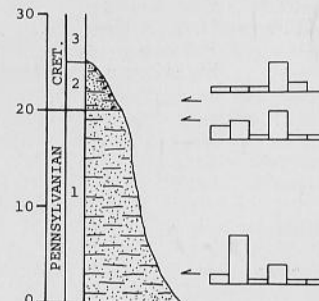
4. Sandstone: red, highly cross-bedded, coarse grained. Interbedded with white, calcium carbonate-cemented conglomerate, loose pea gravel over entire area of unit. 7.5'
3. Sandstone: red-brown, bedded but weakly consolidated. 2.5'
2. Limestone: tan to gray, weathers black, abundant fossil fragments, small crinoid stems and solitary corals. Well bedded thin to massive. Badly slumped. 15.5'
1. Shale: gray-tan, weathers yellow, sand stringers near top, charophytes in lower portion. 35.0'



SECTION 3. Erath County (lat 32°27'N; long 98°15'W)

In small creek 300-400 yards south of Sapok School. Section runs upstream to the east beginning at county road. Contact elevation 1,100 feet.

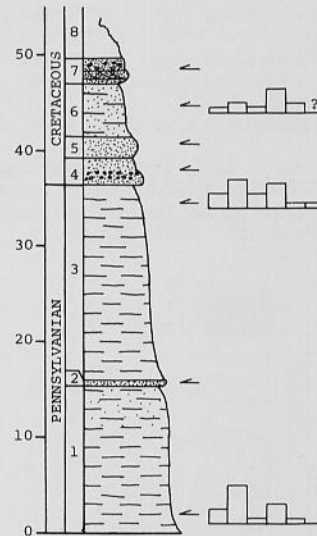
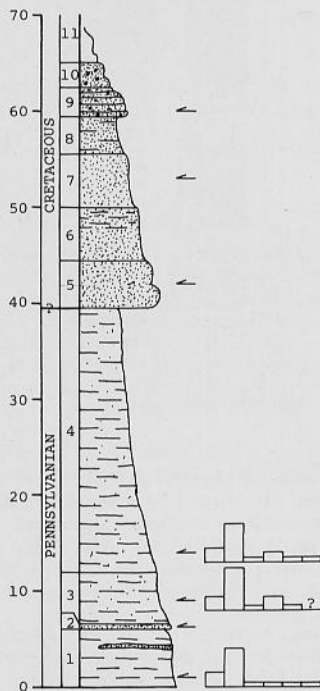
3. Cobbles of opaline-cemented pea-gravel conglomerate in pasture above section.
2. Mud: maroon with green sand streaks, sandy, abundant loose pea gravel with charophytes grades into soil above. 5.0'
1. Mud: maroon-gray-green, weathers tan with yellow streaks, sandy, fissile, some thin siltstone stringers. 20.0'



SECTION 4. Erath County (lat 32°23'N; long 98°23'W)

In bed of Salt Creek and up west-facing bluff, south of county road. Eastern boundary of the Fambro Ranch. Contact elevation 1,230 feet.

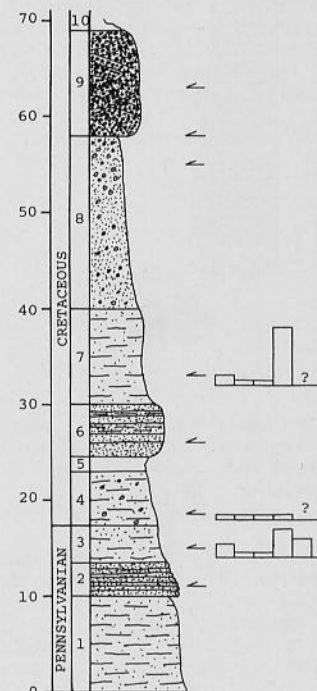
- 11. Loose sand and soil to hill top.
- 10. Sand: red-brown with small pebbles. 3.0'
- 9. Sandstone: white, dense, coarse grained with small pebbles. Opaline-cemented cylindrical concretions. 3.0'
- 8. Mud: white-green, sandy. 4.0'
- 7. Sand: red-brown, spotty consolidation or cementation. 5.5'
- 6. Sand: tan, loose becoming shaley toward top. 5.5'
- 5. Sandstone: tan, massive, loosely consolidated and case hardened, slumped. 5.0'
- 4. Mud: red-gray, weathers light red, some sand, fissile. 27.5'
- 3. Shale: maroon-olive, weathers gray, some sand, fissile. 5.5'
- 2. Sandstone: gray, dense, forms ledge. 0.4'
- 1. Shale: maroon-green, weathers gray and tan, jointed and iron stained. Thin, dense gray sandstone stringer 1.5' from top. 6.0'



SECTION 6. Eastland County (lat 32°24'N; long 98°38'W)

In road cut of county road approximately 0.5 mile north of Farm Road 570. Section runs west to east from Jim Neal Branch about 0.3 mile to crest of hill. Contact elevation 1,465 feet.

- 10. Loose white sand and soil to top of hill.
- 9. Pea-gravel conglomerate: opaline cemented, sandy cross-bedded, massive, dense, badly slumped and weathered. 11.0'
- 8. Sandstone: red with pea gravel, (becoming more abundant toward top). Abundant filled joints and seams. 18.0'
- 7. Mud: white, sandy, iron stains. Poorly exposed. 10.0'
- 6. Sand: red-tan, bedded, not cemented. Interbedded with white, sandy shale. 5.5'
- 5. Covered interval. 1.5'
- 4. Mud: maroon, sandy, some quartz pebbles, poorly exposed. 5.5'
- 3. Mud: gray and yellow, sandy, becoming more sandy toward top. Poorly exposed. 4.0'
- 2. Sandstone: gray, weathers tan, dense, thinly bedded, jointed, filled burrows. 3.5'
- 1. Shale: tan and gray weathers gray, sandy, fissile, iron stains. 10.0'+



SECTION 5. Erath County (lat 32°22'N; long 98°26'W)

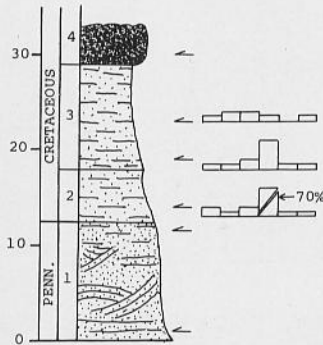
On east-facing bluff above branch of Rush Creek. Downstream (north) of Dripping Springs, Fambro Ranch. Contact elevation 1,275 feet.

- 8. Unconsolidated sand and soil to top of hill.
- 7. Sand and sandstone: dense dark red to black calcium carbonate-cemented sandstone ledges, overlain by soft, cross-bedded sandstone, overlain by sandy conglomerate. 2.7'
- 6. Mud: dark maroon, sandy, fissile with charophytes. 5.5'
- 5. Sandstone: white, stained red and brown from overlying unit. Massive but weakly consolidated. 2.2'
- 4. Sand: white, weathers tan. Dense ledge at bottom. Small quartz pebbles in lower 1/3. 2.8'
- 3. Shale: red-gray, weathers light red, fissile. 20.5'
- 2. Sandstone: gray, dense holds up ledge, calcium carbonate cement. 0.5'
- 1. Shale: maroon-green, weathers tan-light red, fissile. 15.5'

SECTION 7. Eastland County (lat 32°47'N; long 98°45'W)

In road cut along Farm Road 1852. Section begins 0.7 mile south of the Eastland-Stephens County line and continues uphill to the north for approximately 0.2 mile. Contact elevation 1,575 feet.

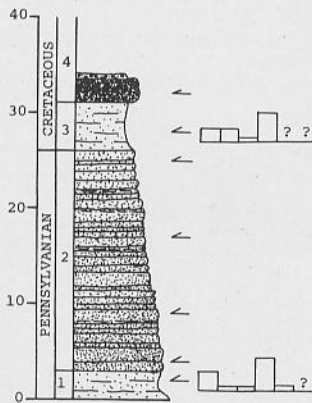
4. Pea-gravel conglomerate: sandy, opaline cement, dense, cross-bedded. 3.0'+
3. Mud: maroon, sandy, badly weathered in upper 2/3. 11.0'
2. Sand: shaley, white to off-white, weathers tan. 5.5'
1. Sandstone: tan, laminated weakly cemented, bedded and cross-bedded. Upper 2'-3' white and shaley. 12.5'



SECTION 8. Eastland County (lat 23°24'N; long 99°00'W)

In road cut along county road, 1.7 miles north of intersection of county road and State Highway 380. Section runs uphill from south to north. Just above abandoned M.K.&T. R.R. tracks. Contact elevation 1,680 feet.

4. Pea-gravel conglomerate: opaline cement, sandy, badly weathered. 2.5'+
3. Mud: tan with maroon streaks, weathers yellow, sandy. 5.0'
2. Sandstone: white, weathers tan, thin to massive bedding, loosely cemented with thin shale partings. Partially covered. 2.3'
1. Shale: red-gray, weathers tan-gray, sandy, laminated, fissile. 3.0'

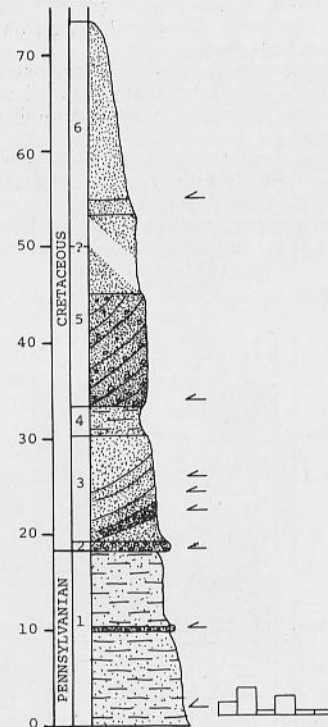


SECTION 9. Eastland County (lat 32°16'N; long 98°42'W)

In road cut of Farm Road 2689 south of Kokomo. Section runs from Natches Creek south to crest of hill, about 0.7-0.8 mile. Contact elevation 1,300 feet.

6. Sand: tan, loose, some calcium carbonate-cemented ledges. Covered below. 23.0'?
5. Sandstone: red-brown, loose to strongly cemented, cross-bedded, quartz pebbles. Pea gravel weathering from lower portion. Covered above. 17.0'?
4. Sand and sandy mudstone: white. 3.0'
3. Sand: tan, loose to indurated, lenses of white, sandy caliche. Lenses bedded, some continuous and some truncated. 11.0'

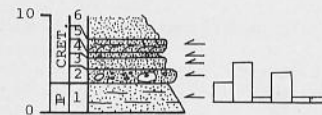
2. Conglomerate: white-tan, calcium carbonate cement, sandy. 1.0'
1. Shale: yellow-gray, weathers tan, sandy, calichefied, iron stains. Dense, calcium carbonate-cemented, white, laminated sandstone ledge with pebbles in center of unit. 18.3'



SECTION 10. Comanche County (lat 32°11'N; long 98°34'W)

In small creek which runs parallel and east of county road. Section runs north to south up the creek and is approximately 300 yards south of old iron bridge over a tributary of the Leon River. Contact elevation 1,280 feet.

6. 20'-30' of pack sand to top of hill. Hill capped with opaline-cemented pea gravel.
5. Sandstone: tan, weathers brown, cross-bedded, dense. 1.5'
4. Sand: off-white to tan, calichefied, some gravel. 0.5'
3. Sandstone: tan-brown, loosely consolidated. 1.0'
2. Conglomerate: pea gravel to boulder size, sandy, calcium carbonate cement. 1.5'
1. Mud: yellow-gray, sandy fissile. 3.0'

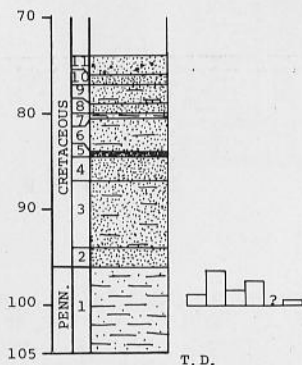


SECTION 11. Comanche County (lat 32°07'N; long 98°33'W)

Sample log taken from well site log of Texas Water Development Board observation well #4. Well on N. L. Box property near DeLeon, footage is from surface elevation of 1,322 feet. Contact elevation 1,225 feet.

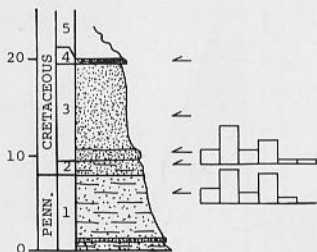
11. Sandstone: gray, fine-to-coarse grained, pebbly, well cemented, poor sorting. 2.0'
10. Sand: gray, fine-to-coarse grained. 1.0'
9. Sand: gray and green, fine-to-medium grained, clayey. 2.0'
8. Sandstone: gray, fine-to-coarse grained, pebbly, well cemented, poor sorting. 1.0'
7. Clay: green, silty. 0.5'
6. Sand: gray, fine-to-medium grained, clay lenses present. 3.5'

5. Conglomerate: multi-colored white, pink, and black, pebble size particles, sandy, poor sorting well cemented, mineral composition, quartz varieties (rose and smoky quartz and chert). 0.5'
4. Sandstone: gray and green, fine grained, silty, well cemented. 2.5'
3. Sand: gray, fine-to-medium grained, clay lenses present. 7.0'
2. Sandstone: gray, fine grained, well cemented. 2.0'
1. Clay: red-brown and gray, silty, sandy. 9.0'



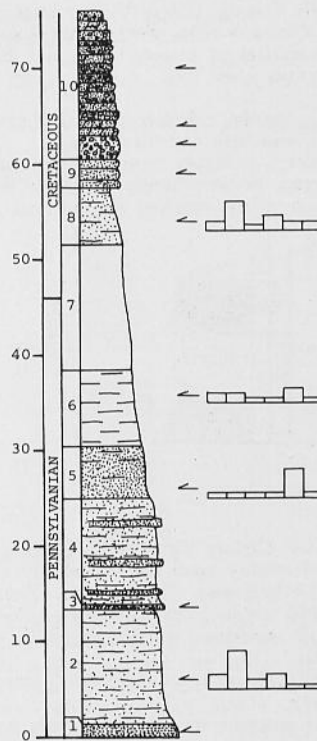
SECTION 12. Comanche County (lat 32°05'N; long 98°35'W)
 In road cut on west side of Farm Road 2318 approximately 2.5 miles south of intersection of Farm Road and State Highway 587. Contact elevation 1,245 feet.

5. Brown sand and sandy soil. 0.5'
4. Pea gravel: red-brown sandy, iron cement, weathers easily. 10.0'
3. Pack sand: off-white to tan, iron stained. White-gray, indurated ledge at bottom. 1.5'
2. Mud: off-white to gray, sandy, fissile. 8.0'
1. Mud: maroon, weathers yellow-gray, fissile, sandy, some sand stringers.



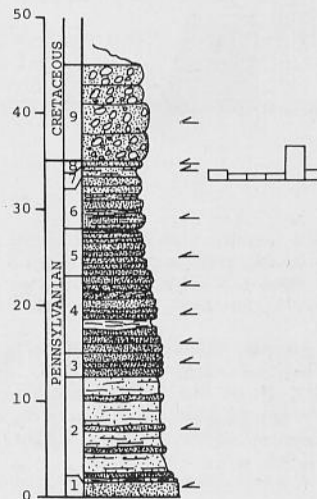
SECTION 13. Mills County (lat 31°18'N; long 98°35'W)
 In road cut of county road. Section runs up hill from west to east for approximately 0.3 mile. Section begins about 0.4 mile from corner in road. Contact elevation 1,260 feet.

10. Alternating beds (1' to 3') of sandy conglomerate and limy sandstone with various gradations between, gray-tan. 15.5'
9. Sandstone: red, calcium carbonate cement, soft. 3.0'
8. Mud: maroon-green, sandy, fissile, calichefied. 6.0'
7. Covered interval. 13.0'
6. Mud: tan-gray, weathers brown, fissile, calichefied. 8.0'
5. Sand: white to tan becoming darker and more shaley toward top, calichefied and poorly exposed. Like caliche soil in appearance. 5.5'
4. Shale: maroon, weathering gray, sandy with alternating finely laminated, dense, gray sandstone ledges. 11.0'
3. Sandstone: gray, dense, finely laminated, calcium carbonate cement, flaggy. 0.5'
2. Shale: maroon-brown, weathers tan-gray, sandy, fissile. 12.0'
1. Sandstone: brown, dense, massive, jointed, fine laminations, iron stained. 1.5'



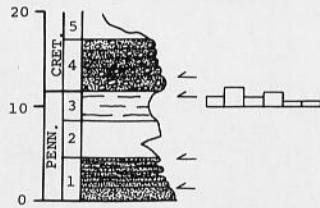
SECTION 14. Mills County (lat 31°20'N; long 98°38'W)
 In road cut of county road. Section about 1.1 miles west of intersection of two county roads. Begins about half way down hillside and continues west to crest of hill. Contact elevation 1,320 feet.

9. Conglomerate, pebbles to cobbles, calcium carbonate cement. Grades into soil on top of hill. 10.0'
8. Sandstone: pink-gray, soft. 0.5'
7. Mud: tan-gray, sandy. 1.0'
6. Sandstone: pink-gray, soft, lower ledge laminated. Interbedded with tan-gray sandy shale. 5.5'
5. Sandstone: brown, muddy, soft, thin shale partings, 0.5' tan shale at top. 5.0'
4. Sandstone: maroon-tan, thin to massive bedding, calcium carbonate cement, some low-angle cross-bedding. 1.0' tan mud in lower portion. 8.0'
3. Sandstone: brown massive jointed. 2.5'
2. Alternating brown-red mud and thin, flaggy, tan, sandstone, poorly exposed. 11.0'
1. Sandstone: brown, massive, dense, calcium carbonate cement. 1.5'

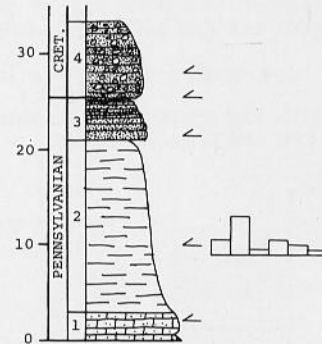


SECTION 15. Mills County (lat 31°32'N; long 98°45'W)
 In road cut of county road. Section approximately 2.2 miles west of intersection of county road and Farm Road 573. Contact elevation 1,260 feet.

- 5. Soil, cover.
- 4. Conglomerate: sandy, calcium carbonate cement. 5.5'
- 3. Mud: brown, weathers tan, fissile. 3.0'
- 2. Covered interval: probably mud or mudstone. 4.0'
- 1. Sandstone: gray, dense. Sandy tan shale in upper portion. Uppermost ledge ripple marked and jointed. 4.5'

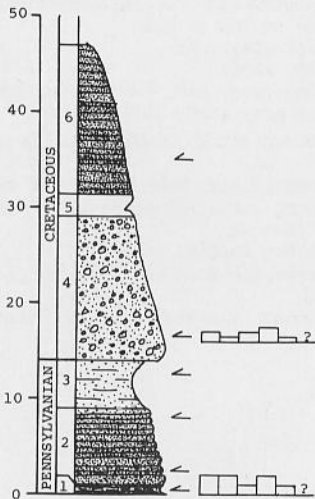


- 1. Limestone: dark gray-brown, sandy, abundant fossil fusulines. 3.0'



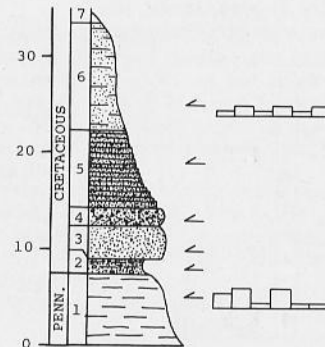
SECTION 16. Brown County (lat 31°37'N; long 98°48'W)
 In road cut of county road approximately 1.3 miles northwest of the Mills-Brown County line. Section begins approximately 100 yards from intersection with county road to Zephyr and continues southeast uphill. Contact elevation 1,375 feet.

- 6. Sandstone: red and gray, weathers tan, dense. 15.5'
- 5. Covered interval. 2.5'
- 4. Conglomerate: gray-brown, sandy, pebble to cobble size. 14.0'
- 3. Mud: brown, sandy, calichefied. 6.0'
- 2. Sandstone: gray, calcium carbonate cement, thin to massive bedding, jointed, weathers gray and brown. 8.0'
- 1. Shale: brown, weathers tan, calichefied. Thin, gray, limy, sandstone stringers. 1.0'



SECTION 18. Brown County (lat 31°45'N; long 98°53'W)
 In railroad cut of Santa Fe Railroad, approximately 0.5 mile south of intersection with county road. Section runs from south to north. Contact elevation 1,435 feet.

- 7. Soil and vegetation over.
- 6. Mud: maroon, sandy, fissile with charophytes. 11.0'
- 5. Sandstone: white, weathers red and white, thin to medium bedding. Upper 1.5' grades into overlying unit. 8.0'
- 4. Conglomerate: gray, weathers, red, sandy, small grained, some low angle cross-bedding. Grades into unit above. 2.0'
- 3. Sandstone: white weathers white to red, massive, calcium carbonate cement. 3.5'
- 2. Muddy sand: white, weathers off-white, some pebbles. 1.5'
- 1. Mud: gray-maroon, weathers light gray-tan, fissile. 7.5'



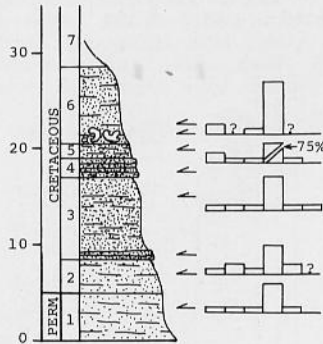
SECTION 17. Brown County (lat 31°39'N; long 99°55'W)
 In road cut of county road approximately 1.8 miles south of intersection of county road and Farm Road 2126. Section runs up hill from southeast to northwest. Contact elevation 1,395 feet.

- 4. Conglomerate: sandy, pebble to cobble size, calcium carbonate cement, badly leached and calcified. 8.0'
- 3. Sandstone: gray, dense, fine grained, massive and blocky in lower portion, becoming thin bedded and flaggy with alternate shale partings in upper portion. Upper, thin beds are ripple marked. 4.5'
- 2. Shale: gray-brown, weathers tan, fissile, iron stained. 18.0'

SECTION 19. Coleman County (lat 31°45'N; long 98°21'W)
 In two draws running into stock tank approximately 200 yards east of U.S. Highway 283. Section runs northwest to southeast up the draws. The draws are located on the west-facing slope of Santa Anna Mountain, Bruce property. Contact elevation 1,735 feet.

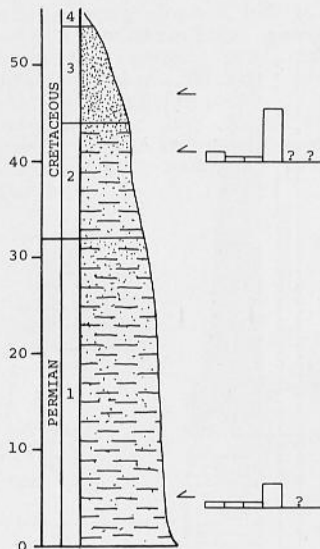
- 7. Soil and caliche.
- 6. Mud: maroon-brown, sandy, grading into caliche above. Large concretions (Septaria?) in lower portion. 8.0'
- 5. Sandy mud: white to off-white. 1.5'
- 4. Sandstone: white, dense, calcium carbonate cement. 2.0'
- 3. Sand: white-tan, loose and tan shale, 6.5' sandstone ledges in lower portion. Poorly exposed. 8.5'

- 2. Mud: gray-yellow, weathers gray-white, sandy, fissile with charophytes. 3.5'
- 1. Mud: maroon-brown, sandy, fissile (charophytes?). 5.0'



SECTION 20. Coleman County (lat 31°48'N; long 99°35'W)
 Along ranch road and into sand quarry. Section south of Hords Creek Reservoir, on north-facing slope of Fowler Hill; U.S. Government property. Section runs north to south. Contact elevation 1,980 feet.

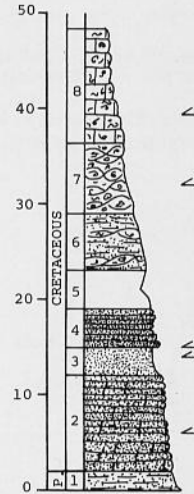
- 4. Soil and caliche cover.
- 3. Pack sand: white-tan, friable. 10.0'
- 2. Mud: yellow-gray, weathers to tan to off-white, becoming more sandy. Toward top and grading into overlying sand unit. 11.0'
- 1. Mud: maroon, weathers red-brown, sandy, becoming more sandy upward. 33.0'



SECTION 21. Coleman County (lat 31°48'N; long 99°38'W)
 Along county road. Section runs from east to west uphill, road ends at bottom of hill. Contact elevation 2,030 feet.

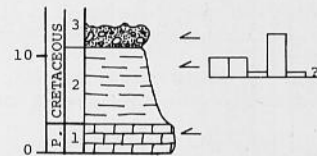
- 8. Limestone: white-gray, weathers off-white to black, thin to massive bedding, fossiliferous. 12.0'
- 7. Limestone: white to off-white-tan, fossiliferous, nodular. Some shale partings. 7.5'
- 6. Mud: tan to off-white, sandy. Some stringers of nodular limestone. 6.0'
- 5. Covered interval (probably mud). 4.0'
- 4. Sand: white, weathering yellow, alternating with dense, brown fossiliferous sandstone ledges. 4.0'
- 3. Sand: weathers white, unconsolidated, somewhat packed. 3.0'

- 2. Calichefied sand. 10.0'
- 1. Mud: red-brown, sandy. 2.0'



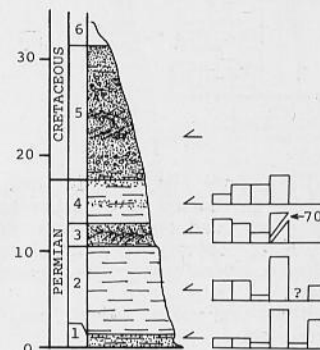
SECTION 22. Runnels County (lat 32°02'N; long 99°44'W)
 In road cut of county road north of Content (Tokeen). Section runs south to north out of small creek to top of small rise in road. Contact elevation 2,005 feet.

- 3. Conglomerate: pebble to small cobble size with clay blebs, sandy, calcium carbonate cement. Slumped and weathered. 2.0'
- 2. Mud: maroon-gray, weathers red-brown, fissile, fine bedding or lamella present. Some mica flecks. 8.0'
- 1. Limestone: gray-brown weathers dark brown to black, massive, holds up ledge, some recrystallized calcium carbonate. 3.0'



SECTION 23. Taylor County (lat 32°10'N; long 99°58'W)
 On east-facing bank of northern branch of Mill Creek. Section is approximately 0.4 mile south of James ranch house, Webb property. Contact elevation 2,105 feet.

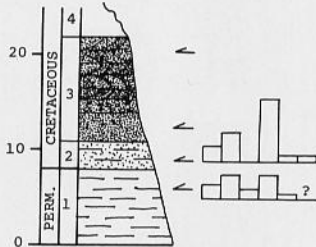
- 6. Holocene gravel and soil.
- 5. Pack sand: white, weathers off-white, cross-bedded, peagravel, thin mud stringers, gray, sand-mud in lower 1.0'. 14.0'
- 4. Mud: dark maroon, waxy fissile, micaceous with white sandy seams. 4.5'
- 3. Sand: white, weathers yellow-gray, small cross-beds, muddy sand in lower 1.0'. 2.5'
- 2. Shale: red with gray streaks, fissile. 9.0'
- 1. Shale: red-gray, fissile sandy, finely laminated. 1.5'



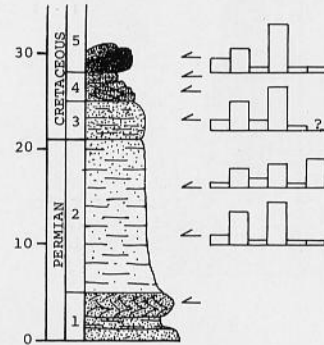
SECTION 24. Taylor County (lat 32°15'N; long 99°56'W)

On small south-facing bluff, north of county road, Bert Young property. Section runs south to north up bluff. Contact elevation 2,120 feet.

4. Loose sand uphill. 11.0'
3. Pack sand: white weathers tan to off-white, iron stained, zone of loose pea gravel, upper 1/2 somewhat cross-bedded. 11.0'
2. Mud: yellow-gray, weathers white, sandy, fissile. 3.0'
1. Mud: maroon-tan, fissile some small gypsum crystals. 8.0'



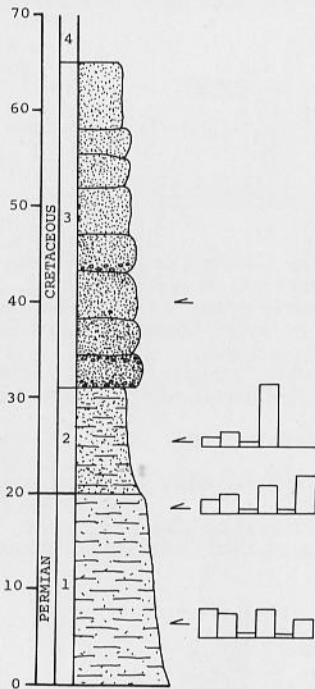
3. Muddy siltstone-sandstone: red-brown becoming less muddy near top. 4.0'
2. Mud: maroon with gray streaks, fissile, appears to be more sandy toward top. 16.0'
1. Sandstone: red-black, cross-bedded, dense, jointed with silty, muddy sand in center of unit. 5.0'



SECTION 25. Taylor County (lat 32°15'N; long 99°57'W)

On west-southwest-facing bank of a small tributary of Elm Creek. Section runs up cut bank approximately 150 yards north of Farm Road 89, Bert Young property. Contact elevation 2,210 feet.

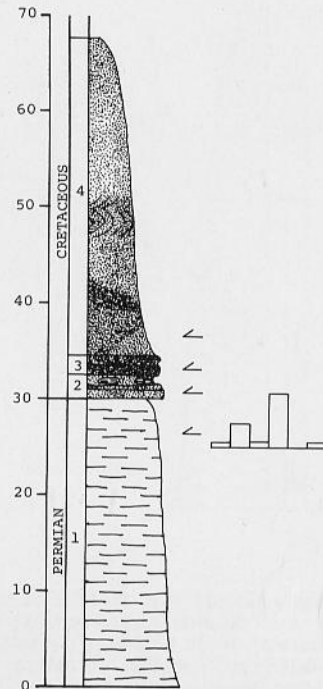
4. Bank capped by caliche and limestone pebbles. 34.0'
3. Pack sand: gray-off-white, massive, pea gravel, some caliche seams, iron stains. 11.0'
2. Mud: maroon and yellow-green, sandier than unit below, varved or thinly laminated. 20.0'
1. Mud: maroon with gray streaks, sandy, fissile. 20.0'



SECTION 27. Taylor County (lat 32°25'N; long 100°08'W)

In abandoned sand pit and draw. Draw runs north off the Callahan Divide. Section approximately 0.6 mile southwest of Mrs. M. G. Bryan's house (property owner). Contact elevation 2,220 feet.

4. Pack sand: white, some cross-bedding, some massive beds, pea gravel, mud lenses that weather, white-pink to purple, caliche seams. 33.0'
3. Pea-gravel conglomerate: gray, cross-bedded, dense, calcium carbonate cement, sandy. 2.0'
2. Sandstone: white-off-white, calichefied near top, inclusions of maroon-yellow shale in upper portion. 2.5'
1. Mud: maroon-gray, fissile. 30.0'



SECTION 26. Taylor County (lat 32°25'N; long 100°06'W)

On small hill on east-facing side of the Callahan Divide. Section along ranch road running up to television broadcasting tower, King property. Contact elevation 2,230 feet.

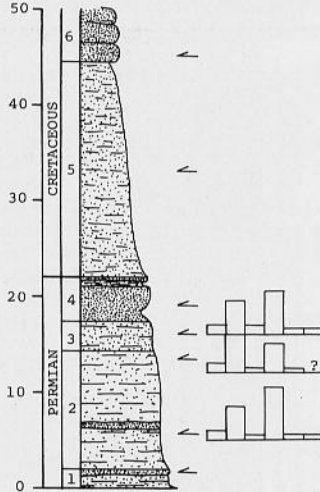
5. Sandy pea-gravel conglomerate: cross-bedded with calcium carbonate cement. 2.0'
4. Sandstone: red-tan, somewhat nodular, upper 1' is muddy, upper 0.2' white sand. 3.0'

SECTION 28. Nolan County (lat 32°07'N; long 100°14'W)

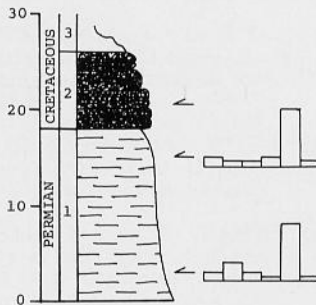
In draw running up southwest-facing slope of mountain (Callahan Divide). Section northeast of Pet. Corp. of Texas compressor plant and approximately 100 yards west of road to tank battery, C. H. Bolin Estate, R. C. (Sunny Watts lessee). Contact elevation 2,200 feet.

6. Pack sand: white weathers off-white to tan, massive, continues uphill. 5.5'+

- 5. Sand: gray and yellow, shaley, partially covered in lower portion. Appears to be reworked mud from unit 4 and sand. 22.5'
- 4. Sandstone: brown, massive, jointed, calcium carbonate cement, gray sandy shale in upper portion. 4.5'
- 3. Mud: gray-yellow, sandy, fissile with gypsum crystals weathering from mid-portion, iron stained. 3.0'
- 2. Mud: maroon and gray, sandy, fissile, gypsum crystals, weathering from thin, brown sand stringer near middle of unit. 12.5'
- 1. Sandstone: tan-brown, overlying maroon-gray sandy mud. 0.5'

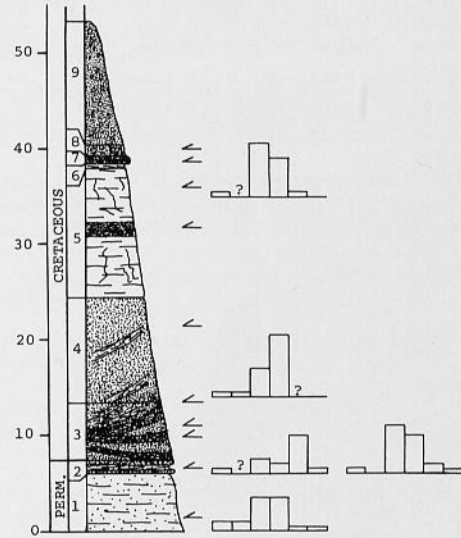


- SECTION 29.** Nolan County (lat 32°27'N; long 100°13'W)
 On east-northeast-facing slope of hill (Callahan Divide). Section is west of county road and approximately 0.7 mile north of Skelly Oil Company pump station, on Adrian Ranch. Contact elevation 2,300 feet.
- 3. Limestone rubble and calichefied soil.
 - 2. Pea-gravel conglomerate: gray, sandy, cross-bedded, thin to medium bedded, calcium carbonate cement. 8.0'
 - 1. Mudstone: red-gray, badly weathered and calichefied. More calichefied near top. 18.0'

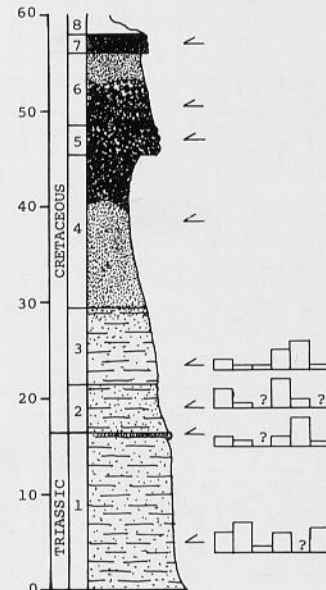


- SECTION 30.** Nolan County (lat 32°24'N; long 100°21'W)
 In road cut of Farm Road 1856 approximately 2.0 miles east of the intersection of Farm Road 1856 and State Highway 70. Section is on north side of road on the east-facing side of a Cretaceous outlier. Contact elevation 2,300 feet.
- 9. Alternating beds of sand and caliche with pea gravel. 13.0'
 - 8. Pack sand: gray and loose pea gravel. 1.0'
 - 7. Sandstone: off-white weathers brown, dense with pea gravel, calcium carbonate cement. 1.0'
 - 6. Mud: gray-tan, sandy. 0.5'
 - 5. Mud: maroon, waxy, fissile with 1.5' cross-bedded, loose pea gravel. Caliche seams. 13.5'
 - 4. Sand and muddy sand: white and maroon with maroon mud streaks. 11.0'
 - 3. Pack sand: laminated with pea gravel to cobble size material, cross-bedded, calcium carbonate cement. Also con-

- tains muddy sand, white and maroon, micaceous. Appears the muddy sand has been cut and filled with sand and gravel. 6.0'
- 2. Sandstone: brown with maroon mud in middle. Calichefied. 1.5'
- 1. Mud: red-maroon, sandy, micaceous, caliche seams. 6.0'



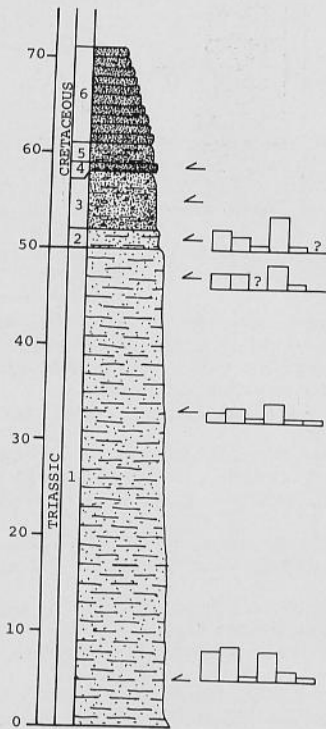
- SECTION 31.** Nolan County (lat 32°15'N; long 100°38'W)
 On east-facing slope of small outlier south of Big Silver Creek, approximately 0.7-1.0 mile south of Spires ranch house. Contact elevation 2,320 feet.
- 7. Pea-gravel conglomerate: sandy, calcium carbonate cement. Holds up outlier. 2.0'
 - 6. Pack sand: gray, abundant pea gravel and high angle cross-bedding in lower portion. Upper 2' covered. 7.5'
 - 5. Pea-gravel conglomerate: gray, opaline cement, cross-bedded. 3.0'
 - 4. Pack sand: tan to white, upper 10' highly cross-bedded with loose pea gravel, some iron stains and caliche seams. 16.0'
 - 3. Mud: yellow-gray, weathers off-white to buff, sandy, becomes more sandy toward top. 8.0'
 - 2. Mud: maroon, sandy, micaceous, fissile with charophytes. 5.0'
 - 1. Mud: maroon, sandy, fissile. Thin laminated, silt-sandstone, ledge near top. Some mica flecks in silt-sandstone. 16.5'



SECTION 32. Howard County (lat 32°12'N; long 101°19'W)
 In draw on northeastern slope of Signal Mountains, just south of Signal Peak, on Garrett Ranch. Contact elevation 2,550 feet.

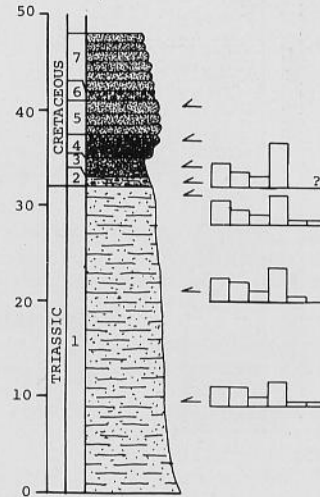
6. Sandstone: brown, massive with thin laminations, weak calcium carbonate cement. 1.0'+
5. Sand: gray to yellow-gray, muddy. 2.0'
4. Sandstone: brown, massive jointed, pea gravel in bottom, calcium carbonate cement. 1.0'
3. Sand: yellow to gray, muddy, iron stained, some small pebbles. 6.0'
2. Mud: Maroon and gray-buff, sandy with sand streaks or stringers, fissile, badly calichefied. 2.0'
1. Mud: maroon, fissile, micaceous in lower portion, sandy-silty. 50.0'

Note: Section begins in mud above 23.0' of gray micaceous, cross-bedded sandstone which grades upward into 10.0' of red-gray thinly laminated silt-sandstone.



SECTION 33. Howard County (lat 32°14'N; long 101°28'W)
 In small draw which runs north into Big Spring Draw. Section in Big Spring city limits behind residence of C. W. Mahoney, No. 4, Highland Heather. Contact elevation 2,550 feet.

7. Sandstone: gray, massive. 6.0'
6. Sand: gray with pea gravel. 1.0'
5. Sandstone: gray, weathers gray-tan, massive, indurated. 3.5'
4. Pea-gravel conglomerate: opaline cement, sandy, massive, dense. 2.5'
3. Sand: white and gray, some pea gravel, iron stained. 2.0'
2. Mud: yellow-gray, sandy with some small pebbles. 1.0'
1. Mud: maroon with some gray blebs, sandy, micaceous. 32.0'



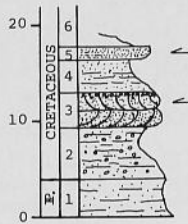
APPENDIX I, PART 3

DESCRIPTION OF LOCALITIES

LOCALITY 34. Parker County (lat 32°55'N; long 98°01'W)
Road cut on the north side of Farm Road 885 approximately 3.5 miles east of the intersection of Farm Road 1885 and U.S. Highway 281. Basal Cretaceous conglomerate and conglomeratic sandstone (Hosston Formation) overlying Pennsylvania shale. Contact elevation 990 feet.

LOCALITY 35. Parker County (lat 32°43'N; long 97°58'W)
Small unnamed branch of Grindstone Creek, approximately 1 mile west of county road on A. C. Young property. Hosston Formation overlying Pennsylvanian shale. Contact elevation 850 feet.

- 6. Covered interval.
- 5. Sandstone: dense finely laminated. 1.0'
- 4. Sand: white, unconsolidated, shale near center. 3.5'
- 3. Sandstone: white, dense, calcium carbonate cemented, sugar texture and color. Weathers black to gray. Cross-bedded with conglomerate in upper portion. 3.0'
- 2. Same as unit 1 with abundant calcareous and siliceous pea gravel. 5.5'
- 1. Shale: gray-green, sandy and iron stained. 4.0'

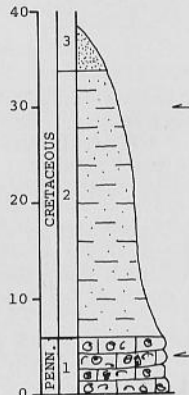


LOCALITIES 36 and 37. Parker County (lat 32°39'N; long 97°59'W)
Area of southwestern Parker County exhibiting pre-Cretaceous topographic relief. Exposures of Cretaceous pea gravel and sand (Hosston Formation) occur over Pennsylvanian limestones and shales at an elevation of 800 feet at locality 37 and 840 feet at locality 36 along county road.

LOCALITY 38. Parker County (lat 32°34'N; long 97°57'W)
On small tributary of Kickapoo Creek. Hosston Formation on Pennsylvanian, Kickapoo Falls Limestone. Contact elevation 785 feet.

LOCALITY 39. Hood County (lat 32°33'N; long 97°59'W)
On Kickapoo Creek where county road fords the creek, Kickapoo Falls Formation exposure.

LOCALITY 40. Hood County (lat 32°33'N; long 97°57'W)
On tributary of Kickapoo Creek east of Farm Road 1534, exposure of basal Cretaceous charophyte-bearing mud.



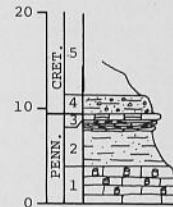
Composite of Localities 38, 39, and 40

Composite of Localities 38, 39, and 40
3. Sand and sandstone: white.
2. Mud: maroon, fissile, sandy with fossil charophytes.
1. Limestone: dark brown to gray, recrystallized, jointed, massive fossil brachiopods and some gastropods and solitary corals.

LOCALITY 41. Erath County (lat 32°29'N; 98°10'W)
Intersection of Buck Creek and county road approximately 0.9 mile south of Patilo. White, unconsolidated Cretaceous sand (Hosston Formation) overlying massive, jointed, crinoid stem, Pennsylvanian limestone. Contact obscured, elevation 1,150 feet.

LOCALITY 42. Erath County (lat 32°27'N; long 98°14'W)
In small creek immediately north of Farm Road 1715 on Ulman Ranch. Hosston Formation overlying Pennsylvanian limestone. Contact elevation 1,020 feet.

- 5. Covered interval.
- 4. Mud: red, sandy with pea gravel. 2.0'+
- 3. Limestone: tan with crinoid stems. 0.5'
- 2. Shale: yellow-gray, iron stains, sandy with thin limestone stringers in upper 2-3 feet. 5.0'
- 1. Limestone: massive jointed with crinoid stems. 4.0'+



LOCALITY 43. Eastland County (lat 32°21'N; long 98°33'W)
Exposure along South Fork of Palo Pinto Creek west of State Highway 16. Massive, cross-bedded, Cretaceous opaline-cemented pea-gravel conglomerate (Hosston Formation) overlying Pennsylvanian crinoidal limestone. Up to 17 feet of relief may be observed where erosional surface of the limestone is in contact with the conglomerate. Contact elevation 1,350 feet.

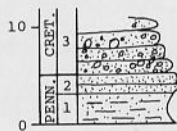
LOCALITY 44. Comanche County (lat 32°08'N; long 98°30'W)
Road cut on county road approximately 2.4 miles northeast of DeLeon, south bank of the Leon River. Opaline-cemented pea-gravel conglomerate (Hosston Formation) above brown Pennsylvanian sandstone. Contact elevation 1,260 feet.

LOCALITY 45. Comanche County (lat 32°05'N; long 98°29'W)
Road cut on county road at intersection with MK&T Railroad 1 mile west of Comyn Church. White and maroon Cretaceous sandy mud (Hosston Formation) overlain by sandstone and thin siltstones underlain by Pennsylvanian sandstones. Contact elevation 1,200 feet.

LOCALITY 46. Comanche County (lat 31°59'N; long 98°38'W)
Road cut on Farm Road 2247 on south bank of Sweetwater Creek. Cretaceous clay, sand and conglomerates (Hosston Formation) overlying Pennsylvanian sandstone and shale. Contact elevation 1,270 feet.

LOCALITY 47. Mills County (lat 31°21'N; long 98°37'W)
Road cut on county road approximately 6.2 miles south of intersection with State Highway 16. Sycamore Formation overlying Pennsylvanian sandstone and shale. Contact elevation 1,290 feet.

3. Conglomerate: massive, dense sandy. 3.0'+
 2. Sandstone: gray-tan, massive. 2.0'
 1. Sandy shale: white-gray. 3.0'+

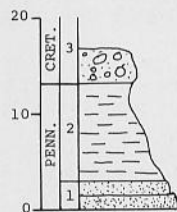


LOCALITY 48. Mills County (lat 31°28'N; long 98°42'W)
 Road cut immediately east of Pecan Bayou on Farm Road 574. Sycamore Formation above Pennsylvanian siltstones and sandstones. Contact elevation 1,220 feet.

LOCALITY 49. Mills County (lat 31°32'N; long 98°44'W)
 Road cut on south side of Farm Road 573 at Pecan Bayou. Sycamore Formation lying on Pennsylvanian sandy limestone. Contact elevation 1,280 feet.

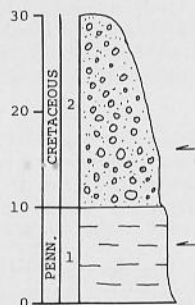
LOCALITY 50. Brown County (lat 31°37'N; long 98°48'W)
 Road cut on county road immediately north of the Brown-Mills County line, approximately 6 miles south of Zephyr. Sycamore Formation overlying Pennsylvanian shale. Contact elevation 1,360 feet.

3. Conglomerate: massive, dense, sandy. 3.0'-4.0'
 2. Shale. 10.0'
 1. Sandstone and caliche. 2.0'+



LOCALITY 51. Brown County (lat 31°30'N; long 98°51'W)
 Series of two road cuts on Farm Road 845 south of Brownwood, approximately 2 miles north of Brown-Mills County line. Sycamore Formation overlying Pennsylvanian shale. Contact elevation 1,420 feet.

2. Conglomerate: pea gravel to cobble size, brown, dense, sandy with calcium carbonate cement. 30.0'
 1. Shale: gray-yellow weathers maroon-brown. 10.0'



LOCALITY 52. Brown County (lat 31°33'N; long 98°57'W)
 Road cut on county road approximately 1 mile southwest of Farm Road 45. Thick sequence of Cretaceous cobble size conglomerate and red-brown sandstone overlain by gray, dense, sandy conglomerates grading upward into white sandstone; Sycamore Formation. These units are underlain by Pennsylvanian sandstones. Contact elevation 1,460 feet.

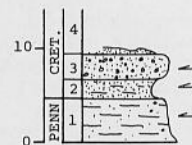
LOCALITY 53. Brown County (lat 31°35'N; long 98°55'W)
 Road cut on county road approximately 2½ miles northeast of Farm Road 45 on the west bank of Mackinally Creek. Massive Cretaceous conglomerate (Sycamore For-

mation) overlying tan-yellow Pennsylvanian shale. Contact elevation 1,420 feet.

LOCALITY 54. Brown County (lat 31°39'N; long 99°00'W)
 Road cut on west side of U.S. Highway 377 at intersection with Farm Road 45. Maroon mud, sandy mud and sandstone (Sycamore Formation) calichefied; above Pennsylvanian limestone. Contact elevation 1,575 feet.

LOCALITY 55. Brown County (lat 31°42'N; long 99°04'W)
 Road cut north of county road at intersection with a second county road. Sycamore Formation near its northern limit. Contact elevation 1,590 feet.

4. Loose sand.
 3. Conglomerate: pea gravel and sand with calcium carbonate cement. 2.5'
 2. Caliche: white, sandy with yellow-gray mud and some small pebbles and fossil charophytes. 1.5'
 1. Mudstone: maroon-tan, sandy with some small pebbles and some fossil charophytes. 4.0'

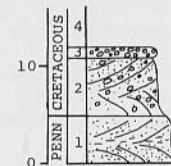


LOCALITY 56. Comanche County (lat 32°01'N; long 98°45'W)
 In Stag Creek northeast of intersection with State Highway 36. White, Cretaceous, thin-bedded sandstone overlain by yellow-gray mud then pea-gravel conglomerate (Hosston Formation) and underlain by massive, brown, Pennsylvanian sandstone. Contact elevation 1,450 feet.

LOCALITY 57. Eastland County (lat 32°14'N; long 98°48'W)
 North side of county road approximately 2.6 miles east of Farm Road 1027, above eastern tributary of Hunting Shirt Creek. Cretaceous, cross-bedded, opaline-cemented pea-gravel conglomerate (Hosston Formation) overlying Pennsylvanian crinoidal limestone. Contact elevation 1,530 feet. Pennsylvanian limestones crop out at an elevation of 1,560 to 1,570 feet on the west side of this tributary.

LOCALITY 58. Eastland County (lat 32°23'N; long 98°50'W)
 Road cut on east side of State Highway 6, approximately 3.5 miles south of Eastland. Hosston Formation. Contact elevation 1,500 feet.

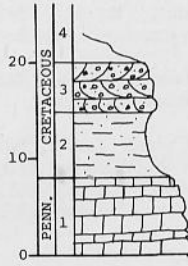
3. Conglomerate: opaline-cemented pea gravel. 1.0'
 2. Sandstone: red, conglomeratic, cross-bedded; appears to cut and fill into unit 1, sand content increasing upward. 6.0'
 1. Sand: white and brown, cross-bedded, massive, muddy streaks and clay blebs in white portions. 5.0'



LOCALITY 59. Eastland County (lat 32°29'N; long 98°51'W)
 Road cut on State Highway 6. Two miles west-northwest of Morton Valley. Cretaceous pea-gravel conglomerate and sandstone (Hosston Formation) above Pennsylvanian siltstone and sandstone. Contact elevation 1,590 feet.

LOCALITY 60. Eastland County (lat 32°24'N; long 98°59'W)
 Road cut on west side of U.S. Highway 380 at Cisco Junior College Campus. Hensel Formation on Pennsylvanian limestone. Contact elevation 1,680 feet.

4. Soil.
 3. Conglomerate: opaline-cemented pea gravel, cross-bedded. 5.0'
 2. Mud and silty mud: maroon. 7.0'-10.0'
 1. Limestone: dense, gray. 7.0'+

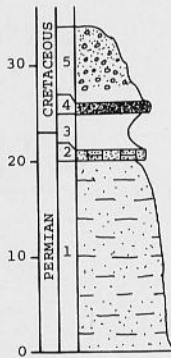


LOCALITY 61. Eastland County (lat 32°18'N; long 98°59'W)
Road cut on county road 1.5 miles west of U.S. Highway 183. Cretaceous cross-bedded, pea-gravel conglomerate, white sand and sandstones (Hensel Formation) overlying Pennsylvanian shale and sandstones. Contact elevation 1,630 feet.

LOCALITY 62. Callahan County (lat 32°17'N; long 99°15'W)
Along banks of small tributary to Deep Creek approximately 100 yards north of Farm Road 2228. Tan, cross-bedded sand with some pea gravel (Antlers Formation) overlying Permian sandstone and mudstones. Contact elevation 1,810 feet.

LOCALITY 63. Callahan County (lat 32°13'N; long 93°32'W)
Road cut west of county road immediately south of State Highway 36. Antlers Formation overlying Permian(?) limestone and shale. Contact elevation 1,875 feet.

- 5. Conglomerate: white, calichefied, lower portion covered. 8.0'
- 4. Conglomerate: pea gravel, red, cross-bedded, sand, grading in unit 5. 10.0'
- 3. Covered interval. 4.0'
- 2. Limestone: brown, sandy, dense. 1.0'
- 1. Shale: maroon. 20.0'+



LOCALITY 64. Callahan County (lat 32°26'N; long 99°26'W)
Road cut on county road approximately 1 mile southeast of Farm Road 2047. Massive, cross-bedded, opaline-cemented pea-gravel conglomerate (Antlers Formation) overlying massive thick-bedded brown Permian sandstone. Contact elevation 1,935 feet.

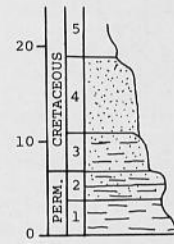
LOCALITY 65. Coleman County (lat 31°59'N; long 99°38'W)
Road cut on county road approximately 2 miles from Farm Road 1770. White sand and some interbedded yellow-gray muds (Antlers Formation) overlying brown Permian sandstone and shale. Contact elevation 2,015 feet.

LOCALITY 66. Taylor County (lat 32°15'N; long 99°48'W)
Road cut on county road on Cretaceous outlier southwest of Buffalo Gap, 2.5 miles east of U.S. Highway 83. Pea-gravel conglomerate (Antlers Formation) overlying Permian shale. Contact elevation 2,060 feet.

LOCALITY 67. Taylor County (lat 32°14'N; long 99°57'W)
Road cut on south side of Farm Road 89, west of Lake Abilene. Antlers Formation overlying Permian shale. Contact elevation 2,120 feet.

- 5. Limestone talus.

- 4. Sand: white. 5.0'-10.0'
- 3. Mud: yellow with some sand. 4.0'
- 2. Siltstone: red, jointed with white mottling. 3.0'
- 1. Shale: dark maroon.

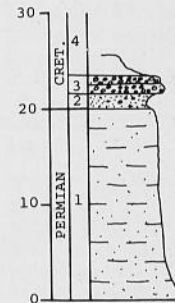


LOCALITY 68. Taylor County (lat 32°08'N; long 100°01'W)
Dry creek bed of tributary to Bluff Creek, east of Bluff Creek Cemetery. Cretaceous sand (Antlers Formation), muddy sand, and abundant loose pea gravel, some indurated cross-bedded sandstone overlying red Permian shales. Contact elevation 2,105 feet.

LOCALITY 69. Taylor County (lat 32°08'N; long 100°04'W)
Creek banks of tributary to Valley Creek immediately east of Farm Road 1086. White and brown (iron-stained) sand, sandstone and interbedded muds (Antlers Formation) overlying red Permian shale. Contact elevation 2,190 feet.

LOCALITY 70. Nolan County (lat 32°08'N; long 100°11'W)
Road cut east of intersection of Farm Roads 53 and 1170. Antlers Formation on Permian shale. Contact elevation 2,180 feet.

- 4. Caliche and soil.
- 3. Conglomerate: (limestone particles) with calcium carbonate cement. 2.0'
- 2. Sand: gray and tan with some small pebbles. 1.5'
- 1. Shale: gray-yellow, fissile and sandy. 20.0'+



LOCALITY 71. Nolan County (lat 32°24'N; long 100°17'W)
Road cut on county road approximately 1 mile east of intersection with Farm Road 2035. Cretaceous, opaline-cemented pea-gravel conglomerate (Antlers Formation) overlying red Permian sandstones and shales. Contact elevation 2,240 feet.

LOCALITY 72. Nolan County (lat 32°23'N; long 100°26'W)
Road cut on county road 0.1 mile west of intersection with Farm Road 1809. White and tan Cretaceous sand (Antlers Formation) overlain by resistant pea-gravel conglomerate (holding up small hill) and underlain by red Permian shale. Contact elevation 2,290 feet.

LOCALITY 73. Coke County (lat 31°46'N; long 100°23'W)
North-facing slope of (south) Nipple Peak. Maroon, Cretaceous mud (Antlers Formation) overlain by yellow-tan mud then white sand, underlain by massive iron-stained Permian conglomerate. Contact elevation 2,110 feet.

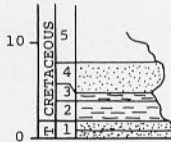
LOCALITY 74. Coke County (lat 31°45'N; long 100°27'W)
Northwest-facing slope of Sand Hill, 600 yards west of State Highway 209. White and yellow Cretaceous (Antlers Formation) sand, and mud interbedded with some indurated sandstones overlying brown-red Permian sandstones. Contact elevation 2,140 feet.

LOCALITY 75. Coke County (lat 31°51'N; long 100°35'W)
Northeast slope of Millican Mountain 1,000 yards east of Farm Road 2034. Dense, thin bedded Cretaceous sandstones (Antlers Formation) alternating with yellow muddy sand and calichefied sand overlying massive Permian sandstone and carbonate units. Contact elevation 2,180 feet.

LOCALITY 76. Coke County (lat 31°50'N; long 100°37'W)
Small outlier (bluff) 400 yards west of Farm Road 2034. White sand and sandstone interbedded yellow-tan mud and sandy mud (Antlers Formation) overlying, Permian sandstone and siltstone. Contact elevation 2,200 feet.

LOCALITY 77. Coke County (lat 31°54'N; long 100°46'W)
North-facing bluff along Pecan Creek, south of State Highway 158. Antlers Formation overlying Triassic sandstone. Contact elevation 2,300 feet.

5. Wash.
4. Sandstone: gray to white, blocky with some granule size particles. 3.0'
3. Mud: yellow-gray. 0.5'
2. Mud: maroon-gray. 2.0'
1. Sandstone: red and gray, dense, jointed. 1.0'+

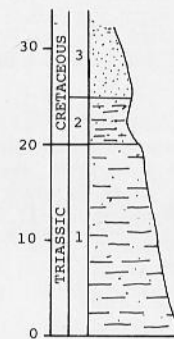


LOCALITY 78. Coke County (lat 32°04'N; long 100°40'W)
On Silver Peak, Cretaceous cross-bedded pea-gravel conglomerate (Antlers Formation) overlain by sandstone and mudstone and underlain by Triassic sandstone and conglomerate. Contact elevation 2,250 feet.

LOCALITY 79. Sterling County (lat 32°02'N; long 100°45'W)
West-facing slope of McWhorter Mountain approximately 11.5 miles east of State Highway 163. Antlers Formation overlying Triassic shale. Contact elevation 2,350 feet.

3. Sand: white. 5.0'
2. Mud: yellow, fissile. 50.0'-60.0'
1. Shale: maroon, silty, underlain by dense, micaceous sandstone.

LOCALITY 80. Sterling County (lat 31°49'N; long 101°00'W)
Road cut west of State Highway 163 approximately 2 miles south of intersection with U.S. Highway 87. Cretaceous, calichefied sands, red-yellow and gray shales (Antlers Formation). Contact elevation 2,320 feet.



APPENDIX II

MINERALOGICAL CONTENT DETERMINATION

During the course of this study numerous lithologic samples were taken. One phase of the laboratory investigation involved determination of mineralogical composition by X-ray diffraction. One hundred twenty-six samples were subjected to X-ray analysis. In Appendix I, part 2, the results of 83 of these analyses are plotted on the measured sections, which also indicate the lithologic unit sampled and, for a given sample, the relative percentages of montmorillonite, illite, kaolinite, quartz, calcium carbonate and dolomite.

Standard powder X-ray diffraction procedures were used. Each sample was pulverized to pass a 200-mesh screen; desiccated to 50% humidity; packed into an aluminum sample holder (open on both sides); exposed to collimated X-radiation emitted from a copper tube, nickel filter; and rotated in an arc from

2 to 40 degrees at the rate of 2 degrees per minute. The X-radiation was collimated by means of 1° divergence and receiving slits in conjunction with a 0.003-inch divergence slit. Diffracted X-rays were scanned, counted by means of a Phillips High Angle Diffractometer and recorded on a paper strip-chart.

The samples were handled in groups of 10 to 50. Before running a group of unknown samples, test runs were made on prepared calibration samples, of known composition. At the end of the run with field samples, the calibration samples were again analyzed and calibration curves prepared. By utilization of the peak intensities for the two calibration sample runs (curves), the relative percentages of minerals were determined for each of the field samples in that run.

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