BUREAU OF ECONOMIC GEOLOGY
The University of Texas
Austin 12, Texas

JOHN T. LONSDALE, Director

Report of Investigations—No. 20

Cretaceous of Llano Estacado of Texas

By

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ILLUSTRATIONS

CRETACEOUS OF LLANO ESTACADO OF TEXAS[1]

John P. Brand[2]

ABSTRACT

Rocks of Cretaceous age crop out along the western margins of the deeper playa basins and along the southern and southeastern margins of the Llano Estacado. The Trinity group, containing only the Paluxy sandstone; the Fredericksburg group, consisting of the Walnut, Comanche Peak, Edwards, and Kiamichi formations; and the Washita group, containing only a portion of the Duck Creek formation, have been identified in the Llano Estacado. Formations of the Trinity and Fredericksburg groups are similar lithologically and paleontologically to equivalent units in the Callahan Divide and in the northern edge of the Edwards Plateau. Zonation, applicable to northern and central Texas and Pecos County, Texas, can be extended to the isolated Cretaceous exposures in the Llano Estacado.

Cretaceous strata in the Llano Estacado dip to the southeast at the rate of 7 to 8 feet per mile. Structures in the underlying Triassic and Paleozoic do not appear to be reflected in Cretaceous strata. Likewise, the locations of the isolated Cretaceous remnants do not appear to be governed by known structures in underlying units.

The Comanche Peak and Edwards limestones and the Kiamichi and Duck Creek shales are chemically suitable for the manufacture of Portland cement. The Edwards limestone is a suitable road ballast material. The sand and gravel of the Paluxy formation could be utilized in concrete aggregate.

INTRODUCTION

The Llano Estacado situated in west Texas and the Texas Panhandle is essentially a plateau bounded on the east and west by prominent escarpments. To the south, the plain passes without sharp physiographic break into the Edwards Plateau. To the north, the plain continues into Oklahoma and Kansas, but generally speaking the valley of the Canadian River is considered to be the northern boundary of the Llano Estacado. The surface of the plain is remarkably flat and, except for short reentrant canyons, generally lacks prominent topographic features. The average slope is 8 to 10 feet per mile to the southeast. Minor relief features include numerous playa lakes, valleys of small intermittent streams, and local sand dune belts. The playas, a distinctive feature of the Llano Estacado, serve as the catchment basins for drainage over a large portion of the interior. Areas drained by individual playas range from a few acres to more than 100 square miles.

The surface of the Llano Estacado generally and the floors of the smaller basins, a few feet below the surface of the plains, are in Quaternary beds; whereas in the larger basins, the floors are 100 feet or more below the surface and are in Cretaceous or Triassic beds. A detailed study of the playa basins was made by Evans and Meade (1945). Aside from the interior drainage afforded by the playa basins, surface waters flow to the east and southeast into tributaries of the Brazos and Colorado Rivers.

The present paper gives the results of a study of all known Cretaceous exposures in the Llano Estacado and includes a consideration of paleontologic, stratigraphic, and structural relationships with some emphasis on possible economic utilization of the Cretaceous rocks. Exposures of the Cretaceous described lie between 101° and 103° W. and 31°45′ and 34°10′ N. Sections were examined in Ector, Andrews, Gaines, Dawson, Borden, Scurry, Terry, Lynn, Garza, Lubbock, Hockley, Bailey, Lamb, and Floyd counties (fig. 5). Localities studied outside the Llano Estacado include exposures along Rita Blanca Creek near Texline, Dallam County, Texas; Buffalo Springs ranch in north-central Dallam County; and several localities in Quay County, New Mexico.

[1] Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The University of Texas, June, 1952.

[2] Associate Professor of Geology, Texas Technological College, Lubbock, Texas.

Field Work

The field work upon which this paper is based, accomplished during the summers of 1950 and 1951, consisted of mapping exposures of Cretaceous strata, measuring sections, and collecting fossil and rock specimens for stratigraphic and economic determinations. Stratigraphic data were obtained primarily from surface exposures, but limited subsurface data were secured from logs of water wells and wells drilled for seismic exploration. Aerial photographs were used as the base for maps of local outcrop areas.

Acknowledgments

The writer is indebted to Dr. John T. Lonsdale, Director, Bureau of Economic Geology, for many helpful suggestions; to Professor R. K. DeFord, The University of Texas, for supervision in the field and for aid in preparation of the manuscript; to the faculties of both The University of Texas and Texas Technological College who provided facilities for laboratory work; and to Mr. Glen L. Evans of The Texas Memorial Museum, who gave freely of his information regarding Cretaceous localities. Special thanks are due Mr. W. S. Adkins and Dr. Keith P. Young for their aid in determining stratigraphic positions of fossil collections. To the many others who have contributed, the writer wishes to express his sincerest thanks.

STRATIGRAPHY

Rocks exposed in the Llano Estacado and adjacent areas are of Triassic, Cretaceous, Pliocene, and Quaternary age, and although this paper deals primarily with those of Cretaceous age, brief descriptions of the other units are included. Classification of strata exposed in the Llano Estacado area is given in table 1.

Table 1. Stratigraphy of Llano Estacado area.

System	Series	Group	Formation
	Recent		Alluvial deposits
Quaternary	Pleistocene		Tahoka beds Tule formation Blanco beds
Tertiary	Pliocene		Bridwell formation Couch formation
		Washita	Duck Creek shale
Cretaceous	Comanche	Fredericksburg	Kiamichi shale Edwards limestone Comanche Peak limestone Walnut formation
		Trinity	Paluxy sandstone
Triassic		Dockum	Trujillo formation (?)

Triassic beds crop out in the escarpments of the Llano Estacado and underlie adjacent lowland areas. Likewise, Triassic beds are thought to occur beneath the entire Llano Estacado.

Cretaceous beds are exposed along the southern and southeastern margins of the Llano Estacado and along the western margins of the deeper playa basins of the interior of the area.

Pliocene beds crop out along the eastern escarpment of the Llano Estacado and occur in the subsurface beneath most of the central and eastern portion of the area.

Quaternary deposits are confined to lake basins or occur as fill in the valleys of streams of the area. Wind-blown deposits, containing sediments blown from Pleistocene lake clays, form wide, elongate dune belts along the eastern margins of the deeper playa basins.

No stratigraphic sequence above the Triassic is continuous over the entire area. This discontinuous distribution has resulted both from lack of initial deposition and from erosion subsequent to deposition.

Triassic System

DOCKUM GROUP

The Triassic of western Texas was described by Cummins (1890, pp. 189–190) as the "Dockum beds" from the type locality at Dockum, Dickens County, and was later subdivided by Drake (1892, pp. 229–231) into three members. Gould (1907, pp. 21–29) subdivided the Dockum group into two formations: a basal shale, the Tecovas; and an upper sandstone, the Trujillo. Hoots (1926, pp. 86–96) believed the Dockum group of the southern Llano Estacado to be divisible into two formations: the lower characterized by red clay and numerous beds of massive, gray, cross-bedded sandstone with a maximum thickness of 275 feet; the upper consisting of red clay with a maximum thickness of more than 175 feet.

Baker (1935) showed that the Triassic beds dip into the "Llano Estacado syncline" and that thickest sections are in the subsurface beneath Gaines, Yoakum, and Hockley counties, Texas, and adjacent Lea County, New Mexico.

At the disconformable contact between the Dockum group and the overlying Cretaceous, a distinct blue-green reduction halo is characteristically present in the upper-

most few feet of the Dockum. This contrasts vividly with the overlying light-colored Cretaceous sand.

Cretaceous System

Rocks of Cretaceous age in the Llano Estacado belong to the Trinity, Fredericksburg, and Washita groups of the Comanche series (fig. 1). Descriptions and general location of exposures of formations of each group follow. Measured sections are included in the Appendix (pp. 26–55).

TRINITY GROUP

PALUXY SANDSTONE

The Paluxy sandstone, the basal sand of the Cretaceous system in the southeastern and southern portions of the Llano Estacado, is absent in places. Elsewhere it ranges from a thin layer to beds up to 40 feet of white to purple, loosely consolidated, fine to coarse-grained, well-sorted unfossiliferous quartz sandstone with scattered lenses of quartz gravel. The Paluxy sandstone disconformably overlies the Dockum group and frequently contains shale pebbles derived from the underlying red beds. The lowermost formation of the Fredericksburg group, the Walnut, disconformably overlies the Paluxy (Pl. II, A).

Water well records from southwestern Lamb County and central Bailey County show a sandstone, 15 to 30 feet thick, between the Kiamichi shale and the Triassic red beds. Here, as in surface exposures, the uppermost 1 to 2 feet of the Triassic shows a distinct blue-green reduction halo. As no fossils have been recovered from this subsurface sandstone, its stratigraphic assignment must be based upon position in the section. Although insufficient data are available upon which to base a conclusive opinion, probably this sandstone is of Kiamichi age and was deposited during a post-Edwards expansion of the Fredericksburg sea.

FREDERICKSBURG GROUP

WALNUT FORMATION

The Walnut formation was described by Hill (1891, pp. 502–512) from exposures at Walnut, Bosque County, Texas.

In the Llano Estacado, the Walnut formation cropping out along the southern and southeastern portion of the plains escarpment, consists of from 4 to 40 feet of limestone, shale, and sandstone. In its typical development, the basal third contains argillaceous sandstone, the middle portion contains argillaceous limestone and calcareous shale, and the upper portion contains shale and nodular argillaceous limestone. In eastern Lynn County and southeastern Lubbock County, the middle limestone and upper shale are absent and the entire section is sandy. The middle limestone, where present, contains a profusion of individuals of *Gryphaea mucronata* Gabb, a characteristic guide fossil which can be traced along the Llano Estacado escarpment from southwestern Garza County through Borden, Dawson, and northwestern Scurry counties.

Except in southeastern Lubbock County and eastern Lynn County where the contact is distinct between the sandstone at the top of the Walnut and the limestone of the overlying Comanche Peak, the upper contact of the Walnut is gradational and must be selected on the basis of slight lithologic and faunal differences. In general, three criteria help determine this contact:

(1) The upper Walnut beds are predominantly shale with interbeds of thin, nodular argillaceous limestone; the basal Comanche Peak is predominantly thickly bedded to massive argillaceous limestone with thin shale interbeds.

(2) The pelecypod *Exogyra texana* is abundant in the upper beds of the Walnut formation but sporadic in the basal Comanche Peak.

(3) The echinoid *Enallaster texanus* is common in the basal Comanche Peak but rare in the upper Walnut.

Fauna.—The following fauna has been collected by the writer from the Walnut formation in the Llano Estacado:

Enallaster
Metengonoceras sp.
Exogyra texana Roemer
Exogyra texana weatherfordensis Cragin
Ostrea sp.
Ostrea crenulimargo Roemer
Gryphaea mucronata Gabb (=*G. marcoui* Vaughan and Hill)
Protocardia texana (Conrad)
Tapes sp.
Turritella sp.
Tylostoma tumidum (Shumard)
Lunatia sp.

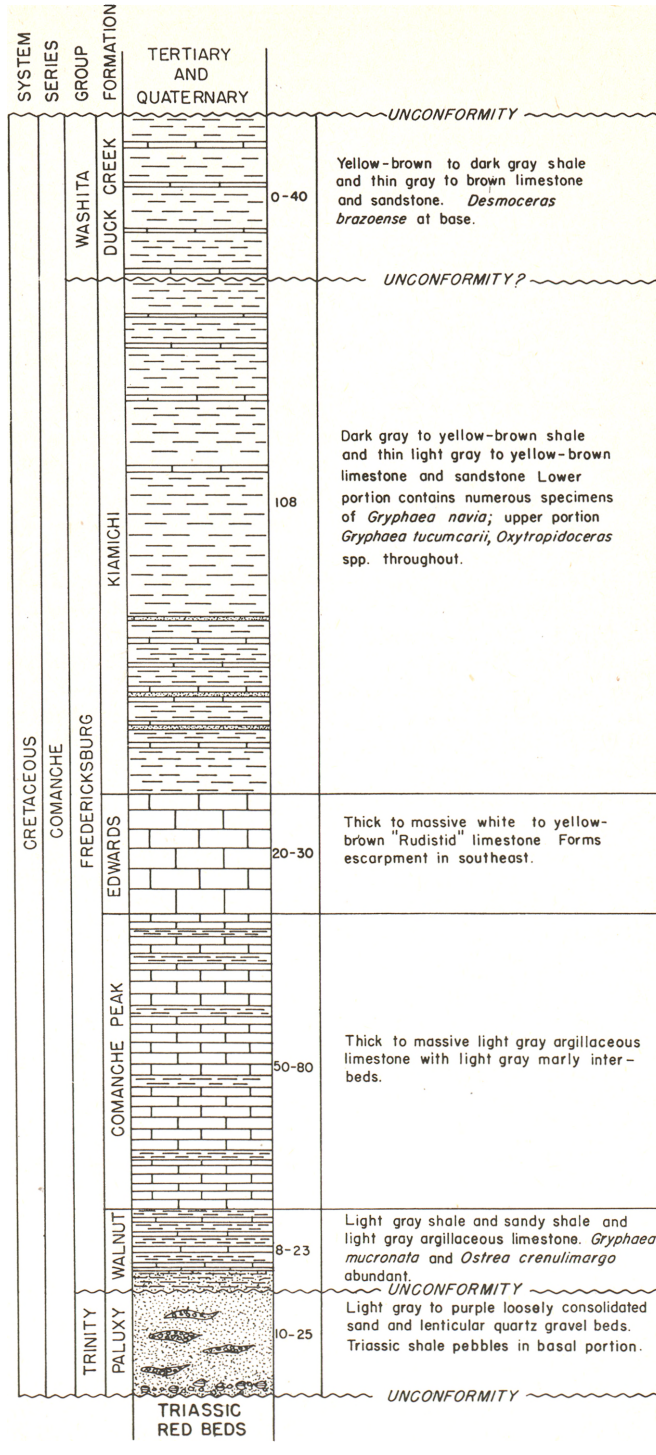

FIG. 1. Columnar section of Cretaceous of Llano Estacado.

Anderson (1950, table 1) reported the following microfauna from the Walnut at localities 10, 14, and 15 (pp. 30, 31, 33):

Foraminifera
Spiroplectammina alexanderi
S. goodlandana
Verneuilinoides schizea
Trochammina sp.
Lenticulina n. sp. A
Lenticulina n. sp. B
Citharina intumescens
Marginulina sp.
Ramulina sp.
Conorbina conica ?
Ostracoda
Monoceratina n. sp.
Bythocypris goodlandensis
Bythocypris n. sp.
Macropypris n. sp.
Paracypris siliqua
Cytherella ovata
C. scotti
C. n. sp. A
C. n. sp. B
C. n. sp. C
C. n. sp. D
C. n. sp. E
Cytherelloides n. sp.
Cytheridea goodlandensis
C. oliverensis
C. washitaensis
C. n. sp.
Loxoconcha n. sp.
Cytheropteron howelli
Cythereis carpenterae
C. fredericksburgensis
C. mahonae
C. n. sp. A
C. n. sp. B
C. n. sp. C
C. n. sp. D
C. n. sp. E
C. n. sp. F

COMANCHE PEAK LIMESTONE

The Comanche Peak limestone was named by Hill (1891, pp. 512–513) from the type locality, Comanche Peak, Hood County, Texas. In the Llano Estacado, the Comanche Peak limestone, exposed in the plains escarpment in Lubbock, Lynn, Garza, Borden, Scurry, and Dawson counties and in isolated exposures in Gaines and Ector counties, consists of from 30 to 80 feet of light gray, thinly bedded to massive, argillaceous limestone with thin, light gray, shaly interbeds. The Comanche Peak thins to the west. The average thickness of complete sections in southeastern Garza and central Borden counties is 70 feet; in western Borden and in eastern and northeastern Dawson counties, 50 feet. At Cedar Lake, Gaines County (locality 7), the Comanche Peak is 37.6 feet thick. In the latter, the section does not extend to the contact between the Comanche Peak and Edwards, but the uppermost Comanche Peak bed is similar, lithologically and paleontologically, to the bed in contact with the Edwards in other sections.

The contact between the Comanche Peak and the Edwards is gradational (Pl. III, A). In some escarpment exposures, the Edwards slightly overhangs because of differential weathering along the contact. In unweathered exposures, the contact must be identified on the basis of slight lithologic and paleontologic differences. The following criteria aid in determining this contact:

(1) The uppermost bed of the Comanche Peak is typically a fine-grained, argillaceous limestone; the basal Edwards is typically a coarse-grained limestone.
(2) Lines of stratification are regular in the Edwards but undulating in the Comanche Peak.
(3) The basal Edwards often contains numerous rudistid fossils or is porous because of solution of these fossils.
(4) Shale interbeds are common in the Comanche Peak but absent in the Edwards.

Fauna.—The following fauna has been collected by the writer from the Comanche Peak limestone in the Llano Estacado (* identified by L. W. Stephenson):

Phymosoma sp.
Salenia mexicana Schlüter
Pyrina bulloides Cragin
Enallaster texanus (Roemer)
Holectypus planatus Roemer
Gryphaea mucronata Gabb (=*G. marcoui* Hill and Vaughan)
Gryphaea sp. (young individuals)
Exogyra texana Roemer
Pecten (Neithea) occidentalis (Conrad)
P. (Neithea) subalpinus (Böse) (?)
P. (Neithea) irregularis Böse
**Anomia* (?) sp.
**Crenella* (?) sp.
Pholadomya sancti-sabae Roemer
**Pleuromya* sp.
Modiola concentrice-costellata Roemer
Trigonia sp.
Inoceramus sp.
Protocardia texana (Conrad)
Cyprimeria texana Roemer
Lima wacoensis Roemer
Pinna comancheana Cragin
Turritella seriatum-granulata (?) Roemer
Tylostoma elevatum (Shumard)
T. tumidum Shumard
Aporrhais sp.
Anchura sp.
Engonoceras pierdenale (v. Buch)
Oxytropidoceras aff. *O. acutocarinatum* (Shumard)
O. aff. *O. belknapi* (Marcou)

EDWARDS LIMESTONE

The Edwards limestone was named by Hill and Vaughan (1898, p. 2) from exposures on the Edwards Plateau in Nueces and Uvalde quadrangles, Texas. In the Llano Estacado, the Edwards ranges from a thin layer to 35 feet of hard, light gray to grayish-yellow, thickly bedded to massive, fine to coarse-grained limestone. The Edwards forms the cap of the High Plains escarpment in southern Garza, northern Borden, and eastern and northeastern Dawson counties. It occurs in isolated exposures in the floor of Guthrie Lake, Lynn County, and in the walls of a caliche pit north of Floydada, Floyd County. In most exposures, one or more of the beds are porous because of solution of rudistid fossils (Pl. III, B). In some exposures, the cavities have been partly or entirely filled by secondary calcite or chalcedony.

The contact between the Edwards and Kiamichi, exposed only in the floor of the present playa of Guthrie Lake, apparently is conformable.

Fauna.—The following fauna has been collected by the writer from the Edwards limestone in the Llano Estacado:

Salenia mexicana Schlüter
Goniopygus sp.
Holectypus planatus Roemer
Gryphaea mucronata Gabb (=*G. marcoui* Hill and Vaughan)
Chondrodonta munsoni (Hill)
Caprinula anguis (?) (Roemer)
Eoradiolites davidsoni (Hill)
Toucasia patagiata C. A. White
Monopleura sp.

KIAMICHI SHALE

The Kiamichi shale was named by Hill (1891, pp. 515–516) for the Kiamichi River, Choctaw County, Oklahoma. In the Llano Estacado the Kiamichi consists of dark gray to moderate yellowish-brown shale, thin, light gray limestone, and moderate yellowish-brown sandstone. The basal contact of the Kiamichi is exposed only in the floor of the present playa of Guthrie Lake, Lynn County, but localities containing higher Kiamichi beds are in Lynn, Terry, Hockley, Lamb, and Bailey counties. In all localities, exposures are limited to the walls of the deeper playa basins.

The contact between the Kiamichi and the overlying Duck Creek is difficult to identify in most localities in the Llano Estacado. Typically, both units consist of shale and thin-bedded limestone, and although the basal Duck Creek, at most places, contains more limestone than the upper Kiamichi, the exact line of contact cannot be determined. In Lynn County (localities 22, 23, and 24; Pl. V, A) and in Bailey County (locality 37) the base of the Duck Creek is a limestone member 0.8 to 1.5 feet thick, containing *Desmoceras brazoense* (Shumard) and *Mortoniceras* aff. *M. trinodosum* (Böse). In other exposures this member is absent and the contact is obscure.

The following criteria have been employed in differentiating between the Kiamichi and the Duck Creek:

(1) The basal Duck Creek contains *Desmoceras brazoense* (Shumard) and *Mortoniceras* aff. *M. trinodosum* (Böse). The Kiamichi is marked by *Oxytropidoceras* spp. *Oxytropidoceras* associated with either *Desmoceras* or *Mortoniceras* has not been found in the Llano Estacado.

(2) The Duck Creek contains several species, some in abundance, which have not been found in the upper Kiamichi of the area. These are *Cymatoceras texanum* Roemer, *Hamites* sp., *Prohysteroceras* (?) *burckhardti* (Böse), *Ostrea subovata* Shumard, *O. quadriplicata* Shumard, and "*Solarium*" *planorbis* Roemer.

(3) The upper Kiamichi consists typically of medium gray to black shale with interbeds of nodular, argillaceous, unfossiliferous limestone. The basal Duck Creek consists of moderate yellow to gray shale with interbeds of brown, thinly bedded, fossiliferous limestone.

Fauna.—The following fauna has been collected by the writer from the Kiamichi shale in the Llano Estacado:

Exogyra texana Roemer
Gryphaea navia Hall
G. tucumcarii Marcou
G. corrugata Gabb
Cyprimeria texana Roemer
Protocardia texana (Conrad)
Tapes sp.
Trigonia emoryi Conrad
Inoceramus sp.
Pecten (Neithea) irregularis Böse
P. (Neithea) subalpinus Böse
Elobiceras sp.
Oxytropidoceras acutocarinatum (Shumard)
O. belknapi (Marcou)
O. supani (Lasswitz)
O. bravoense (Böse)
O. trinitense (Gabb)
O. sp.

Stainbrook (1940) reported the following gastropods from the Kiamichi at locality 21 (p. 36).

Phasianella estacadoensis Stainbrook
Amberleya mudgeana (Meek)
Trochus texanus Roemer
Nerita ? semipleura Twenhofel
Natica smolanense Twenhofel
Gyrodes pattoni Stainbrook
Turritella belviderii Cragin
T. lynnensis Stainbrook
T. macropleura Stainbrook
Cerithium laeviculum Stainbrook
Anchura kiowana Cragin
Avellana texana Shumard

Stultz (1935, p. 19) reported the following foraminifera from the Kiamichi at localities 21, 24, 33, and 36 (pp. 36, 40, 48, 52):

Lenticulina sp.
L. cf. *rotalata*
L. cf. *reniformis*
Planularis sp.
Robulus cf. *munsteri*
Lenticulina sp.
Vaginulina cf. *kochi*
V. kochi
V. recta
V. sp.
V. cf. *simondsi*
Flabellina rugosa
F. sp.
Frondicularia verneuiliana
Nodosaria sp.
Reophax sp.
R. subgoodlandensis
Textularia conica
T. rioensis
T. washitensis

WASHITA GROUP

DUCK CREEK SHALE

The Duck Creek shale was named by Hill (1891, p. 516) from the type locality, Duck Creek, Grayson County, Texas. In the Llano Estacado, beds of Duck Creek age, exposed in Lynn, Terry, Hockley, Lamb, and Bailey counties, consist of moderate yellow shale and thin moderate yellowish-brown limestone ranging in thickness from a thin layer to 36 feet thick. The outcrop at Mound Lake, Terry County (locality 26), contains more limestone than any other in the Llano Estacado (Pl. V, B).

In Lynn County, the basal bed is composed of light gray argillaceous limestone which contains *Desmoceras brazoense* (Shumard) and *Mortoniceras* aff. *M. trinodosum* (Böse). In Hockley, Lamb, and Bailey counties, this limestone is absent or poorly developed. Here, *Desmoceras* has not been found but *Mortoniceras* occurs in the basal beds of the Duck Creek.

Fauna.—The following fauna has been collected by the writer from the Duck Creek shale in the Llano Estacado:

Trochosmilia sp.
Leiocidaris ? spines and plates
Enallaster texanus (Roemer)
Exogyra texana Roemer
Ostrea subovata ? Shumard
O. quadriplicata Shumard
Gryphaea corrugata Gabb
G. tucumcarii (Marcou)
G. washitaensis Hill
Pecten (Neithea) sp.
Lima sp.
Tapes sp.
Trigonia emoryi Conrad
Desmoceras brazoense (Shumard)
Mortoniceras aff. *M. trinodosum* (Böse)
Prohysteroceras burckhardti (Böse)
Hamites sp.
"*Solarium*" *planorbis* Roemer
Amberleya sp.
Trochus sp.
Turritella sp.
Avellana sp.

PALEONTOLOGY AND ZONATION

Faunal zones defined by Adkins (1927, pp. 49–60) for the Fort Stockton area are generally applicable to the Cretaceous of the Llano Estacado. Ammonite genera and species are the most useful for delimiting local stratigraphic subdivisions, but other faunal elements have been used where ammonites have not been found. Correlation of some isolated exposures of Kiamichi and Duck Creek beds presents a particular problem because of limited extent of outcrops and paucity of established zone fossils.

Following is a list of Cretaceous formations of the High Plains area together with species which serve as markers.

Paluxy sandstone.—This unit is unfossiliferous and must be determined on the basis of position in sections.

Walnut formation.—The best marker is the pelecypod *Ostrea crenulimargo* Roemer. This species has not been found above the Walnut in the area. Other guide species, in local sections, include *Gryphaea mucronata* Gabb, which in many places forms an agglomerate in the middle limestone portion of the formation, and robust specimens of *Lunatia* sp.

Comanche Peak limestone.—The ammonite genus *Oxytropidoceras* appears, for the first time, in the Comanche Peak. The species *O.* aff. *O. belknapi* (Marcou) and *O. acutocarinatum* (Shumard), however, range upward into Kiamichi. The best guides are *Enallaster texanus* (Roemer), *Holectypus planatus* Roemer, *Salenia mexicana*

Schlüter, *Tylostoma* spp., *Pinna comancheana* Cragin, *Lima wacoensis* Roemer, and *Engonoceras pierdenale* (v.Buch) associated with the ammonites listed above.

Edwards limestone.—The best guide fossils are *Toucasia patagiata* C. A. White, *Eoradiolites davidsoni* (Hill), and *Chondrodonta munsoni* (Hill). Other guide species, in local sections, are *Monopleura* sp. and *Caprinula anguis* (?) (Roemer).

Kiamichi shale.—The best guide fossils are *Gryphaea navia* Hall, restricted to a zone 12 to 16 feet above the base, and *Gryphaea tucumcarii* Marcou, which appears, for the first time, 6 to 8 feet below the Kiamichi—Duck Creek contact. The ammounite *Oxytropidoceras* aff. *O. brazoense* (Böse) (slightly curved ribs, one-half of which reach umbilical margin) appears to mark the middle of the formation. The gastropod *Turritella belviderii* Cragin occurs in great abundance 25 feet above the base. Poorly preserved specimens of *Elobiceras* have been found at locality 38, Bailey County, but the range of this genus has not been accurately determined in the local area.

Duck Creek shale.—The ammonites *Desmoceras brazoense* (Shumard) and *Mortoniceras* aff. *M. trinodosum* (Böse) appear in the basal bed of the Duck Creek. *Prohysteroceras burckhardti* (Böse) and *Hamites* occur with *Mortoniceras* but apparently above the range of *Desmoceras*. Other guide species include *Cymatoceras texanum* Roemer, *Ostrea subovata* Shumard, *O. quadriplicata* Shumard, and "*Solarium*" *planorbis* Roemer.

The accompanying chart (table 2) shows graphically the probable range of species in the Cretaceous of the Llano Estacado. Forms listed under the heading of "other fossils" are not necessarily restricted to the formation in question but serve to support evidence based upon ammonites.

Table 2. Zonation of Cretaceous of Llano Estacado.

Formation	Ammonites	Other Fossils
Duck Creek	*Prohysteroceras* and *Hamites* *Mortoniceras* aff. *M. trinodosum* *Desmoceras brazoense* *Gryphaea tucumcarii*	*Cymatoceras texanum* *"Solarium" planorbis* *Ostrea quadriplicata* *Ostrea subovata*
Kiamichi	*Elobiceras* *Oxytropidoceras* aff. *bravoense* *belknapi* *utocarinatum*	*Turritella belviderii* (abundance) *Gryphaea navia*
Edwards	aff. *O. ras* aff. *O. s*	*Chondrodonta munsoni* *Eoradiolites davidsoni* *Toucasia patagiata*
Comanche Peak	*Oxytropidoceras* *Oxytropidoce* *Engonoceras* spp.	*Lima wacoensis* *Tylostoma* sp. *Pinna comancheana* *Holectypus planatus* (abundance) *Pyrina bulloides* *Salenia mexicana* *Enallaster*
Walnut		*Ostrea crenulimargo* *Gryphaea mucronata* (abundance)
Paluxy		
Triassic red beds		

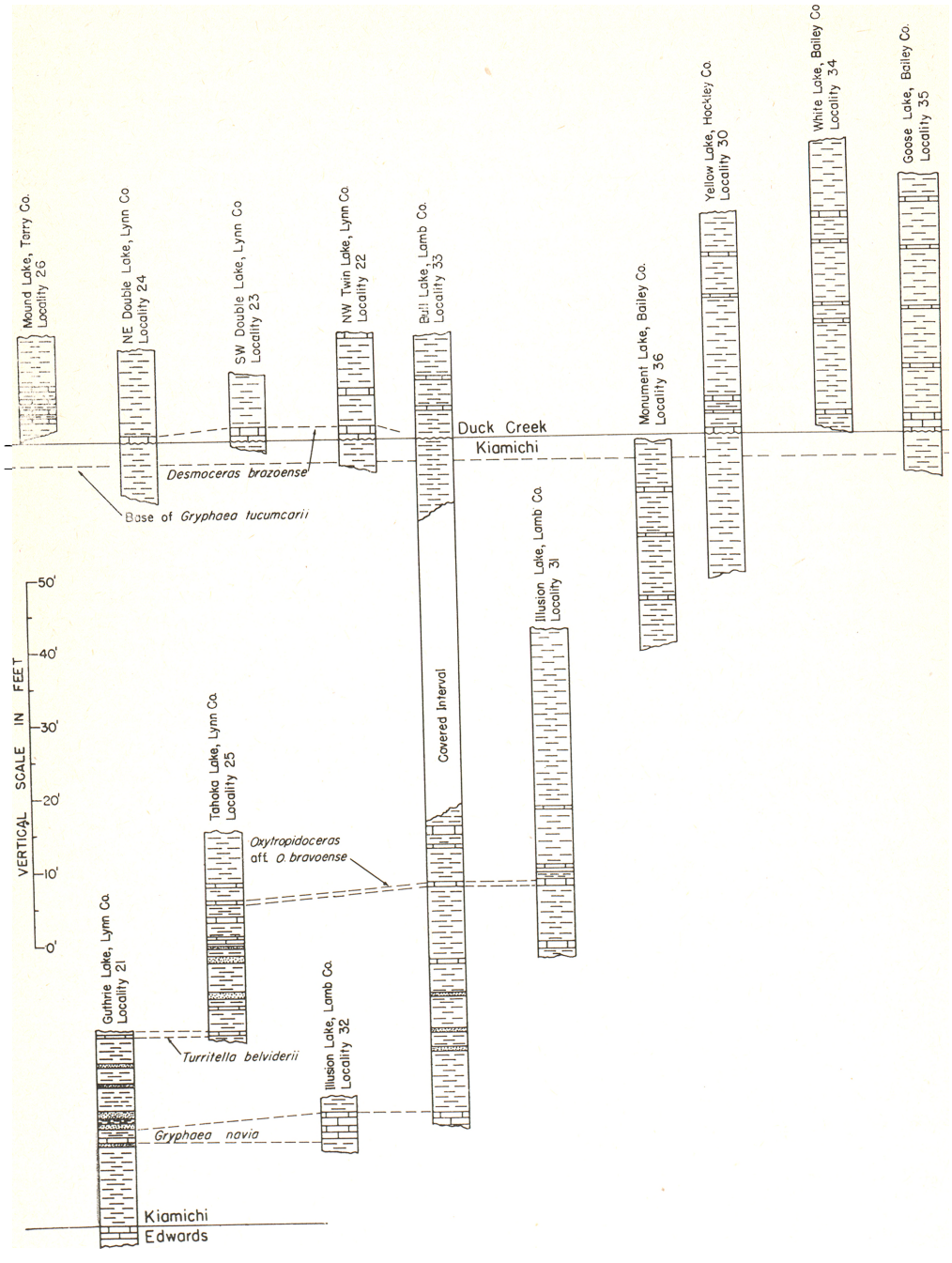

FIG. 2. Correlation of Kiamichi and Duck Creek exposures in Llano Estacado.

CORRELATION OF KIAMICHI AND DUCK CREEK EXPOSURES IN LLANO ESTACADO

On the accompanying chart (fig. 2) correlation of the isolated exposures of Kiamichi and Duck Creek age is based upon the following guide fossils:

(1) *Gryphaea navia* Hall. This species is restricted to a zone 12 to 16 feet above the base of the Kiamichi formation.
(2) *Turritella belviderii* Cragin. This species occurs in abundance in a thin bed 25 feet above the base of the Kiamichi. It has been found in limited numbers below this bed but is rare above.
(3) *Oxytropidoceras* aff. *O. bravoense* (Böse). A small form appears to be restricted to a zone about 50 feet above the base of the Kiamichi.
(4) *Gryphaea tucumcarii* (Marcou). This species has not been found below the upper 10 feet of the Kiamichi. However, it extends into the Duck Creek.
(5) *Desmoceras brazoense* (Shumard). This species first appears in the basal Duck Creek but has not been found above the basal 10 feet.
(6) *Mortoniceras* aff. *M. trinodosum* (Böse). This species appears to be limited to the Duck Creek formation.

As a complete section of the Kiamichi is nowhere exposed in the Llano Estacado area, its approximate thickness is based upon the correlation of several outcrops. By using the above species as guides, a composite Kiamichi section is constructed as follows:

The contact between the Edwards and the Kiamichi is exposed only at Guthrie Lake (locality 21), and only in this section are beds below the zone of *Gryphaea navia* exposed. The basal units of the Bull Lake section (locality 33) and the Illusion Lake section (locality 32) are correlated with the Guthrie Lake section by means of *Gryphaea navia*. The Bull Lake section is continuous to the base of the Duck Creek, but an interval 44 feet thick subjacent to the base of the beds containing *Gryphaea tucumcarii* is covered. The uppermost unit of the Guthrie Lake section contains a profusion of *Turritella belviderii* and is correlated with the basal unit of the Tahoka Lake section (locality 28) by means of this species. *Oxytropidoceras* aff. *O. brazoense* serves to correlate the Tahoka Lake exposure with the sections at Bull Lake and at locality 31. Sections at Monument Lake (locality 36) and sections at localities 22, 23, and 24 in Lynn County are correlated with the Bull Lake section on the first appearance of *Gryphaea tucumcarii*.

Duck Creek exposures are correlated by means of *Desmoceras brazoense* and *Mortoniceras* aff. *M. trinodosum*. In all outcrops except those at Mound Lake (locality 26) and at Rich Lake (locality 27), Duck Creek beds are superjacent to the Kiamichi—Duck Creek contact.

CRETACEOUS EXPOSURES IN ADJACENT AREAS

QUAY COUNTY, NEW MEXICO

Beds of Cretaceous age occur in discontinuous outcrops along the margins of the Llano Estacado and in outlying buttes and mesas in Quay County, New Mexico. These are of interest in the study of the Cretaceous of the Llano Estacado of Texas as they are of nearly equivalent age and were deposited during the same marine invasion. In Quay County, beds of Cretaceous age which rest unconformably upon Jurassic and Triassic rocks were deposited near the margin of marine deposition. A short distance to the west, correlatives of these strata, if present, are represented by rocks of continental origin (Dobrovolny et al., 1946, sheet 1).

Lower Cretaceous deposits of Quay County are assigned to the Purgatoire formation. Dobrovolny and Summerson (1946, sheet 2) have subdivided the Purgatoire into members as follows:

Tucumcari shale member.—Gray shale and buff calcareous sandstone with nodules of argillaceous limestone. From this interval the following fauna has been reported: *Ostrea quadriplicata, O. subovata. Gryphaea corrugata* var. *tucumcarii, G. corrugata, Exogyra texana, Plicatula* sp., *Neithea occidentalis, Trigonia emoryi, Protocardia* sp., *Pinna comancheana, Cardita belviderensis, Tapes belviderensis, Cyprimeria* sp., *Turritella seriatim-granulata,* and *Pervinquieria leonensis.* This fauna suggests Kiamichi—Duck Creek age for the Tucumcari shale member.

Mesa Rica sandstone member.—White or brownish-buff, cross-bedded, medium or coarse-grained sandstone that is massive or cliff-forming. Locally, lenses of quartz-pebble conglomerate occur at the base.

Pajarito shale member.—Soft brown sandstone alternating with gray shale that contains *Ostrea quadriplicata.*

The writer visited the Quay County, New Mexico, area briefly during the summer of

1950. A limited examination of the Tucumcari shale fauna suggests that the unit may be analogous to the Kiamichi—Duck Creek shale unit of the Llano Estacado of Texas. Future study might reveal a Kiamichi equivalent in the lower portion of a Duck Creek equivalent in the upper portion.

Dr. Raymond Sidwell has kindly supplied the following section of the Tucumcari shale member from Quay County.

Section of Tucumcari shale member of Purgatoire formation in escarpment 18-3/4 miles west and 6 miles north of Ragland, Quay County, New Mexico.

	Thickness *Feet*
Quaternary. Caliche.	
Tucumcari shale member—	
13. Sandstone, yellow-gray, conglomeratic. Grades upward into caliche	5.0
12. Sandstone, light gray, thin to heavy, fine grained. Two thin shale members in unit	6.0
11. Shale, light purplish-gray, arenaceous, moderately thickly laminated	4.0
10. Sandstone, light yellowish gray, thin to heavy, fine to medium grained, with thin clay interbeds	6.0
9. Shale, medium dark gray, thinly laminated, slightly calcareous	6.0
8. Sandstone, dark yellowish gray, massive, fine grained, slightly calcareous	15.0
7. Covered	5.0
6. Shale, pale yellowish brown, arenaceous, slightly calcareous	5.5
5. Shale, medium gray, thinly laminated, calcareous	12.0
4. Shale, light grayish green, thinly laminated, calcareous	10.0
3. Covered	7.0
2. Shale, light gray, moderately thickly laminated, calcareous	0.5
1. Covered	12.0
Total Tucumcari shale	94.0
Morrison formation.	

DALLAM COUNTY, TEXAS

Isolated exposures of Purgatoire (?) age occur in several localities in Dallam County, Texas. At Buffalo Springs ranch (XIT ranch headquarters) about 17 miles east of the northwestern corner of Dallam County and half a mile south of the Texas-Oklahoma State line, sandstone, lithologically similar to the Cheyenne sandstone, overlies purple mudstone and yellow-green sandstone. Adkins (1933, p. 258) suggested that the lower mudstone and sandstone are lithologically similar to the Morrison formation of northeastern New Mexico. He correlated the overlying sandstone unit with the Purgatoire formation of northeastern New Mexico.

About 1½ miles south of the railroad station at Texline, Dallam County, beds of Purgatoire (Cheyenne?) age are exposed along the banks of Rita Blanca Creek. Here, cross-bedded and ripple-marked sandstone is interbedded with thin bentonitic shale and clay. No fossils were recovered from the exposure, but fucoidal markings and limonitic concretions suggest possible organic materials.

Although some doubt exists regarding the origin of the Cheyenne sandstone, all suggestions point to deposition at or near the margin of the Cretaceous sea. If the isolated exposures of Dallam County are correlative with the Cheyenne, they give another indication of the paleogeography during Comanche time.

The following sections in Dallam County were measured by the writer during the summer of 1950.

Section of Morrison formation (?) in draw half a mile west of Buffalo Springs ranch headquarters, Dallam County, Texas.

	Thickness *Feet*
Quaternary. Caliche.	
Morrison formation (?)—	
7. Sandstone, light gray with moderate yellow spots, very fine grained, argillaceous	0.7
6. Shale, light gray to light yellowish gray, thinly laminated, slightly arenaceous	2.0
5. Sandstone, light gray to greenish gray, very fine grained, slightly calcareous	0.7
4. Shale, light gray to light yellowish gray, slightly arenaceous	3.0
3. Sandstone, light gray with purplish-gray streaks and dark brown ferruginous spots, fine to medium grained, slightly argillaceous	0.5
2. Siltstone, grayish purple, massive	5.5
1. Sandstone, yellowish gray, thin to thickly bedded, fine to medium grained, argillaceous	2.0
Total Morrison (?)	14.4

Purgatoire (Cheyenne?) section, 1,000 yards southwest of Buffalo Springs ranch headquarters, Dallam County, Texas.

	Thickness *Feet*
Quaternary. Caliche.	
Purgatoire formation (?)—	
2. Sandstone, light gray, thin to thickly bedded, fine to medium grained, with thin, light gray sandy shale interbeds. Unfossiliferous except for fucoidal markings on bedding surfaces in lower 2 feet of unit	9.0
1. Sandstone, light gray to moderate brown, thickly bedded to massive, cross-bedded in massive beds, slightly micaceous	8.0
Total Purgatorie (?)	17.0

Purgatoire (Cheyenne?) section along Rita Blanca Creek 1-1/2 miles south of railroad station at Texline, Dallam County, Texas.

	Thickness *Feet*
Quaternary. Caliche.	
Purgatoire formation (?)—	
9. Shale, light gray, faintly laminated, arenaceous, with numerous ¼ to ½-inch dark brown limonitic concretions	6.0
8. Shale, light gray to light green, faintly laminated, bentonitic, with streaks of ironstained clay and other botryoidal masses of barite	6.0
7. Sandstone, light purplish gray, thinly bedded, fine to medium grained, with light gray shale interbeds	2.0
6. Sandstone, light brown to moderate brown, cross-bedded, slightly micaceous. Upper bedding surface marked by asymmetrical ripple marks. Strike of ripples N. 5° E., current direction west-east	12.0
5. Sandstone, light gray, thinly bedded, very fine grained, with light gray siltstone interbeds	3.0
4. Sandstone, dark yellowish orange, thin to thickly bedded, fine to medium grained, argillaceous. Fucoidal markings on bedding surfaces	4.5
3. Siltstone, light gray, faintly bedded	1.5
2. Sandstone, light gray to moderate brown, massive, argillaceous, slightly micaceous. Limonitic concretions up to 10 inches diameter in upper 3 feet	3.0
1. Siltstone, pale red-purple, faintly bedded. Poorly exposed in stream bed	1.0
Total Purgatoire (?)	39.0

CONDITIONS OF DEPOSITION OF CRETACEOUS SEDIMENTS

Throughout Cretaceous time, the sites of deposition in the High Plains area of Texas were within the epineritic and littoral environments of stable shelf seas. Subsidence was slow, and during several time intervals, limestone accumulated close to the shore lines.

The sand and gravel of the Paluxy formation reflect deposition during marine transgression. Particles of sand size and larger show a high degree of abrasional wear and must have been subjected to extensive reworking. The coarse material probably represents the littoral zone of an advancing sea. The fine, argillaceous "pack sands" probably occupy a position intermediate between littoral and offshore environments. The numerous gravel lenses indicate action of inflowing streams or rip currents.

The Fredericksburg group records a marine transgression during Walnut time and an expansion during Kiamichi time. Subsidence during Comanche Peak and Edwards time was slow, and the shoreline remained relatively stable; the sea was warm and shallow. Limestone precipitation during Comanche Peak time probably involved mainly inorganic chemical processes, but during Edwards time organic agencies contributed considerable sediment. The rudistid biostromes of the Edwards limestone reflect a particularly stable environment over most of Texas.

Kiamichi time began by marine expansion and an influx of mud from the adjacent Triassic landmass. Angular quartz grains and unabraded crystals of tourmaline, zircon, and magnetite suggest short transportation and slight abrasional wear. The absence of feldspar indicates either that the Triassic provenance was free of these minerals or that weathering was dominantly decomposition during Cretaceous time. The mud that entered the Cretaceous sea during Kiamichi and Duck Creek time probably reflects more humid climates than during the preceding time intervals. That the Kiamichi sea was shallow is indicated by a profusion of massive, thick-shelled pelecypods (*Gryphaea* and *Exogyra*), ripple-marked and cross-bedded sandstone, and conglomeratic limestone. The paucity of fossils and thinly laminated dark gray and black shales of the

upper Kiamichi indicate slow deposition in a reducing environment.

Washita time began by another marine expansion and increased circulation in the sea. Although the Duck Creek shales are mineralogically similar to those of the Kiamichi, the colors differ because of the change from a reducing environment in the Kiamichi to an oxidizing environment in the Duck Creek. The new faunal elements of the Duck Creek formation likewise reflect distinct changes from the conditions existing during upper Kiamichi time.

Tertiary System

Pliocene Series

Couch Formation

The name Couch was proposed by Evans (1949, p. 5) from the type locality, Couch ranch, Crosby County, Texas, where it is composed of compact, well-sorted calcareous sand and gravel. Regarding the position of the Couch, Evans (1949, p. 6) stated:

> The formation rests unconformably on Triassic and Cretaceous rocks and is separated by unconformity from the overlying Bridwell formation. At the type locality, about 7 miles east of Crosbyton, the formation is 125 feet thick, but its thickness varies markedly with the relief on the underlying bed rock surface. . . . At the type locality and in the other exposures in Blanco Canyon, the Couch contains numerous vertebrate fossils occurring at different levels throughout almost the entire thickness. . . . This fauna indicates an early Pliocene age for the formation.

Bridwell Formation

The name Bridwell was proposed by Evans (1949, p. 5) from the type locality, Bridwell ranch, Crosby County, Texas. Evans (1949, p. 6) described the Bridwell as follows:

> At the type locality, the Bridwell is 155 feet thick and this thickness is maintained at other exposures within the area. . . . The Bridwell formation represents channel and flood plain facies of broad aggrading stream valleys. . . . Vertebrate fossils have been found in several zones in the Bridwell deposits. . . . The fauna, particularly *Astrohippus*, indicates a middle Pliocene age for the Bridwell.

Quaternary System

Pleistocene Series

Blanco Beds

Pleistocene beds of Blancan age are not exposed in the area considered in this paper. They are, however, of considerable interest locally and should be included in any brief summary of the stratigraphy of the Llano Estacado.

The Blanco beds were laid down in large basins which were eroded into the Bridwell formation after development of a Pliocene caliche cap rock. The deposits consist of white to light gray bentonitic clay, sand, nonmarine limestone, and local beds of diatomite. The Blanco beds are overlain unconformably by 20 to 40 feet of red-brown eolian sand. Meade (1945) has assigned the Blanco beds to lower Pleistocene (Nebraskan) age on the basis of vertebrate fossils.

Tule Formation

The Tule formation, like the Blanco beds, is restricted to lake basin deposits. Lithologically, the Tule beds are similar to those of the Blanco. The largest deposits of Tule age in the Llano Estacado are on Spring Creek in western Garza County and adjacent portions of eastern Lynn County. Evans and Meade (1945, pp. 493–495) have assigned the Tule beds to intermediate Pleistocene age.

Tahoka Clay

The Tahoka clay was named by Evans and Meade (1945, pp. 495, 498) for exposures in the vicinity of Tahoka, Lynn County, Texas, and described as follows:

> The Tahoka clay consists mainly of bluish-gray calcareous and gypsiferous clays and gray sands which grade marginally to coarser sands and gravels. Thin, discontinuous beds and small lentils of fresh-water limestone are locally present in the basinward facies of the deposit. . . . The fact that the Tahoka clay appears to record the last prolonged humid stage preceding the generally more arid conditions which have prevailed to modern times indicates a late Pleistocene Wisconsin age for the main body of the deposits.

SUBSURFACE AND STRUCTURAL GEOLOGY

Subsurface Extent

Beds of Cretaceous age occur in the subsurface in all counties considered in this paper. Existing information does not permit precise determination of extent, but a general distribution, based on information from surface exposures, logs of water wells, and logs of wells drilled for seismic exploration, is known.

Following the Laramide revolution and withdrawal of the Cretaceous sea, all or part of the Cretaceous deposits of the area were removed by early and middle Tertiary erosion. The pre-Pliocene surface was one of considerable relief upon which Cretaceous remnants capped the divides between major stream valleys and formed the floors of shallow valleys. In deeper valleys, excavated to depths below the basal Cretaceous beds, Triassic beds were exposed. During Pliocene time, Couch and Bridwell sediments accumulated in the valleys, and in some localities completely covered the Cretaceous beds on the divides. Some of the Cretaceous remnants are large, occupying an area of several counties; others underlie only a few acres.

A comprehensive study of the location and extent of the Cretaceous remnants would be of inestimable value to the knowledge of ground water of the High Plains area, as it would indicate the sites of deposition of thick, water-bearing Pliocene sections. Unfortunately, the many wells, sections of which would provide data vital to a study, have been incompletely and inaccurately logged. However, the "blue shale," "blue clay," "blue slate," and "blue rock" of driller's terminology prob-

ably may be interpreted as Kiamichi shale.

On the accompanying map (fig. 3), areas designated as underlain by Cretaceous rocks are not necessarily continuous expanses. Rather, these are areas in which Cretaceous formations predominate over the Triassic beds as the bed rock subjacent to the Pliocene sand, gravels, or caliche.

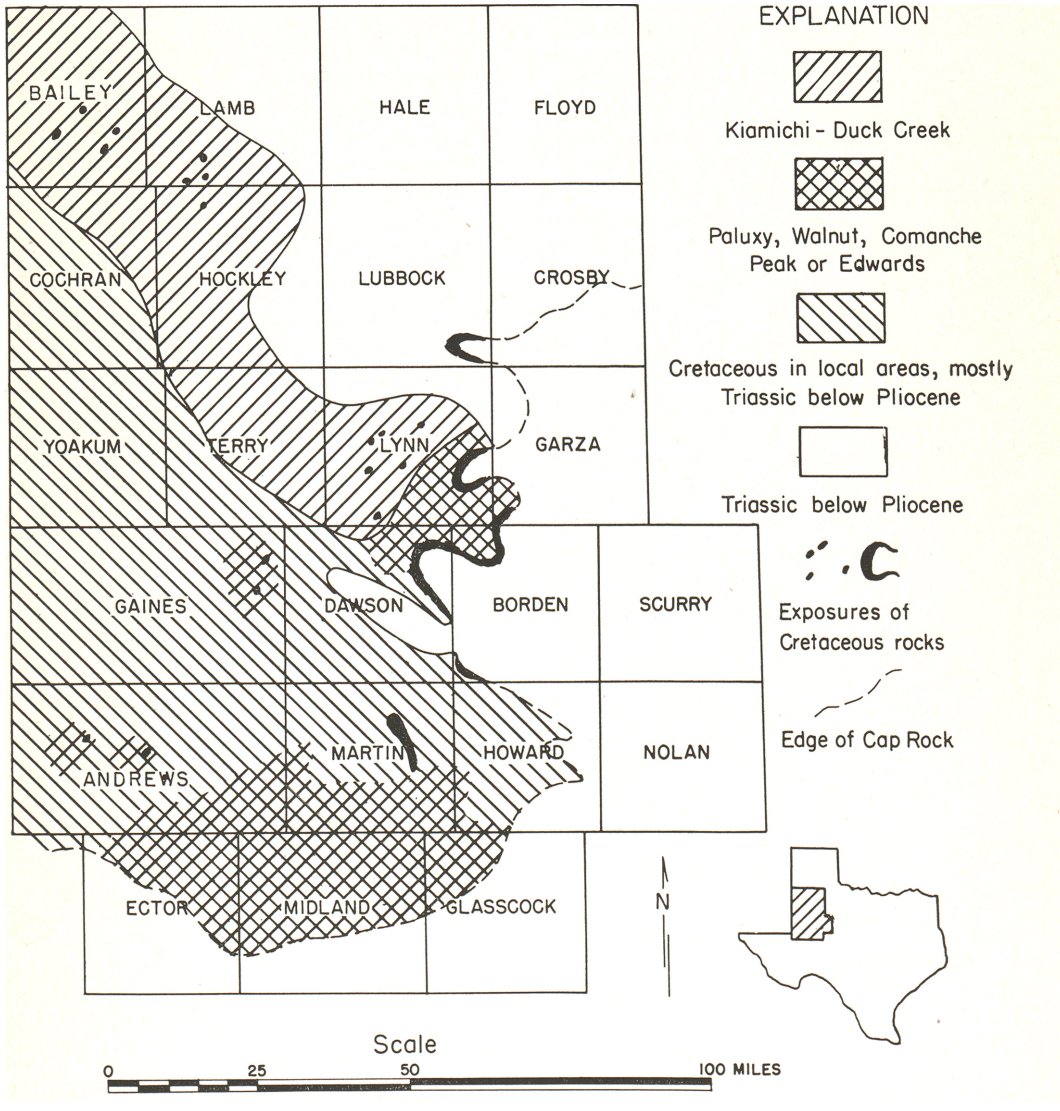

FIG. 3. Subsurface distribution of Cretaceous beds in Llano Estacado.

Structural Geology

Cretaceous beds in the Llano Estacado dip to the southeast essentially parallel to the 8 to 10 feet per mile slope of the surface of the plain. Contours on the accompanying map (fig. 4) are on the *Gryphaea navia* zone of the Kiamichi shale. In areas outside the outcrop of this zone, datum has been established on other key beds and adjusted to the *Gryphaea navia* zone by addition or subtraction of interval as indicated by the nearest surface section. These secondary markers are the *Gryphaea mucronata* agglomerate of the Walnut formation, the top of the Comanche Peak limestone, and the contact between the Kiamichi and Duck Creek shales. Elevations were determined by means of a Paulin altimeter with highway and railroad bench marks as closing points.

The data for Ector, Midland, Andrews, and Martin counties are taken from a map by Morgan Roberts (*in* Scott and others, 1941, p. 66, fig. 11).

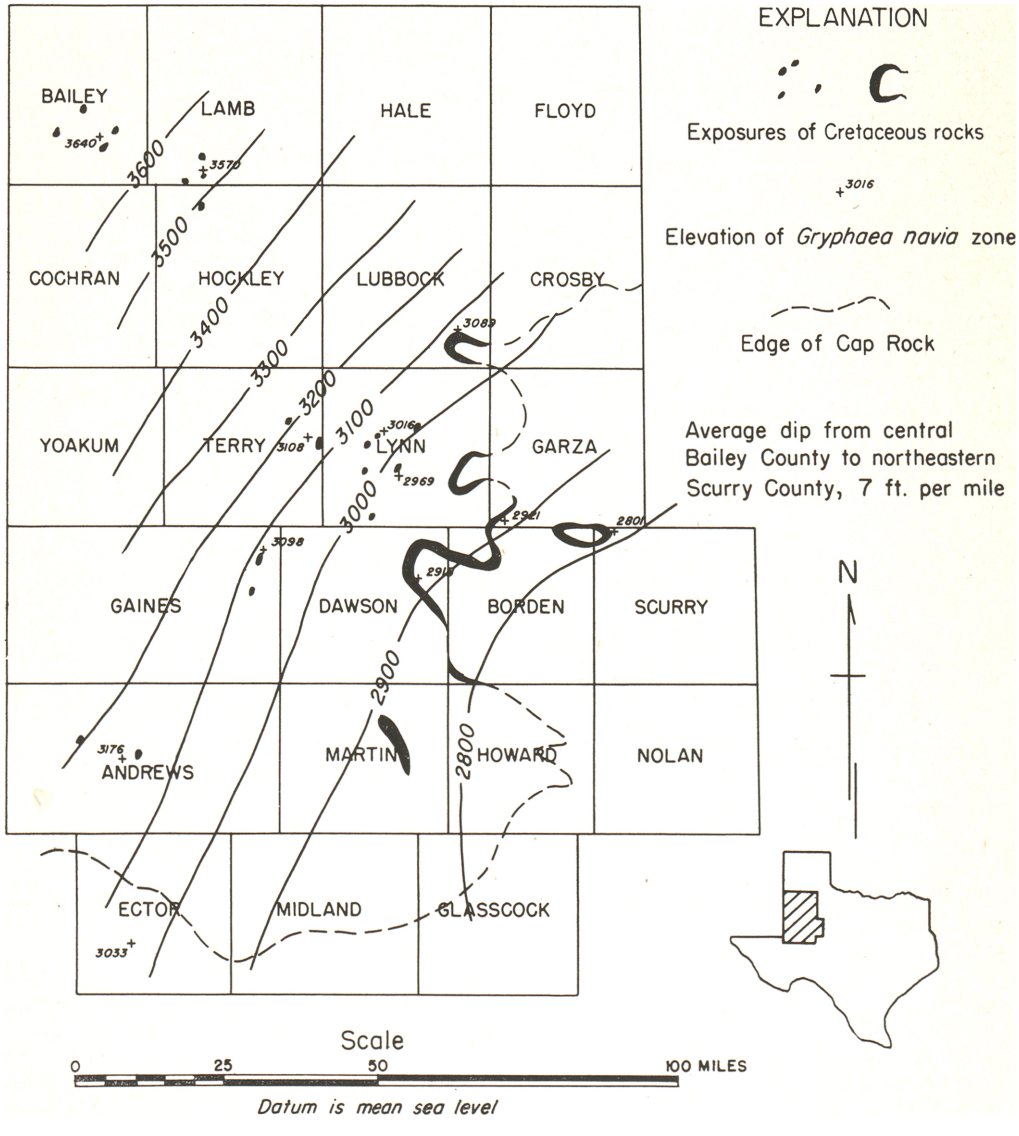

Fig. 4. Contours showing elevation of *Gryphaea navia* zone of Kiamichi shale.

Ground Water

Ground water is the most valuable resource in the High Plains area. Most municipal and irrigation needs are supplied by water from Pliocene sand and gravel, but locally Cretaceous limestone and sandstone supplement the Pliocene supply. In Lubbock, several municipal wells penetrate thin layers of Cretaceous limestone and sandstone which probably include Comanche Peak, Walnut, and Paluxy beds. The quantity of water obtained from the Cretaceous in these wells has not been determined, but water from them contains an exceptionally high percentage of calcium, magnesium, and bicarbonate.

E. R. Leggat, of the U. S. Geological Survey, gave the writer a fragment of fossiliferous limestone, probably Edwards, from a municipal well at O'Donnell, Lynn County. No log of the well is available, but the total depth is reported to be about 35 feet. Pumping tests, conducted at a rate of 700 gallons per minute, have produced draw-down curves characteristic of a cavernous aquifer. If this water is from the Edwards, it is the only Cretaceous water in quantities sufficient for municipal or irrigation needs known in the Llano Estacado.

In southwestern Lamb and central Bailey counties, the basal sandstone beneath the Kiamichi shale probably would produce water in sufficient quantities for household and livestock needs.

Sand and Gravel

Although the Paluxy sand and gravel is suitable for concrete aggregate, it has been little used for this purpose in the Llano Estacado area. The more accessible Pliocene and Recent sand and gravel supply most of the local demand.

Adequate supplies of Paluxy sand and gravel, accessible from major highways and good secondary roads, could be obtained from the following localities (pp. 31–32, 33, 34, 30, 35, 46):

	Approximate thickness *Feet*
Gail Mountain, Borden County, locality 14	26.0
Eppler-Fluvanna road, Garza County, locality 15	23.0
Southwestern Garza County, locality 17	22.0
Eastern Dawson County, locality 10	20.0
Valley of South Double Mountain Fork of Brazos River, Lynn County, in vicinity of localities 18 and 19	16.0
Northeast of Posey, Lubbock County, locality 28	?

Building Stone

No Cretaceous limestone has been quarried for building stone in the Llano Estacado area. The Edwards, the only unit that might be suitable, lacks most of the properties of a good building stone. Most of the beds are so porous as to permit entry of excessive moisture and allow subsequent damage by solution, freezing, and thawing. In some exposures, the extreme lithologic variations result in severe weathering effects.

Road Metal

The Edwards limestone is used locally as ballast for secondary roads, and this use could be extended to the limits of economical transportation. Over most of the area, however, caliche containing a high percentage of silica is the preferred road material.

In Borden County (locality 13), a small quarry for road metal has been operated intermittently during the past several years. In Floyd County (locality 38), Edwards limestone has been quarried along with caliche and used as road ballast. Other localities where the Edwards limestone is accessible from major highways include:

	Approximate thickness *Feet*
Gail Mountain, Borden County, locality 14	30.0
Eppler-Fluvanna road, Garza County, locality 15	24.0
Eastern Dawson County, locality 10	20.0
Floor of Guthrie Lake, Lynn County, locality 21	?

Cement Materials

The basic raw materials for the manufacture of cement are:

(1) Lime (CaO). This is usually obtained from limestone, marl, fossil shell, recent shell, or alkali waste; limestone must contain less than 3 percent MgO and must be relatively low in silica.
(2) Alumina (Al_2O_3). This is usually obtained from clay, shale, ash from coal, slag, or igneous rocks.
(3) Silica (SiO_2). This is usually obtained fram clay, shale, ash, slag, sand, or sandstone.
(4) Iron (Fe_2O_3). This is usually obtained from limestone, clay, shale, iron ores, slag, pyrite cinder, or mill scale.
(5) Gypsum, used as a retarder.

The percentage of each of the above in finished cement varies according to the type of cement. Five types of cement have been recognized by The American Society for Testing Materials, and a very close chemical control over raw materials is necessary to meet the specifications for the various types.

In the Llano Estacado, Cretaceous limestone and shale possibly could be combined to produce proper chemical composition for Portland cement. Table 4 shows analyses of the materials from selected localities.

The most favorable localities from the standpoint of volume of raw materials appear to be in Lynn, Garza, Borden, and Dawson counties. Probably less favorable geographically are localities in northern Hockley, southwestern Lamb, and central Bailey counties. In all areas, additional sampling and analyses and probably drilling would be necessary to establish the adequacy of supplies of raw materials for a cement industry. Other factors, especially economic ones, beyond the scope of this paper enter into this question. The purpose

Table 3. *Cement materials in Llano Estacado area.*

County, locality, and page reference	Limestone (thickness in feet) Edwards	Limestone (thickness in feet) Comanche Peak	Shale (thickness in feet) Kiamichi	Shale (thickness in feet) Duck Creek
Bailey County—				
Nos. 34, 35 (p. 50)	.....	.....	1.0*	.....
No. 36 (p. 52)	.....	.....	27.0*	.....
No. 37 (p. 54)	.....	.....	20.0*	.....
Borden County—				
No. 8 (p. 29)	14.0	41.0	.....	.....
No. 9 (p. 29)	14.0	41.0	.....	.....
No. 13 (p. 31)	20.0	60.0	.....	.....
Dawson County—				
No. 10 (p. 30)	14.0	49.0	.....	.....
No. 11 (p. 30)	8.00	50.0	.....	.....
No. 12 (p. 31)	23.0	54.0	.....	.....
Gaines County—				
No. 7 (pp. 28–29)	.....	37.0†	.....	.....
Garza County—				
No. 14 (pp. 31–32)	34.0	78.0†	.....	.....
No. 15 (p. 33)	26.0†	65.0†	.....	.....
No. 16 (p. 34)	24.0	79.0	.....	.....
Hockley County—				
No. 30 (p. 47)	.....	.....	21.0*	30.0
Lamb County—				
No. 33 (p. 48)	.....	.....	93.0*†	18.0
Lubbock County—				
No 28 (p. 46)	.....	31.0	.....	.....
No. 29 (p. 46)	.....	26.0†		.....
Lynn County—				
No. 21 (p. 36)	1.0*	.....	26.0†	
No. 22 (p. 38)	.....	.....	4.0*	8.0
No. 23 (p. 40)	.....	.....	2.0*	8.0
No. 24 (p. 40)	.....	.....	10.0*	12.0†
No. 25 (p. 42)	.....	.....	28.0*	.....

* Additional section in subsurface.
† Chemical analysis shown in table 4.

here is to call attention to occurrence of the raw materials which may merit investigation by industry.

Following is a list of localities (table 3) where cement materials might be obtained. Thicknesses shown are from surface exposures, but additional material probably exists beneath the surface at some localities. Page references are to measured sections included in the Appendix (pp. 26–55).

Table 4. Analyses of Cretaceous rocks (Robert M. Wheeler, analyst).

Sample No.*	1	2	3	4	5	6	7	8	9
SiO_2	7.90	8.35	2.87	8.74	2.84	0.98	62.15	58.29	55.35
Al_2O_3	2.01	1.60	0.76	1.17	0.69	0.27	17.17	16.22	16.94
TiO_2	0.07	0.06	0.03	0.05	0.03	0.01	0.62	0.52	0.60
Fe_2O_3	0.74	0.72	0.52	0.66	0.56	0.21	3.75	3.69	4.86
FeO	.....	.....	.....	.....	.....	.....	0.45	0.30	0.40
CaO	47.60	48.30	51.90	48.00	52.80	54.18	0.77	1.98	4.62
MgO	0.90	0.81	0.64	0.75	0.60	0.42	1.77	2.87	2.30
Na_2O	.....	.....	.....	.....	.....	.....	1.02	0.64	1.19
K_2O	.....	.....	.....	.....	.....	.....	1.19	0.69	0.61
Ign. loss	39.82	40.04	42.46	39.77	43.39	43.42	6.01	6.80	8.71
H_2O at 105° C.	.....	.....	.....	.....	.....	.....	6.05	8.15	6.16
Total	99.04	99.88	99.18	99.14	100.91	99.49	100.95	99.05	101.74

* Channel sample including complete thickness of unit sampled.

1. Comanche Peak limestone, locality 15, Scurry County.
2. Comanche Peak limestone, locality 14, Borden County.
3. Comanche Peak limestone, locality 7, Gaines County.
4. Comanche Peak limestone, locality 29, Lubbock County.
5. Edwards limestone, locality 15, Scurry County.
6. Edwards limestone, locality 39, Floyd County.
7. Kiamichi shale, locality 21, Lynn County.
8. Kiamichi shale, locality 33, Lamb County.
9. Kiamichi—Duck Creek shale, locality 24, Lynn County.

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APPENDIX

Localities and Measured Sections

Sections measured in connection with this work are detailed in the following pages. The localities mentioned are shown on figure 5. More detailed geologic maps of some particular areas are also included as indicated in the individual descriptions.

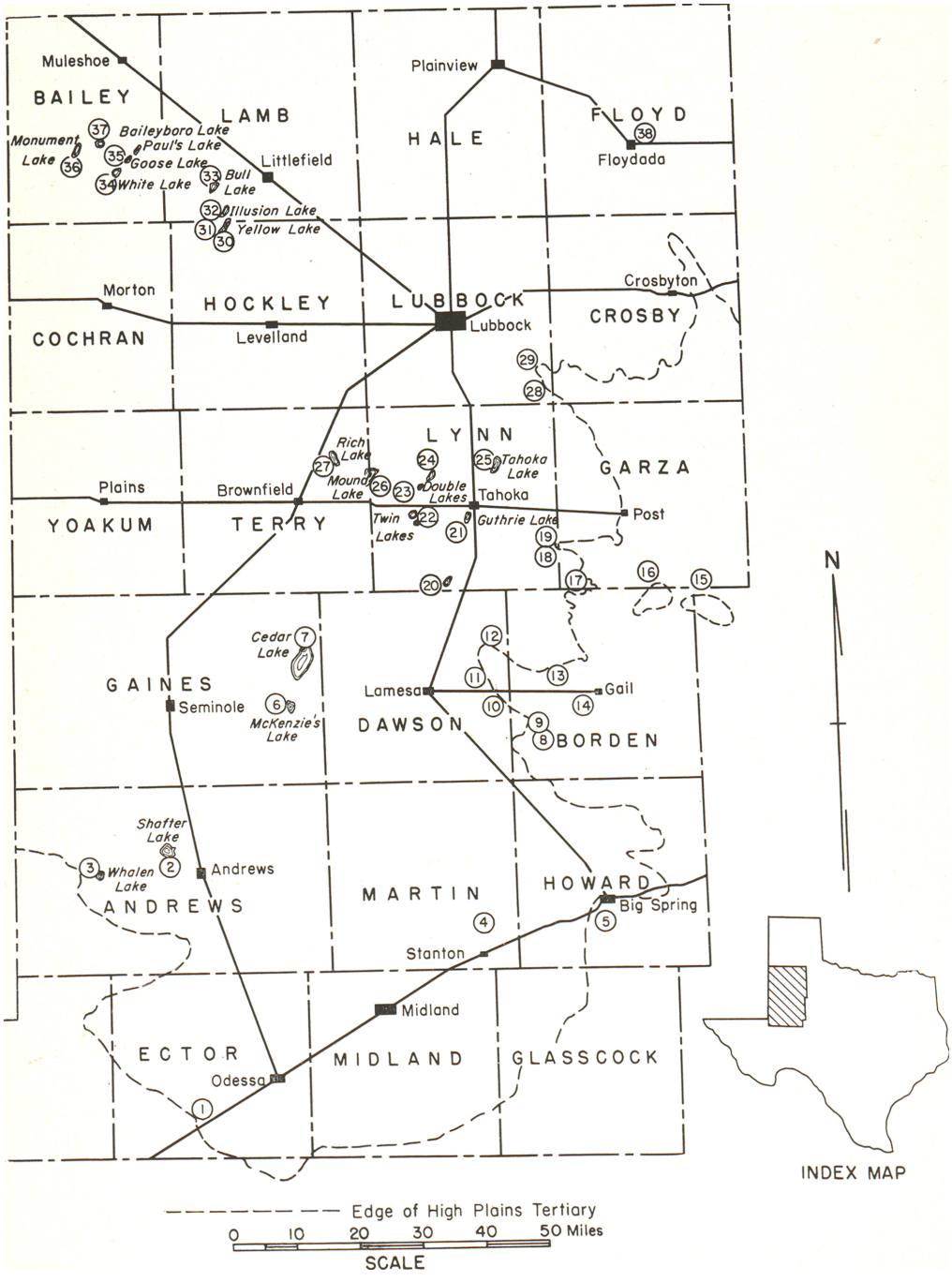


Fig. 5. Map of portion of Llano Estacado showing location of sections described in text.

Section at locality 1, 13 miles southwest of Odessa, Ector County, on U. S. highway No. 180 at east approach to Texas and Pacific Railroad underpass. Additional exposures are in ditch 300 yards northwest of underpass and on small knoll 150 yards south of highway.

	Thickness *Feet*
Quaternary. Caliche.	
Comanche Peak limestone—	
7. Shale, yellowish gray, thinly laminated with light gray, nodular limestone in upper portion	2.0
6. Limestone, light gray, thick bedded, argillaceous. Weathers to grayish yellow. Contains numerous small *Gryphaea mucronata*	1.5
5. Shale, yellowish gray, thinly laminated	2.2
4. Limestone, yellowish gray, thick bedded, argillaceous. Upper 3 inches marked by lenses of *Gryphaea* breccia	7.9
3. Shale, moderate yellow, thinly laminated, and light gray, nodular, argillaceous limestone. Fossiliferous; fauna includes *Tylostoma tumidum, T. elevatum, Exogyra texana,* and *Gryphaea mucronata*	3.6
2. Limestone, light gray, thin to thick bedded, argillaceous	0.8
1. Shale, moderate yellow, moderately thickly laminated, and light gray, nodular, argillaceous limestone	1.0
Total Comanche Peak	19.0
Walnut formation—	
3. Covered to base of Comanche Peak limestone	6.0
2. Limestone, light gray to light yellowish gray, thin to thick bedded, argillaceous, with scattered streaks of moderate yellow clay. Contains numerous *Gryphaea mucronata*	1.4
1. Sandstone, moderate yellowish brown, loosely consolidated, faintly bedded, and light gray, nodular argillaceous limestone. Both sandstone and limestone are fossiliferous. Fauna includes *Gryphaea mucronata, Exogyra texana,* and *Cyprimeria texana*	2.0
Total Walnut	9.4
Paluxy sandstone—	
Sandstone, moderate brown, hard, uniformly fine grained, siliceous and ferruginous cement	3.0

Section at locality 2, along southern and southwestern margins of Shafter Lake, Andrews County, 2½ miles north of Farm Road No. 87 and 7 miles west-northwest of Andrews.

	Thickness *Feet*
Quaternary. Pleistocene lake clays.	
Paluxy sandstone—	
Sandstone, grayish pink to moderate reddish brown, loosely consolidated, massive, uniformly medium grained, with lenses of quartz gravel (diameter ⅛ to ¾ inch)	10.0

Section at locality 3, in gully at north end of Whalen Lake, Andrews County, 2 miles south of Farm Road No. 87 and 24 miles west-northwest of Andrews.

In this locality, the sandstone has been cemented by silica, much of which is in form of opal. Similar development of opal has been observed in some localities where caliche has developed in Pliocene sandstone.

	Thickness *Feet*
Quaternary. Caliche.	
Paluxy sandstone—	
Sandstone, moderate reddish brown to grayish yellow, thin to massive bedded, uniformly medium grained with scattered quartz gravel (diameter ⅛ to ½ inch). Cementing material is siliceous (opal) and ferruginous	6.0

Section at locality 4, Martin County, on northeast face of escarpment 5 miles north-northeast of Stanton. Exposures are on south side of unimproved road leading north-northeast from Stanton.

	Thickness *Feet*
Quaternary. Caliche.	
Paluxy sandstone—	
Sandstone, moderate brown, moderately well indurated, with lenses of quartz gravel (diameter ⅛ to 1 inch). Mostly covered by rubble from overlying caliche	18.0 est.

Paluxy section at locality 5 in north slope of Signal Hill south of Big Spring, Howard County.

	Thickness *Feet*
Walnut formation.	
Paluxy sandstone—	
8. Sandstone, moderate brown, moderately well indurated, massive, uniformly fine grained, ferruginous	7.8
7. Mostly covered. Surface rubble contains fragments of very fine-grained flaggy sandstone	6.0
6. Sandstone, yellowish gray, loosely consolidated, massive, argillaceous, uniformly fine grained	4.0
5. Sandstone, yellowish gray, moderately well indurated, thin to thickly bedded, fine to medium grained, with lenses of quartz gravel (diameter ⅛ to ½ inch)	3.0
4. Sandstone, light bluish gray, loosely consolidated, massive, fine to medium grained	6.8
3. Sandstone, yellowish gray, loosely consolidated, faintly bedded, fine grained	4.6
2. Sandstone, pale reddish brown, loosely consolidated, massive, fine to medium grained, with lenses of quartz gravel (diameter ⅛ to ¾ inch)	5.0
1. Sandstone, light gray, loosely consolidated, massive, medium grained, with scattered quartz gravel (diameter ⅛ to 1 inch)	6.0
Total Paluxy	43.2
Triassic.	

Section at locality 6, along the western margin of McKenzie's Lake (Little Cedar Lake), Gaines County, 1 mile north of U. S. highway No. 180 and 16 miles east of Seminole.

	Thickness *Feet*
Quaternary. Caliche.	
Comanche Peak limestone—	
Limestone, light gray, thin to thickly bedded, argillaceous, with thin light gray shale interbeds. Fossiliferous; fauna includes *Enallaster texanus, Protocardia texana, Lima wacoensis, Tylostoma tumidum,* and *Aporrhais* sp.	5.0

Section at locality 7, in steep bluff at northwestern margin of Cedar Lake, 4¾ miles south of U. S. highway No. 328 and 18 miles east of Seagraves, Gaines County.

	Thickness *Feet*
Quaternary. Caliche.	
Comanche Peak limestone—	
8. Limestone, light gray to grayish yellow, thin to thickly bedded, argillaceous. Upper 2 feet altered to caliche but contains fragments of Comanche Peak fossils	4.0
7. Limestone, grayish yellow, thin to thickly bedded, argillaceous, and grayish-yellow shale interbeds. Fossiliferous	4.0
6. Shale, dusky yellow, thinly laminated, slightly calcareous and light gray, nodular, argillaceous limestone	3.0
5. Limestone, light gray, thickly bedded to massive, argillaceous, with several thin marly layers in basal 1 foot. Weathers to a honeycomb mass	2.7
4. Shale, grayish yellow, thinly laminated, calcareous, and light gray, nodular, argillaceous limestone	0.9
3. Limestone, light gray, thin bedded to massive, nodular in part, argillaceous. Weathers to a honeycomb mass	10.0
2. Shale, yellowish gray, thinly laminated, and light gray, nodular, argillaceous limestone	3.0
1. Limestone, light gray, thinly bedded to massive, argillaceous, with thin dark gray shale interbeds. Fossiliferous; fauna includes *Enallaster texanus, Engonoceras pierdenale, Oxytropidoceras* aff. *O. acutocarinatum, Gryphaea mucronata, Exogyra texana, Cyprimeria texana, Lima wacoensis, Tapes* sp., *Tylostoma tumidum, Turritella* sp., *Aporrhais* sp., and *Pleurotomaria* sp.	10.0
Total Comanche Peak	37.6

	Thickness *Feet*
Walnut formation—	
4. Shale, light olive-gray, thinly laminated, and light gray, nodular, argillaceous limestone. The shale is unfossiliferous, the limestone sparsely fossiliferous	5.5
3. Shale, dark gray, thinly laminated and light olive-gray, nodular, argillaceous limestone. Both limestone and shale are fossiliferous. Common species include *Enallaster texanus, Engonoceras* sp., *Metengonoceras* sp., *Oxytropidoceras* sp., *Gryphaea mucronata, Lima wacoensis, Exogyra texana, Cyprimeria texana, Tapes* sp., *Pecten (Neithea) irregularis, Tylostoma tumidum, T. elevatum,* and *Turritella* sp.	3.1
2. Shale, light olive-gray, thin to moderately thickly laminated, with streaks of limonitic clay	5.5
1. Limestone, light gray with limonitic streaks, massive, argillaceous, contains numerous specimens of *Gryphaea mucronata*	1.0
Total Walnut	15.1

Comanche Peak section at locality 8, SW ¼ section 22, block 33, T. 5 N., T. & P. R.R. Company, Borden County, 0.9 mile south of U. S. highway No. 180 on west side of small butte separated from main escarpment.

	Thickness *Feet*
Edwards formation.	
Comanche Peak limestone—	
3. Limestone, light gray, thin to thickly bedded, argillaceous, sparsely fossiliferous	6.0
2. Mostly covered, rubble indicates light gray limestone as in overlying unit. Comanche Peak fossils on surface	25.0
1. Mostly covered. Isolated exposures consist of light gray to yellowish-gray limestone	10.5
Total Comanche Peak	41.5
Walnut formation.	

Section at locality 9, Borden County, one-fourth mile west of locality 8 in east face of escarpment.

	Thickness *Feet*
Edwards limestone—	
Quaternary. Caliche.	
3. Limestone, light yellowish gray, thick bedded, coarse grained. Discontinuous bedding planes divide the unit into as many as 8 separate subequal strata. The uppermost 2 feet are characterized by numerous cavities presumably caused by solution of rudistid fossils. The entire unit is fossiliferous. Fauna includes *Toucasia patagiata, Eoradiolites davidsoni, Chondrodonta munsoni, Monopleura,* and caprinid fragments	10.0
2. Limestone, light yellowish gray, fine grained, slightly argillaceous, unevenly bedded. Fossiliferous but weathering has destroyed original features of fossils	3.0
1. Limestone, light yellowish gray, thick bedded, very fine grained, argillaceous. Upper bedding surface distinct; lower surface, presumably at the contact with the underlying Comanche Peak, is not exposed. Fossiliferous; fauna includes *Toucasia patagiata* and casts of small pelecypods	1.5
Comanche Peak limestone—	
The Comanche Peak is mostly covered in this section, but the thickness and description reported under locality 8 are probably applicable to this section.	
Walnut formation—	
4. Limestone, light gray, thin bedded, argillaceous, and medium gray calcareous shale interbeds. Both limestone and shale are fossiliferous. Fauna includes *Exogyra texana, Gryphaea mucronata, Tylostoma* spp., *Lunatia* sp., and *Engonoceras* (?) sp.	5.5
3. Limestone, light gray, slightly argillaceous, thick bedded. Entire unit contains numerous shells of *Gryphaea mucronata.* This is the *Gryphaea* agglomerate of Walnut sections in the southern and southeastern portions of the area	2.0
2. Shale, light gray to light yellowish gray, with light gray calcareous shale interbeds. Sparsely fossiliferous	4.5
1. Limestone, medium gray, arenaceous, unevenly bedded, and thin arenaceous shale interbeds. Both limestone and shale contain scattered specimens of *Ostrea crenulimargo*	0.8
Total Walnut	12.8
Paluxy sandstone—	
The Paluxy is poorly exposed in a gully on west side of road. Examination at isolated exposures shows typical development of uniformly fine to medium-grained quartz sand and scattered lenses of ⅛ to ¾ inch quartz gravel	18.0 est.

Section at locality 10, NE ¼ section 20, block 33, T. 5 N., T. & P. R.R. Company, 4 miles east of Key, Borden County, along U. S. highway No. 180.

	Thickness *Feet*
Edwards limestone—	
The Edwards is poorly exposed at the top of the section. Rubble shows 12 to 13 feet of light yellowish-gray coarsely crystalline limestone	13.0 est.
Comanche Peak limestone—	
4. Covered to base of Edwards	11.0
3. Limestone, yellowish gray, massive, argillaceous, sparsely fossiliferous	17.0
2. Limestone, light gray to yellowish gray, thin to thickly bedded, argillaceous	10.0
1. Limestone, light gray, thin to thickly bedded, argillaceous, fossiliferous. Common species include *Enallaster texanus, Gryphaea mucronata, Exogyra texana, Protocardia texana, Tapes* sp., *Tylostoma* spp., *Lima wacoensis, Engonoceras pierdenale, Turritella* sp.	11.0
Total Comanche Peak	49.0
Walnut formation—	
3. Mostly covered. Surface rubble indicates thin, argillaceous limestone and interbedded shale. Numerous specimens of *Exogyra texana*	4.0
2. Limestone, light gray to light yellowish gray, massive, argillaceous. Contains numerous specimens of *Gryphaea mucronata*	3.0
1. Shale, moderately yellowish brown, thinly laminated, arenaceous, and light gray, nodular, argillaceous limestone. Both shale and limestone are fossiliferous. Common species include *Ostrea crenulimargo, Exogyra texana, Gryphaea mucronata,* and *Cyprimeria texana*	3.0
Total Walnut	10.0
Paluxy sandstone—	
3. Sandstone, greenish gray, loosely consolidated, massive, uniformly fine grained, slightly calcareous	3.0
2. Sandstone, light gray, loosely consolidated, massive, fine to medium grained, slightly argillaceous	8.0
1. Sandstone, dark yellowish orange, loosely consolidated, massive, with scattered quartz pebbles (diameter ¼ to ½ inch)	11.0
Total Paluxy	22.0
Triassic.	

Section at locality 11, 2½ miles north and 2 miles east of Key, Dawson County, in east wall of canyon.

	Thickness *Feet*
Edwards limestone—	
Limestone, light gray to light yellowish gray, fine grained, slightly argillaceous in basal portion. The basal stratum is 2 to 4 feet thick and is followed by two subequal 10 to 12-inch coarsely crystalline layers. The upper unit is partly altered to caliche but appears to be a 3 to 4-foot coarse-grained limestone	6.0 to 8.0
Comanche Peak limestone—	
The Comanche Peak is poorly exposed in a slope below Edwards bluff. Surface rubble contains light gray limestone, some of which contains lenses of *Gryphaea* breccia. Surface collection contains typical Comanche Peak fossils	54.0
Walnut formation—	
3. Limestone, light gray, thin bedded, and medium gray shale interbeds. Contains numerous *Exogyra texana*	3.5
2. Limestone, light gray to light yellowish brown, unevenly thick bedded, slightly argillaceous. Contains numerous *Gryphaea mucronata*	2.5
1. Shale, olive-gray, arenaceous, and light gray argillaceous limestone interbeds	2.0
Total Walnut	8.0
Paluxy sandstone—	
Sandstone, light gray to yellowish brown with scattered ⅛ to 1-inch quartz gravel. Poorly exposed except in shallow gulley. The contact with the underlying red beds is covered	25.0 est.

Section at locality 12, 6 miles south and 4 miles east of O'Donnell, Dawson County, in northeastern wall of canyon 1 mile south of Flying W ranch headquarters.

	Thickness *Feet*
Edwards limestone—	
2. Limestone, light yellowish gray, massive, fine grained. Differential weathering in cliff produces 3 to 4 subequal massive strata	17.5
1. Limestone, light yellowish gray, evenly thick bedded, fine grained, slightly argillaceous. Uppermost stratum (12 inches) porous because of solution of rudistid fossils. Entire unit contains fragments of rudistids	5.5
Total Edwards	23.0
Comanche Peak limestone—	
3. Limestone, light gray, thick bedded to massive, argillaceous. Forms low cliff below main escarpment	15.0
2. Limestone, light gray, thick bedded to massive, argillaceous, and medium gray shale interbeds. Fossiliferous; fauna includes *Enallaster texanus, Exogyra texana, Lima wacoensis, Oxytropidoceras* sp., *Engonoceras pierdenale,* and *Tylostoma* sp.	30.0
1. Mostly covered. Surface rubble contains light gray, argillaceous limestone. Uppermost 6 inches contains numerous *Gryphaea.* To valley floor	9.0
Total Comanche Peak	54.0
Walnut formation—	
The Walnut and underlying Paluxy are not exposed in this section.	

Section at locality 13, Borden County, in south face of escarpment along road leading from U. S. highway No. 180 to O'Donnell. Junction with highway No. 180 is 6 miles west of Gail, Borden County.

	Thickness *Feet*
Quaternary. Caliche.	
Edwards limestone—	
3. Limestone, moderate yellow, unevenly thin bedded, slightly argillaceous, fine grained. Upper 2 to 3 feet altered to caliche	3.5
2. Limestone, grayish yellow, thick bedded, coarse grained. The thickest stratum in this unit, a 4 to 5-foot rudistid biostrome, has been quarried for road metal in recent years. The entire unit is fossiliferous. Fauna includes *Caprinula anguis, Eoradiolites davidsoni, Monopleura* sp., and *Chondrodonta munsoni*	8.0
1. Limestone, moderate yellow, evenly thick bedded, fine grained, slightly argillaceous, sparsely fossiliferous	6.0
Total Edwards	17.5
Comanche Peak limestone—	
The Comanche Peak is unexposed except for a small quarry at the base of the hill. Here the Comanche Peak is a light gray, unevenly thin-bedded, fine-grained, argillaceous limestone. Exact thickness cannot be determined as the section is completely covered below the quarry. Estimated	65.0 to 70.0

Section at locality 14, 1 mile west of Gail, Borden County, in road cut along west side of Gail Mountain. Additional exposures in knoll west of main mountain mass (Pl. III).

	Thickness *Feet*
Quaternary. Caliche.	
Edwards limestone—	
6. "Caliche" with remnants of fossiliferous Edwards limestone	1.0
5. Limestone, grayish yellow, thick bedded, basal 1 foot fine grained, argillaceous, upper portion coarse grained, fossiliferous. Fauna includes *Salenia mexicana, Chondrodonta munsoni, Eoradiolites davidsoni, Caprinula* sp., and *Tapes* sp.	8.3

	Thickness *Feet*
4. Limestone, moderate yellow, thinly bedded to massive, coarse grained, porous because of solution of rudistid fossils. Fauna as above	8.0
3. Limestone, grayish yellow, massive, argillaceous. Uneven, discontinuous bedding surfaces produce 5 subequal units	7.0
2. Limestone, grayish yellow, massive, fine grained, with numerous calcite and chalcedonic cavity fillings	6.0
1. Limestone, moderate yellow, massive, fine grained, with fragments of rudistid fossils	4.0
Total Edwards	34.3
Comanche Peak limestone—	
12. Limestone, light gray to yellowish gray, massive, argillaceous, sparsely fossiliferous	6.0
11. Limestone, light gray, massive, argillaceous, and moderate yellowish-brown shale. Upper 18 inches is a single thick-bedded limestone. Sparsely fossiliferous	12.0
10. Limestone, light gray, massive, argillaceous. Upper 8 inches contains numerous small cavities which probably result from solution of fossils	4.0
9. Limestone, yellowish gray, massive, argillaceous. Lower 7 feet contain lenticular bodies of *Gryphaea* breccia. Upper portion sparsely fossiliferous	19.0
8. Shale, yellowish gray, thinly laminated and light gray, nodular, argillaceous limestone. Fossiliferous; common species include *Enallaster texanus, Gryphaea mucronata, Exogyra texana, Protocardia texana, Tapes* sp., *Pholadomya sancti-sabae, Tylostoma tumidum, T. elevatum,* and *Turritella* sp.	0.5
7. Limestone, light gray to yellowish gray, thickly bedded, argillaceous, sparsely fossiliferous	2.0
6. Shale, yellowish gray, thinly laminated, slightly calcareous, unfossiliferous	0.3
5. Limestone, light gray, thick bedded, argillaceous, with lenses of *Gryphaea* breccia	1.2
4. Shale, yellowish gray, thinly laminated, and light gray, nodular, argillaceous limestone. Fossiliferous. Common species include those in unit 8	0.8
3. Limestone, yellowish gray, thickly bedded, argillaceous, fossiliferous; common species include *Gryphaea mucronata, Pecten (Neithea) subalpinus, Tapes* sp., and *Protocardia texana*	3.6
2. Limestone, light gray, thinly bedded to massive, argillaceous, with scattered quartz pebbles (diameter ⅛ to ¼ inch). Unfossiliferous	6.0
1. Covered with rubble from overlying beds. Surface fragments indicate light gray, argillaceous limestone. Numerous Comanche Peak fossils found in surface debris. To base of Comanche Peak	23.0
Total Comanche Peak	78.4
Walnut formation—	
5. Covered to base of Comanche Peak limestone. Surface collection contains numerous *Exogyra texana*	4.0 est.
4. Limestone, light gray, massive, argillaceous. Contains numerous specimens of *Gryphaea mucronata*	2.5
3. Limestone, light gray, nodular, argillaceous, and dark gray shale interbeds. Contains numerous specimens of *Cyprimeria texana*	2.0
2. Sandstone, moderate yellow, loosely consolidated, massive, argillaceous	1.6
1. Shale, dark gray to black, thinly laminated, arenaceous, and light gray, nodular, argillaceous limestone. Fossiliferous; common species include *Ostrea crenulimargo, Exogyra texana, Gryphaea mucronata, Protocardia texana,* and *Cyprimeria texana*	2.6
Total Walnut	12.7
Paluxy sandstone—	
3. Sandstone, grayish yellow, loosely consolidated, massive, uniformly fine grained, with lenses of quartz gravel (diameter ⅛ to 1 inch)	5.5
2. Sandstone, moderate greenish yellow, loosely consolidated, massive, with gravel lenses as above	6.0
1. Sandstone, yellowish gray to dusky yellow, loosely consolidated, massive, with scattered lenses of quartz gravel (diameter ¼ to 1 inch). Basal 1 foot contains clay pebbles from underlying Triassic beds	14.5
Total Paluxy	26.0
Triassic.	

Section at locality 15, 5½ miles south and 3½ miles east of Justiceburg, Garza County, in cut along Eppler-Fluvanna road (Pl. II).

	Thickness *Feet*
Quaternary. Caliche.	
Edwards limestone—	
5. Limestone, moderate yellow, thin to thickly bedded, argillaceous, fossiliferous. Stringers of calcite in upper 1 foot	4.0
4. Limestone, light gray to yellowish gray, thickly bedded, coarse grained. Porous because of solution of rudistid fossils. Some fossil forms are replaced by calcite and chalcedony. Fauna includes *Chondrodonta munsoni, Eoradiolites davidsoni, Toucasia patagiata, Monopleura* sp., and *Caprinula* sp.	4.5
3. Limestone, grayish yellow, massive, fine to coarse grained. Fossiliferous, fauna as above	12.5
2. Limestone, light gray, massive, coarse grained	2.5
1. Limestone, light gray, massive, fine to coarse grained. Scattered cavities (diameter ½ to 1½ inches) in upper 1 foot	3.0
Total Edwards	26.5
Comanche Peak limestone—	
8. Shale, light gray to dusky yellow, thinly laminated, and light gray, nodular, argillaceous limestone. Fossiliferous; common species include *Enallaster texanus, Oxytropidoceras* aff. *O. belknapi, Exogyra texana, Protocardia texana, Pecten (Neithea) irregularis, Pinna comancheana, Tylostoma elevatum, T.* sp., *Turritella* sp., and *Aporrhais (?) subfusiformis*	2.6
7. Limestone, light gray, massive, argillaceous, with dark gray, thinly laminated shale interbeds in basal 6 feet. This unit forms the steep middle bluff of the escarpment. Fossiliferous; common species include *Enallaster texanus, Engonoceras pierdenale, E. gibbosum, Oxytropidoceras* aff. *O. belknapi, Exogyra texana, Homomya* sp., *Tapes* sp., *Lima wacoensis, Cyprimeria texana, Protocardia texana, Pecten (Neithea) irregularis, Modiola concentrice-costellata, Gervilliopsis* sp., *Tylostoma elevatum, T. tumidum, Turritella* sp., and *Aporrhais* sp.	17.5
6. Limestone, light gray, nodular, argillaceous, and light gray shale interbeds. Fossiliferous; fauna as in overlying unit except *Pholadomya sancti-sabae* and *Pinna comancheana* are found here	5.0
5. Limestone, light gray, massive, argillaceous, with lenses of dark gray, thinly laminated shale and nodular limestone. In the basal 1 foot of the unit are lenses of *Gryphaea.* Fossiliferous. Fauna as in overlying unit	20.5
4. Shale, olive-gray to light olive-gray, thinly laminated with light gray, nodular, argillaceous limestone. Shale contains gypsum crystals. Sparsely fossiliferous	1.0
3. Limestone, light gray, massive. Fossiliferous; common species include *Enallaster texanus, Pyrina bulloides, Gryphaea mucronata, Protocardia texana,* and *Tylostoma* spp.	7.0
2. Shale, yellowish gray, thinly laminated, and thin, light gray, argillaceous limestone. Fossiliferous; fauna as in overlying unit	1.0
1. Limestone, light gray, massive, argillaceous. Fossiliferous; fauna as above	11.0
Total Comanche Peak	65.6
Walnut formation—	
5. Shale, medium gray to olive-gray, slightly calcareous, and light gray, nodular, argillaceous limestone. Sparsely fossiliferous	10.0
4. Limestone, light gray, massive, argillaceous. Contains numerous specimens of *Gryphaea mucronata*	2.0
3. Limestone, light gray, nodular, argillaceous, and blue-gray shale interbeds	1.0
2. Limestone, light gray, nodular, argillaceous, and thinly laminated, blue-gray shale. The limestone contains scattered quartz pebbles (diameter ⅛ to ½ inch)	2.0
1. Sandstone, moderate yellowish brown, loosely consolidated, massive, argillaceous, fine to medium grained	2.0
Total Walnut	17.0
Paluxy sandstone—	
3. Sandstone, moderate yellow, loosely consolidated, massive, ferruginous, slightly argillaceous	2.0
2. Sandstone, light gray to moderate yellow, loosely consolidated, massive, fine to medium grained, with lenses of quartz gravel (diameter ¼ to ½ inch)	10.0
1. Covered to Paluxy-Triassic contact	13.0
Total Paluxy	25.0

Section at locality 16, Garza County, 5 miles south and 5 miles west of Justiceburg, in north face of escarpment 1 mile north of the Borden-Garza County line.

	Thickness *Feet*
Quaternary. Caliche.	
Edwards limestone—	
Mostly covered and slumped. Rubble consists of light gray to light yellowish-gray, fine to coarse-grained limestone. The weathered slope suggests a basal unit about 6 feet thick. Above this appear to be a series of 1 to 2-foot limestone beds. To top of bluff	24.0
Comanche Peak limestone—	
The Comanche Peak section is completely covered, but surface rubble indicates typical Comanche Peak strata. Thickness determined by hand level measurements from near base	75.0 est.
Walnut formation—	
The Walnut is covered and badly slumped. Blocks of light gray argillaceous limestone containing numerous *Gryphaea mucronata* are on surface	10.0 est.
Paluxy sandstone—	
Sandstone, light gray to moderate yellowish brown, loosely consolidated, uniformly medium-grained and scattered quartz gravel (diameter ⅛ to 2 inches)	22.0 est.

Walnut and Paluxy sections at locality 17, 10½ miles south and 1¾ miles west of Graham, Garza County, in cut along ranch road.

	Thickness *Feet*
Comanche Peak limestone—	
The Comanche Peak contains a single layer of light gray, argillaceous, fine-grained limestone	1.5
Walnut formation—	
7. Shale, light gray to moderate yellow, thinly laminated, and light gray, nodular, argillaceous limestone. Sparsely fossiliferous	8.5
6. Limestone, light gray, massive, argillaceous. Contains numerous specimens of *Gryphaea mucronata*	1.5
5. Limestone, light gray, nodular, argillaceous, and light gray, thinly laminated shale. The limestone contains quartz pebbles (diameter ⅛ to 1 inch)	1.0
4. Shale, dark gray to black, thinly laminated, with brown limonitic streaks. Fossiliferous but most specimens are fragmental. Common species include *Ostrea crenulimargo, Exogyra texana, Gryphaea mucronata, Protocardia texana,* and *Turritella* sp.	0.7
3. Limestone, light yellowish gray, thin bedded, argillaceous	0.5
2. Shale, olive-gray, thinly laminated, slightly arenaceous. Fossiliferous; common species include *Ostrea crenulimargo, Exogyra texana,* and *Gryphaea mucronata*	0.7
1. Sandstone, moderate yellow, moderately well indurated, faintly bedded, fine to medium grained, and interbeds of light gray to moderate yellowish-brown shale. Very fossiliferous; common species include *Holectypus planatus, Exogyra texana, Ostrea crenulimargo,* and *Gryphaea mucronata*	1.3
Total Walnut	14.2
Paluxy sandstone—	
4. Sandstone, light gray to pale purple, moderately well indurated, massive, slightly argillaceous	10.5
3. Sandstone, light gray to grayish purple, loosely consolidated, massive, fine to medium grained, with scattered quartz gravel (diameter ⅛ to 1 inch)	2.0
2. Sandstone, pinkish gray to dusky yellow, loosely consolidated, massive, fine to medium grained with scattered lenses of very coarse-grained sand and quartz gravel	3.5
1. Sandstone, light gray, loosely consolidated, massive, fine to medium-grained, ferruginous to calcareous, with lenses of quartz gravel (diameter ⅛ to ½ inch). Basal 1 foot contains 1 to 3-inch clay pebbles derived from underlying Triassic beds	6.0
Total Paluxy	22.0
Triassic.	

Walnut section at locality 18, 2 miles south and 1 mile east of Grassland, Lynn County, in west wall of canyon (Pl. I).

	Thickness *Feet*
Comanche Peak limestone.	
Walnut formation—	
2. Sandstone, dark gray, moderately well indurated, faintly bedded, argillaceous, and dark gray to black shale interbeds. Fossiliferous; common species include *Holectypus planatus, Exogyra texana, Ostrea crenulimargo, Protocardia texana,* and *Tapes* sp.	1.0
1. Sandstone, dark gray, loosely consolidated, faintly bedded, argillaceous, sparsely fossiliferous	3.2
Total Walnut	4.2
Paluxy sandstone.	

Walnut and Paluxy sections at locality 19 in north wall of canyon of South Double Mountain Fork of Brazos River, 4 miles southeast of Grassland, Lynn County (Pl. I).

	Thickness *Feet*
Comanche Peak limestone.	
Walnut formation—	
5. Sandstone, moderate yellow, friable, faintly bedded, argillaceous, fine to medium grained. Fossiliferous; fauna includes *Holectypus planatus, Gryphaea mucronata, Exogyra texana, Protocardia texana,* and *Tapes* sp.	3.0
4. Limestone, light gray to yellowish gray, thin bedded, arenaceous. Fossiliferous; fauna includes *Holectypus planatus, Ostrea crenulimargo, Exogyra texana,* and *Lunatia* sp.	1.3
3. Sandstone, moderate yellow, loosely consolidated, faintly bedded, fine to medium grained. Fossiliferous; fauna includes *Ostrea crenulimargo, Exogyra texana, Gryphaea mucronata, Lunatia* sp., *Tylostoma* sp.	1.2
2. Shale, dark gray, thinly laminated, arenaceous. Fossiliferous; fauna includes *Ostrea crenulimargo, Gryphaea mucronata, Exogyra texana,* and *Tylostoma* sp.	1.0
1. Shale, dark gray to moderate yellow, arenaceous, unfossiliferous	1.0
Total Walnut	7.5
Paluxy sandstone—	
4. Sandstone, moderate yellow, moderately well indurated, faintly bedded, uniformly fine grained	10.0
3. Sandstone, yellowish gray, loosely consolidated, faintly bedded, uniformly fine grained	9.5
2. Sandstone, moderate yellow, loosely consolidated, massive, uniformly fine grained. In lower 6 inches are alternating bands of white and yellow-brown clay	1.3
1. Sandstone, dark yellowish orange, loosely consolidated, massive, uniformly fine grained, with lenses of argillaceous sand	1.3
Total Paluxy	22.1
Triassic.	

Section at locality 20, 7½ miles west of O'Donnell, Lynn County, at southwestern margin of small playa at termination of Lost Draw.

	Thickness *Feet*
Quaternary. Lake clays.	
Kiamichi—	
6. Limestone, greenish gray (5 GY 6/1), argillaceous	0.5
5. Shale, medium gray, thinly laminated, and thin, dusky yellow, argillaceous limestone	5.0
4. Limestone, dusky yellow, unevenly thin bedded, arenaceous. Lower bedding surface fucoidal. Contains *Protocardia texana, Pecten (Neithea) subalpinus,* and *Gryphaea corrugata*	0.2
3. Shale, medium gray, thinly laminated, slightly calcareous	2.0
2. Sandstone, dusky yellow, evenly thick bedded, calcareous, slightly micaceous, with medium gray, thinly laminated shale in upper 2 inches	1.0
1. Shale, dark gray, thinly laminated, unfossiliferous. To floor of lake	1.0
Total Kiamichi	9.7

Kiamichi section at locality 21 in western and northwestern margins of present playa of Guthrie Lake, Lynn County, 1½ miles west of U. S. highway No. 87 and 3 miles south of Tahoka (fig. 6; Pl. IV, B).

	Thickness *Feet*
Quaternary. Pleistocene lake clays.	
Kiamichi formation—	
14. Limestone, light gray, evenly thin bedded, slightly arenaceous, with numerous *Turritella belviderii*	0.5
13. Sandstone, moderate yellow, very fine grained, calcareous. Contains *Oxytropidoceras acutocarinatum* and fragments of *O. belknapi* (?)	5.0
12. Shale, light gray to moderate yellow, thinly laminated, unfossiliferous	3.5
11. Sandstone, moderate yellow, thin bedded, calcareous, sparsely fossiliferous, weathers to ¼-inch flags	0.5
10. Shale, dark gray, thinly laminated, unfossiliferous	2.0
9. Sandstone, light gray, unevenly thin bedded, bedding surfaces fucoidal. Fossiliferous; fauna includes *Gryphaea corrugata, Protocardia texana,* and *Tapes* sp.	0.5
8. Shale, dark gray, thinly laminated, with lenses of dark yellowish-orange sand. Unfossiliferous	3.2
7. Sandstone, light brown, thin bedded, fine grained, with yellowish-gray shale interbeds. Contains numerous specimens of *Gryphaea navia.* This is the upper limit of this species in this section	1.1
6. Shale, dark gray, thinly laminated, unfossiliferous	1.0
5. Sandstone, yellowish gray, thin bedded, fine grained, slightly calcareous, weathers to flags (¼ to ¾ inch thick). Contains fragments of *Oxytropidoceras belknapi*	0.9
4. Shale, dark gray, thinly laminated, with yellowish-gray sandstone lenses. Unfossiliferous	1.0
3. Limestone, light gray to moderate yellow, thin to thick bedded, lower bedding surface fucoidal. Fossiliferous; fauna includes *Exogyra texana, Gryphaea navia, Pecten (Neithea) subalpinus, P. (Neithea) irregularis, Protocardia texana, Cyprimeria texana, Tapes, Plicatula incongrua, Engonoceras* sp., *Oxytropidoceras acutocarinatum,* and *O. belknapi*	0.7
2. Sandstone, light gray, thin bedded, very fine grained, calcareous, unfossiliferous	0.5
1. Shale, dark gray to black, thinly laminated, slightly arenaceous, unfossiliferous	10.0
Total Kiamachi	25.9
Edwards formation.	

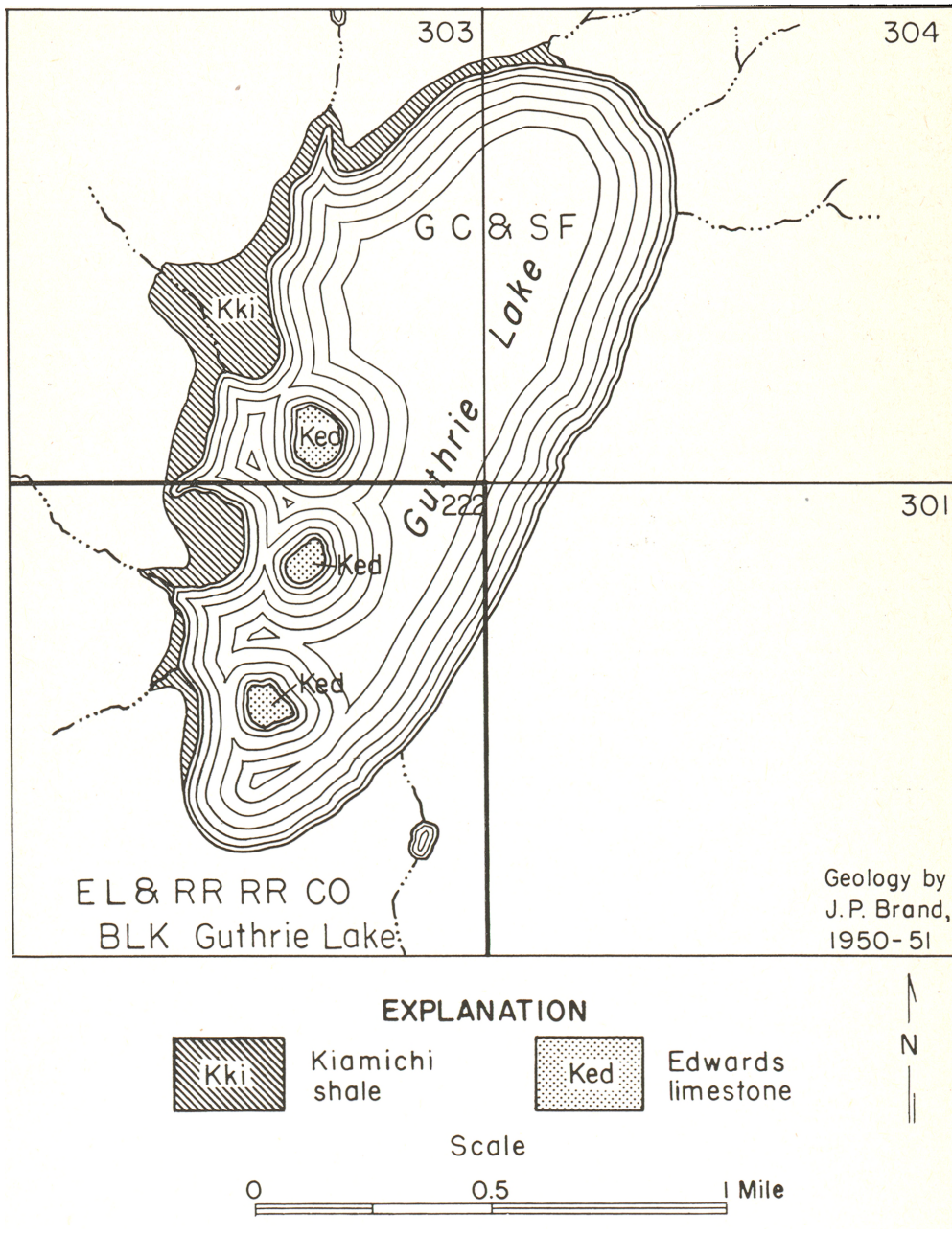


FIG. 6. Cretaceous exposures at Guthrie Lake, Lynn County, Texas (locality 21).

Duck Creek section at locality 22, along western margin of present playa of northwest Twin Lake, 1¼ miles south of U. S. highway No. 380 and 9 miles west of Tahoka, Lynn County (fig. 7; Pl. V, A).

	Thickness *Feet*
Pleistocene. Lake clays.	
Duck Creek shale—	
3. Limestone, light gray, nodular, argillaceous, weathers to ½ to 1-inch subrectangular blocks. Fracture surfaces coated with dendritic manganese oxide. Contains *Desmoceras brazoense*. This is the only observed occurrence of this species above the basal limestone	0.8
2. Shale, dark gray, thinly laminated, with thin-bedded, moderate yellow limestones. Both shale and limestone are fossiliferous. Fauna includes *Trochosmilia* sp., *Leiocidaris* (?) spines and plates, *Ostrea quadriplicata*, *Gryphaea tucumcarii*, *G. corrugata*, and *Turritella* sp.	6.5
1. Limestone, moderate yellow in basal 2 inches, light gray above, unevenly thick bedded, argillaceous. The lower surface is covered by *Gryphaea tucumcarii*. The upper portion contains *Desmoceras brazoense*	1.0
Total Duck Creek	8.3
Kiamichi shale.	

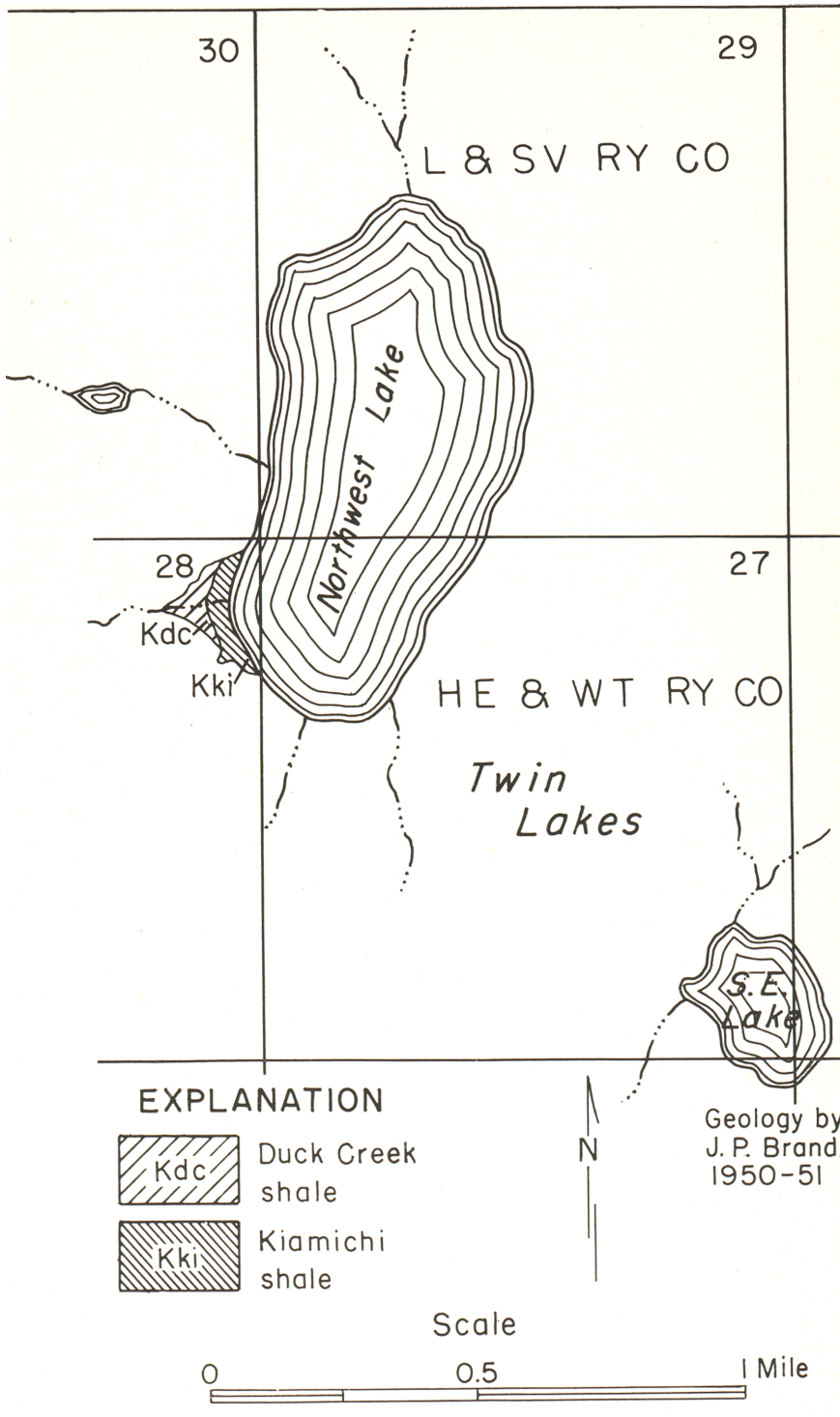


FIG. 7. Cretaceous exposures at Twin Lakes, Lynn County, Texas (locality 22).

Duck Creek section at locality 23, along southwestern margin of playa of southwest Double Lake, 2 miles north of U. S. highway No. 180 and 9 miles west of Tahoka, Lynn County (fig. 8).

	Thickness *Feet*
Pleistocene. Lake clays.	
Duck Creek shale—	
2. Shale, medium gray to moderate yellow, thinly laminated, with light brown calcareous sand lenses. Contains *Gryphaea corrugata*	7.0
1. Limestone, light gray, thin to thickly bedded, argillaceous, with medium gray shale interbeds. Contains *Desmoceras brazoense* and *Mortoniceras* aff. *M. trinodosum*	1.5
Total Duck Creek	8.5
Kiamichi shale.	

Section at locality 24, along northwestern margin of present playa of northeast Double Lake, 6 miles west of U. S. highway No. 87 and 5 miles north of Tahoka, Lynn County (fig. 8).

	Thickness *Feet*
Pliocene. Bridwell (?) formation.	
Duck Creek shale—	
2. Shale, medium gray to moderate yellow, thinly laminated, with moderate yellow, lenticular, calcareous sandstone. Contains *Gryphaea tucumcarii* and *G. corrugata*	12.0
1. Limestone, light brown, thickly bedded, argillaceous. The lower surface is covered by specimens of *Gryphaea tucumcarii* and *G. corrugata. Desmoceras brazoense* first appears in this unit	0.7
Total Duck Creek	12.7
Kiamichi shale—	
3. Shale, dark gray, thinly laminated, with lenses of light brown, argillaceous, fine-grained sand. Contains *Gryphaea tucumcarii* and *G. corrugata*	6.5
2. Sandstone, moderate yellow, thin bedded, calcareous, fine to medium grained	0.2
1. Shale, dark gray to black, thinly laminated, with lenses of moderate yellow, arenaceous clay. The upper 1 foot contains *Gryphaea tucumcarii*	3.0
Total Kiamichi	9.7

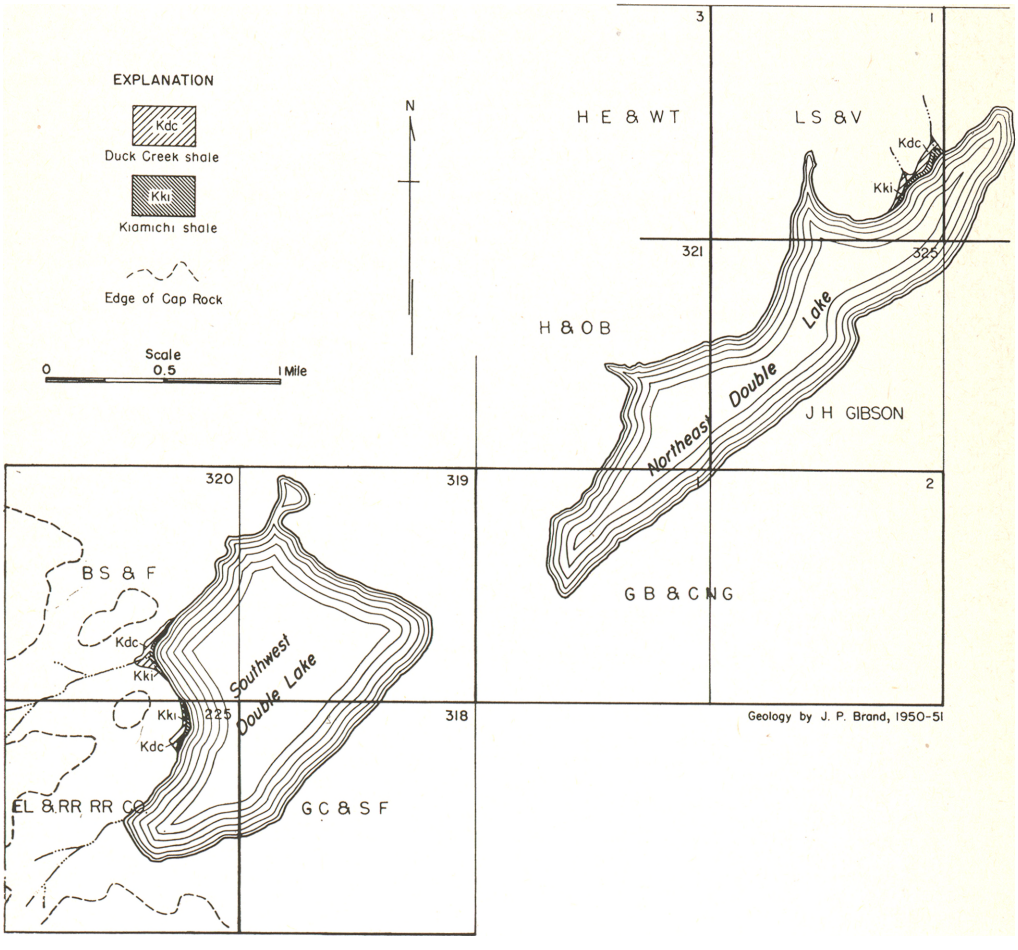


FIG. 8. Cretaceous exposures at Double Lakes, Lynn County, Texas (localities 23 and 24).

Section at locality 25, 6 miles north and 4 miles east of Tahoka, Lynn County, along western margin of present playa of Tahoka Lake (fig. 9).

In this section the basal layer contains numerous *Turritella belviderii* and is correlated with the uppermost bed of the Guthrie Lake section (locality 21). Near the top of the section (unit 14) a single specimen of *Oxytropidoceras* aff. *O. bravoense* has been found. This species appears to be characteristic of the middle Kiamichi and has been found at approximately the same level in exposures in Lamb County.

	Thickness *Feet*
Pliocene and Quaternary.	
Kiamichi formation—	
18. Covered to base of Pliocene. Surface rubble indicates thin calcareous limestone and gray shale. Numerous *Gryphaea corrugata* on surface	7.0
17. Limestone, light gray, evenly thick bedded, argillaceous. Weathers to chalky blocks. Unfossiliferous	0.6
16. Shale, medium gray, thinly laminated, with lenses of moderate yellow sandstone. Unfossiliferous	2.0
15. Limestone, light gray, evenly thick bedded, argillaceous. Contains *Oxytropidoceras* aff. *O. bravoense*	0.6
14. Shale, medium gray, thinly laminated, unfossiliferous	1.7
13. Limestone, light gray, evenly thick bedded, argillaceous, sparsely fossiliferous	0.7
12. Shale, medium gray, thinly laminated, with lenses of moderate yellow sand	2.0
11. Limestone, medium gray, thin bedded, argillaceous. Fossiliferous; fauna includes *Gryphaea corrugata, Exogyra texana, Protocardia texana, Tapes* sp., *Pecten (Neithea) irregularis, P. (Neithea) subalpinus,* and *Trigonia* sp.	1.1
10. Shale, medium gray, thinly laminated, with lenses of moderate yellow sand. Unfossiliferous	1.0
9. Sandstone, light olive-gray, thin bedded, calcareous	0.3
8. Shale, medium gray, thinly laminated, unfossiliferous	1.0
7. Sandstone, moderate yellow, uniformly fine grained, slightly calcareous	1.0
6. Shale, medium gray, thinly laminated, unfossiliferous	4.0
5. Sandstone, yellowish gray, micaceous, slightly calcareous	0.8
4. Shale, medium gray, thinly laminated, unfossiliferous	1.0
3. Limestone, yellowish gray, evenly thin bedded, slightly arenaceous, unfossiliferous	0.5
2. Shale, medium gray, thinly laminated, with dark yellowish-orange sandstone interbeds. Unfossiliferous	3.0
1. Limestone, medium gray, thin bedded, argillaceous. The upper surface is covered with specimens of *Turritella belviderii.* The lower surface contains impressions of *Oxytropidoceras* aff. *O. belknapi*	0.3
Total Kiamichi	28.6
Covered to lake floor.	

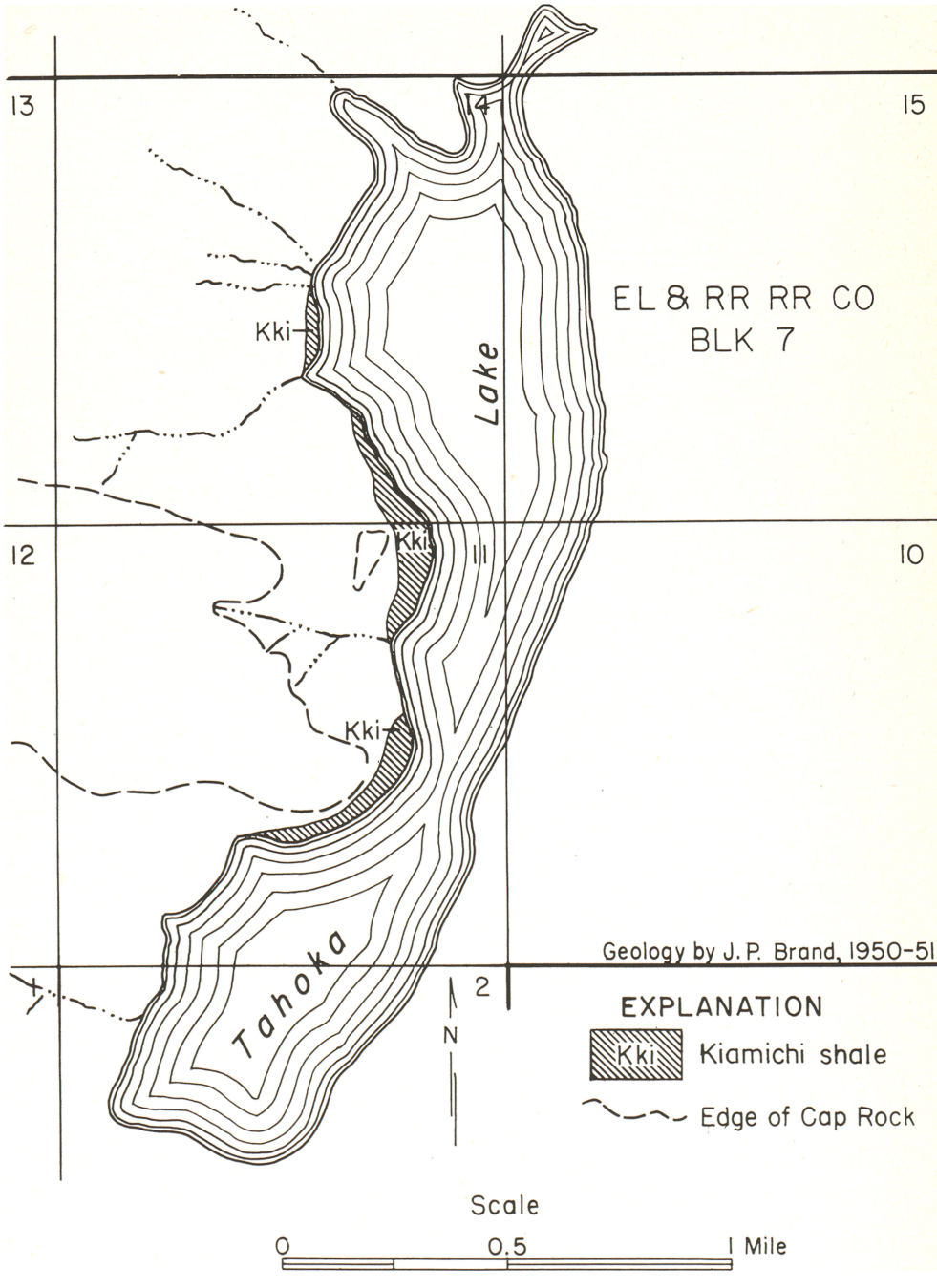


FIG. 9. Cretaceous exposures at Tahoka Lake, Lynn County, Texas (locality 25).

Section at locality 26, along western margin of playa of Mound Lake, 3 miles north of U. S. highway No. 380 and 11 miles east of Brownfield, Terry County (fig. 10; Pl. V, B).

	Thickness *Feet*
Quaternary. Pleistocene lake clays.	
Duck Creek shale—	
7. Shale, light gray to moderate yellow, faintly laminated, unfossiliferous. To base of Pleistocene	7.0
6. Limestone, moderate yellow, unevenly thin bedded, slightly argillaceous, fossiliferous	0.2
5. Shale, moderate olive-brown, thinly laminated, arenaceous, fossiliferous	1.5
4. Limestone, moderate yellow, unevenly thick bedded, argillaceous. Fossiliferous; fauna includes *Trochosmilia* sp., *Mortoniceras* aff. *M. trinodosum*, *Ostrea quadriplicata*, *O. subovata*, *Plicatula incongrua*, *Pecten (Neithea) subalpinus*, *Gryphaea corrugata*, and *"Solarium" planorbis*	0.9
3. Shale, moderate olive-brown, faintly laminated	1.0
2. Limestone, moderate yellow, nodular, argillaceous. Fossiliferous; fauna includes *Plicatula incongrua*, *Pecten (Neithea) subalpinus*, and *Gryphaea corrugata*	0.9
1. Shale, moderate olive-brown, faintly laminated, with lenses of moderate yellow calcareous sandstone. To lake bed	2.0
Total Duck Creek	13.5

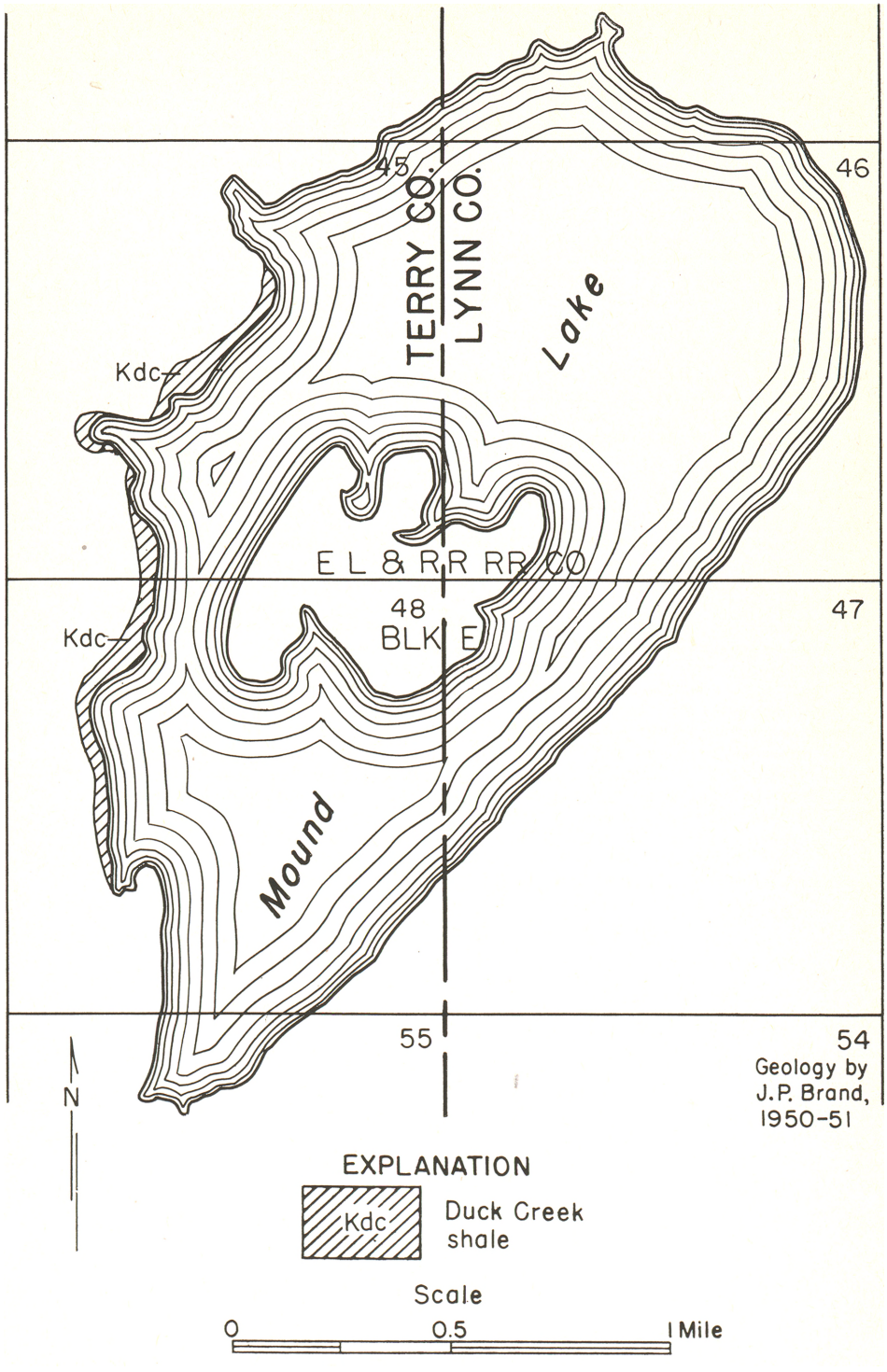


FIG. 10. Cretaceous exposures at Mound Lake, Terry and Lynn counties, Texas (locality 26).

Section at locality 27, 4 miles south and 1 mile east of Meadow, Terry County, along northwestern margin of playa of Rich Lake.

	Thickness *Feet*
Quaternary. Lake clays.	
Duck Creek shale—	
Shale, moderate yellow, thinly laminated, slightly calcareous, and thin-bedded, moderate yellow, argillaceous limestone. Fossiliferous; fauna includes *Ostrea quadriplicata, O. subovata,* and *Plicatula incongrua*	6.0

Comanche Peak and Walnut sections at locality 28, 2 miles north and 2 miles east of Posey, Lubbock County, along southwest wall of canyon of Double Mountain Fork of Brazos River.

	Thickness *Feet*
Pliocene. Couch formation.	
Comanche Peak formation—	
5. Limestone, light gray, thin to thick bedded, argillaceous. Fossiliferous; common species include *Protocardia texana, Gryphaea mucronata, Lima wacoensis, Pinna comancheana,* and *Tapes* sp.	16.5
4. Limestone, light gray, thin to thick bedded, argillaceous. Fossiliferous; common species include *Salenia mexicana, Enallaster texanus, Exogyra texana, Protocardia texana, Cyprimeria texana, Tapes, Tylostoma tumidum*	8.5
3. Limestone, light gray, argillaceous, with scattered ⅛ to ¼-inch quartz pebbles	0.5
2. Limestone, light gray to grayish yellow, thin bedded, argillaceous, with thin, dark gray shale interbeds. Both limestone and shale fossiliferous; fauna includes *Holectypus planatus, Enallaster texanus, Pecten (Neithea) irregularis, Tapes* sp., and *Gervilliopsis* sp.	2.5
1. Limestone, moderate yellow, unevenly thinly bedded, arenaceous. Weathers to brown argillaceous sand. Fossiliferous. Common species include *Protocardia texana, Cyprimeria texana, Exogyra texana*	3.0
Total Comanche Peak	31.0
Walnut formation—	
5. Sandstone, moderate yellow, loosely consolidated, massive, argillaceous. Fossiliferous; fauna includes *Ostrea crenulimargo, Exogyra texana,* and *Gryphaea mucronata*	8.0
4. Sandstone, dark yellowish orange, moderately well indurated, thin bedded, fine to medium grained, with light gray shale interbeds. Unfossiliferous	1.2
3. Sandstone, light gray to yellowish gray, loosely consolidated, massive, argillaceous, unfossiliferous	3.0
2. Sandstone, light olive-brown, moderately well indurated, massive, argillaceous, containing scattered 1 to 3-inch spherical to elliptical limonitic concretions. Unfossiliferous	5.5
1. Shale, medium bluish gray, thinly laminated, arenaceous, with streaks of moderate yellowish-brown clay	2.0
Total Walnut	19.7
Paluxy sandstone.	

Section at locality 29, 500 yards downstream from dam at east end of lower Buffalo Lake. Lubbock County.

	Thickness *Feet*
Pliocene. Couch formation.	
Comanche Peak limestone—	
4. Limestone, light gray, thin to thickly bedded, argillaceous, sparsely fossiliferous	15.0
3. Limestone, light gray to yellowish gray, thin to thickly bedded, argillaceous, with thin, dark gray shale interbeds. Fossiliferous; fauna includes *Protocardia texana, Cyprimeria texana, Tylostoma* sp., and *Turritella* sp.	4.0
2. Limestone, light gray, massive, argillaceous, with scattered quartz pebbles in lower portion. Fossiliferous; fauna includes *Holectypus planatus, Enallaster texanus,* and *Tapes* sp.	4.1
1. Limestone, light gray, thin bedded, argillaceous, with scattered sand grains and ⅛ to 1-inch quartz pebbles. Fossiliferous; fauna includes *Enallaster texanus, Holectypus planatus, Salenia mexicana, Exogyra texana,* and *Tylostoma* sp.	3.0
Total Comanche Peak	26.1

Section at locality 30, in west wall of abandoned gravel pit at entrance to Yellowhouse ranch, 8 miles west of farm road 51 and 2⅓ miles north of Whitharral, Hockley County.

	Thickness *Feet*
Quaternary. Caliche.	
Duck Creek shale—	
4. Limestone, moderate brown (5 YR ¾), unevenly thin bedded, limonitic. Contains numerous casts of pelecypods. A fragment, probably from this unit, found on the lower slope contains a mold of *Mortoniceras* aff. *M. trinodosum*	0.5 est.
3. Mostly covered. Small exposures show moderate yellow, faintly laminated, unfossiliferous shale and thin, light brown limestones	24.0
2. Shale, moderate yellowish brown, thinly laminated, and thin-bedded, moderate yellow, argillaceous limestone. Fossiliferous; fauna includes *Trochosmilia* sp., *Gryphaea corrugata, G. tucumcarii, Ostrea quadriplicata, Pinna guadalupae, Plicatula incongrua,* and *Mortoniceras* aff. *M. trinodosum.* Exposed in "fire break" road	3.0
1. Covered to top of Kiamichi shale	4.0 est.
Total Duck Creek	31.5
Kiamichi shale—	
1. Shale, medium gray, thinly laminated, with interbeds of light gray, nodular, argillaceous limestone and moderate yellow, argillaceous sandstone. Contains numerous *Gryphaea tucumcarii* in upper 5 feet	21.0

Section at locality 31, 4 miles north of locality 30, along north bank of stream entering southwest end of Illusion Lake, Lamb County.

	Thickness *Feet*
Pliocene. Sands, caliche.	
Kiamichi shale—	
8. Shale, medium gray to moderate yellow, thinly laminated, with moderate yellow, calcareous sandstone lenses	24.0
7. Limestone, light gray, evenly thin bedded, argillaceous, with light brown clay nodules	0.5
6. Shale, moderate yellow to medium gray, thinly laminated, unfossiliferous	7.5
5. Limestone, light gray, unevenly thin bedded, argillaceous, with medium gray shale interbeds	0.8
4. Limestone, light gray, unevenly thin bedded, argillaceous, with moderate yellow shale interbeds. Fossiliferous; fauna includes *Exogyra texana, Exogyra* (small individuals), *Gryphaea corrugata, Plicatula incongrua, Pecten (Neithea) subalpinus,* and *Oxytropidoceras* aff. *O. bravoense*	2.0
3. Shale, light gray to moderate yellow, thinly laminated, with thin (¼ inch) argillaceous limestone. Fossiliferous; fauna includes *Exogyra texana, Exogyra* (small individuals), *Gryphaea corrugata, Plicatula incongrua,* and *Pecten (Neithea) subalpinus*	7.5
2. Limestone, light gray, nodular in lower 6 inches, evenly thin bedded above, argillaceous. Contains fragments of *Oxytropidoceras* sp.	1.0
1. Shale, dark gray, thinly laminated, arenaceous	1.0
Total Kiamichi	44.3

Section at locality 32, 2½ miles northeast of locality 31, in bed of stream entering northwest end of Illusion Lake (Pl. IV, A).

	Thickness *Feet*
Pleistocene. Lake clays.	
Kiamichi shale—	
3. Shale, medium gray, thinly laminated, arenaceous, sparsely fossiliferous	1.5
2. Limestone, light gray to dusky yellow, unevenly thin bedded, with dark gray, thinly laminated shale interbeds. The limestone contains numerous ⅛ to ¾-inch rounded to subangular quartz pebbles. The conglomeratic limestone is fossiliferous and the specimens do not show sign of abrasional wear. Fauna includes *Exogyra texana, Gryphaea navia, Plicatula incongrua, Pecten (Neithea) subalpinus, P. (Neithea) irregularis, Protocardia texana, Tapes* sp., *Trigonia* sp., *Engonoceras* sp., *Oxytropidoceras acutocarinatum, O. belknapi, O. trinitense,* and *O.* sp.	4.0
1. Shale, medium gray, thinly laminated, slightly arenaceous, sparsely fossiliferous	1.0
Total Kiamichi	6.5

Section at locality 33, along western margin and in western wall of playa of Bull Lake, 1 mile north of farm road 54 and 9 miles west of Littlefield, Lamb County (fig. 11).

	Thickness *Feet*
Quaternary. Caliche.	
Duck Creek shale—	
5. Shale, moderate greenish yellow, faintly laminated, unfossiliferous. This may be Quaternary. To base of caliche	5.5
4. Limestone, moderate yellow, unevenly thin bedded, argillaceous. Lower surface fucoidal	0.4
3. Shale, moderate yellow, faintly laminated, unfossiliferous	3.7
2. Limestone, moderate yellow, evenly thin bedded, slightly argillaceous, with moderate yellow, thinly laminated shale interbeds. Fossiliferous; fauna includes *Trochosmilia* sp., *Gryphaea corrugata, Pinna guadalupae, Trigonia clavigera,* and *Mortoniceras* aff. *M. trinodosum*	2.0
1. Shale, moderate yellow, faintly laminated, contains *Gryphaea tucumcarii*	7.0
Total Duck Creek	18.6
Kiamichi shale—	
15. Shale, dark gray, thinly laminated, with numerous specimens of *Gryphaea tucumcarii*	9.0
14. Covered on slope	44.0
13. Limestone, light gray, unevenly thin bedded, argillaceous, with medium gray shale interbeds. Contains numerous *Gryphaea corrugata*	1.0
12. Shale, moderate yellow, thinly laminated; contains *Gryphaea corrugata*	1.3
11. Limestone, light gray, unevenly thin bedded, argillaceous. Contains *Oxytropidoceras* aff. *O. bravoense*	0.3
10. Shale, medium gray, thinly laminated, sparsely fossiliferous	4.5
9. Limestone, light gray, unevenly thin bedded, argillaceous, unfossiliferous	0.5
8. Shale, light gray to moderate yellow, thinly laminated, with thin stringers of moderate yellow sand. Contains *Gryphaea corrugata*	10.0
7. Limestone, light gray, nodular, argillaceous with medium gray shale interbeds	10.0
6. Shale, medium gray to yellowish gray, thinly laminated, unfossiliferous	4.0
5. Sandstone, moderate yellow, unevenly thin bedded, calcareous	0.3
4. Shale, medium gray, thinly laminated, unfossiliferous	4.4
3. Sandstone, moderate yellow, nodular, uniformly fine grained	0.4
2. Shale, medium gray, thinly laminated, with moderate yellow sand lenses. Contains *Gryphaea corrugata*	11.0
1. Covered to water level; surface rubble contains conglomeratic limestone containing unabraded *Gryphaea navia.* This is probably the *Gryphaea navia* zone of other sections. To water level	2.0
Total Kiamichi	93.6

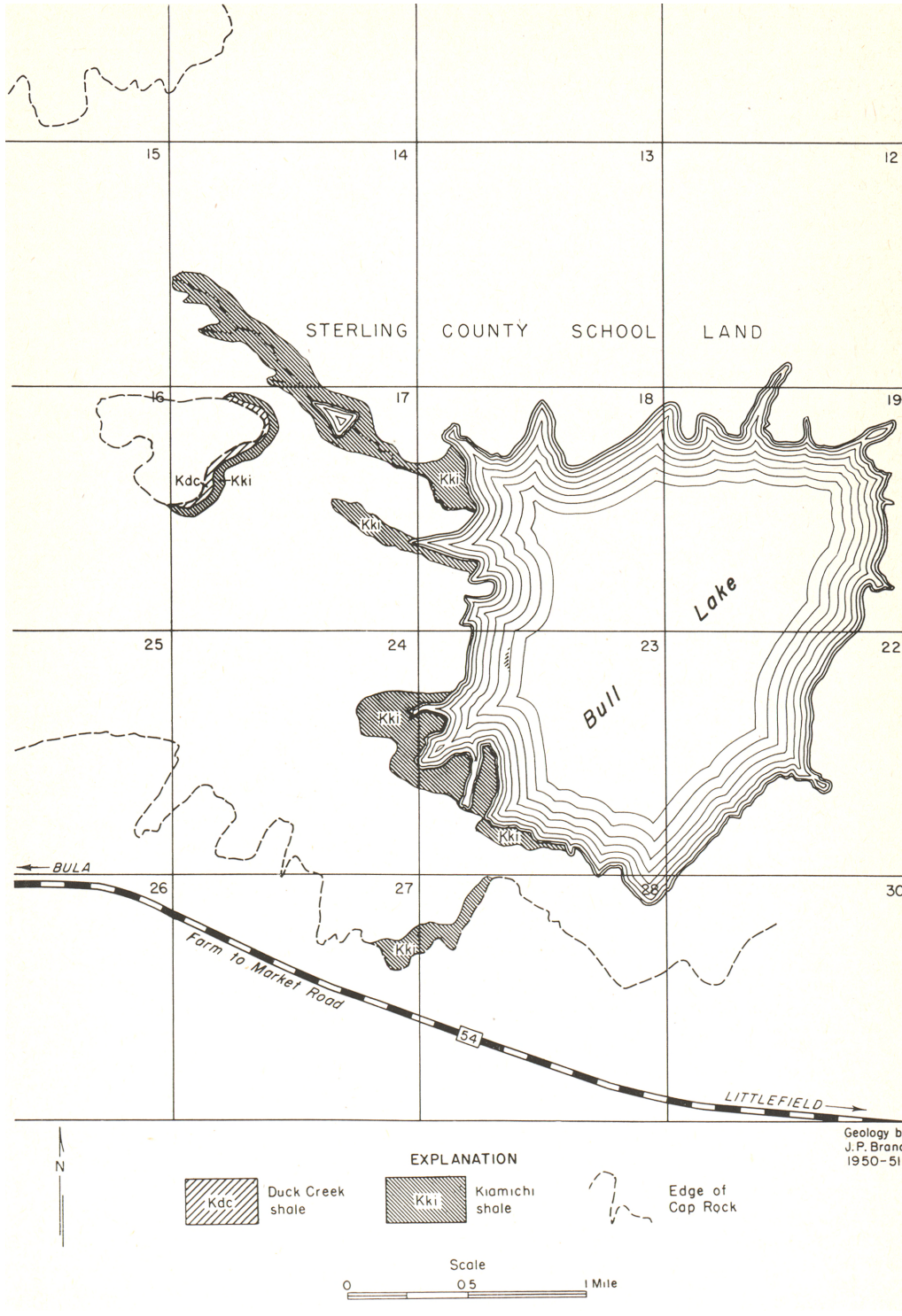


FIG. 11. Cretaceous exposures at Bull Lake, Lamb County, Texas (locality 33).

Section at locality 34, along western margin of present playa of White Lake, Muleshoe National Wildlife Refuge, Bailey County. Access road is 3¾ miles south of Needmore (fig. 12).

In this locality, beds of Duck Creek age are discontinuously exposed along the western and northwestern margins of White Lake, Bailey County. The exposures are badly slumped, and fossils usually are not found in place. Surface collections have yielded several specimens of the ammonite *Hamites* sp. One of these is associated with a mold of *Prohysteroceras burckhardti* (Böse). At locality 35, approximately 3 miles northeast of the White Lake section, *Mortoniceras* aff. *M. trinodosum* is found in the basal portion of the section.

	Thickness *Feet*
Pliocene. Bridwell formation.	
Duck Creek shale—	
6. Limestone, light gray, evenly thin bedded, argillaceous, unfossiliferous. Weathers to half-inch fragments	0.2
5. Shale, light gray to moderate yellow, thinly laminated, with streaks of moderate yellow sand. No fossils in place, but *Hamites* sp. has been found on the surface	2.0
4. Limestone, light gray to light yellowish gray, evenly thick bedded, unfossiliferous. Weathers to half-inch flags	0.6
3. Shale, light gray, thinly laminated, with thin, moderate yellow, argillaceous limestones. Unfossiliferous	11.0
2. Limestone, moderate yellow, unevenly thin bedded, with medium gray shale interbeds	1.0
1. Shale, medium gray, feebly laminated, with moderate yellow argillaceous sand. Contains *Gryphaea corrugata* and *G. tucumcarii*	5.5
Total Duck Creek	20.3
Kiamichi shale.	

Duck Creek section at locality 35, along northwestern margin of present playa of Goose Lake, Muleshoe National Wildlife Refuge, Bailey County (fig. 12).

	Thickness *Feet*
Pliocene. Caliche.	
Duck Creek shale—	
4. Mostly covered. Scattered exposures show feebly laminated, moderate yellow shale and thin, light gray, argillaceous limestone. To base of caliche	33.0
3. Limestone, light gray, unevenly thin to thick bedded, argillaceous, unfossiliferous	1.0
2. Shale, light gray to moderate yellow, thinly laminated, unfossiliferous	1.0
1. Limestone, light gray, unevenly thin to thick bedded, argillaceous. The basal 1 inch is arenaceous. Fossiliferous; fauna includes *Pinna guadalupae (?), Mortoniceras* aff. *M. trinodosum*, and *Cymatoceras texanum*	1.0
Total Duck Creek	36.0
Kiamichi shale.	

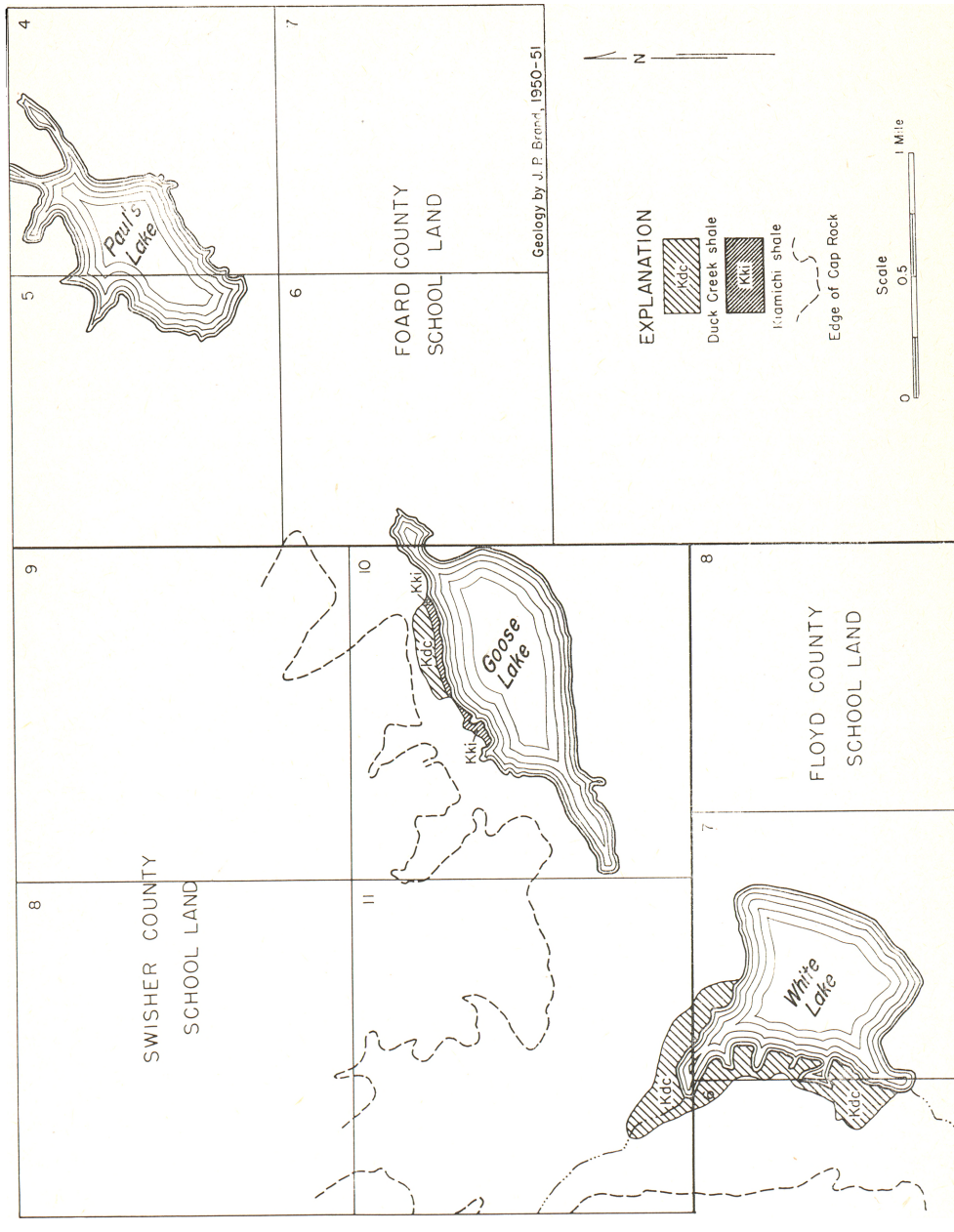


FIG. 12. Cretaceous exposures at Muleshoe National Wildlife Refuge, Bailey County, Texas (localities 34 and 35).

Section at locality 36, 3½ miles south and 3½ miles west of Baileyboro, Bailey County, along northern margin of playa of Monument Lake (fig. 13).

	Thickness *Feet*
Quaternary. Caliche.	
Kiamichi shale—	
7. Shale, medium gray to moderate yellow, thinly laminated, with light gray, nodular, argillaceous limestones. Fossiliferous; fauna includes *Exogyra texana, Gryphaea tucumcarii, G. corrugata, Inoceramus* sp., and small fragments of *Oxytropidoceras* sp. To base of caliche	6.0
6. Limestone, light gray, unevenly thick bedded, argillaceous, with coarsely crystalline calcite stringers. Unfossiliferous	0.6
5. Shale, medium gray, thinly laminated, with lenses of light brown arenaceous clay. Contains numerous *Gryphaea corrugata*	5.5
4. Limestone, light gray, evenly thick bedded, argillaceous, unfossiliferous	0.5
3. Shale, light gray to moderate yellow, thinly laminated, with moderate yellow sand lenses. Contains *Gryphaea corrugata* and *Exogyra texana*	8.0
2. Limestone, light gray, nodular, argillaceous, unfossiliferous	0.5
1. Shale, light gray, thinly laminated, unfossiliferous. To water level	6.0
Total Kiamichi	27.1

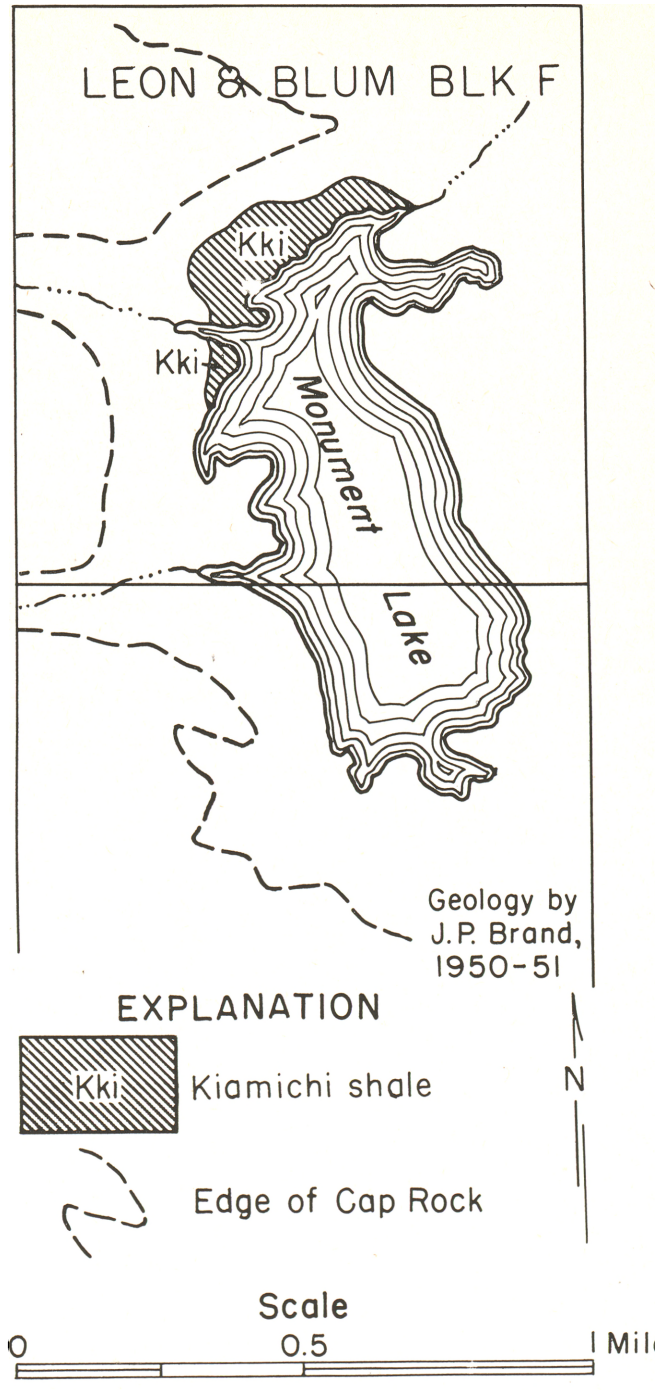


FIG. 13. Cretaceous exposures at Monument Lake, Bailey County, Texas (locality 36).

Section at locality 37, 1½ miles south of Baileyboro, Bailey County, along western margin of Baileyboro Lake. Additional exposures in banks of stream entering lake at northwest margin (fig. 14).

	Thickness *Feet*
Quaternary. Caliche.	
Kiamichi shale—	
4. Shale, olive-gray to medium gray, faintly laminated, unfossiliferous	6.0
3. Limestone, light gray, unevenly thick bedded, argillaceous, unfossiliferous	0.5
2. Shale, medium gray, thinly laminated, with moderate yellow, thin (¼ to ½ inch) limestone. Unfossiliferous	10.0
1. Shale, medium gray, thinly laminated, with stringers of selenite along bedding planes. Top marked by a thin (half-inch) argillaceous limestone. Fossiliferous; fauna includes *Gryphaea corrugata, Pecten (Neithea) subalpinus, Protocardia texana, Tapes* sp., *Plicatula incongrua*, and *Elobiceras* sp.	3.2
Total Kiamichi	19.7

Section at locality 38, in caliche pit on east side of Floydada-Silverton highway, 4 miles north of Floydada, Floyd County.

The Edwards has been extensively altered, and some layers are nearly pure, chalky calcium carbonate.

	Thickness *Feet*
Quaternary. Caliche.	
Edwards limestone—	
5. Limestone, grayish yellow, thickly bedded, coarse grained. Fossiliferous; fauna includes *Chondrodonta munsoni, Eoradiolites davidsoni, Caprinula* sp., and *Monopleura* sp.	2.0
4. Limestone, grayish yellow, thin to thickly bedded, argillaceous	1.5
3. Limestone, light gray, thickly bedded, coarse grained, fossiliferous; fauna as in unit 5	1.5
2. Limestone, light gray, nodular, argillaceous, fine to coarse grained	1.0
1. Limestone, grayish yellow, nodular, argillaceous, fossiliferous	1.0
Total Edwards	7.0

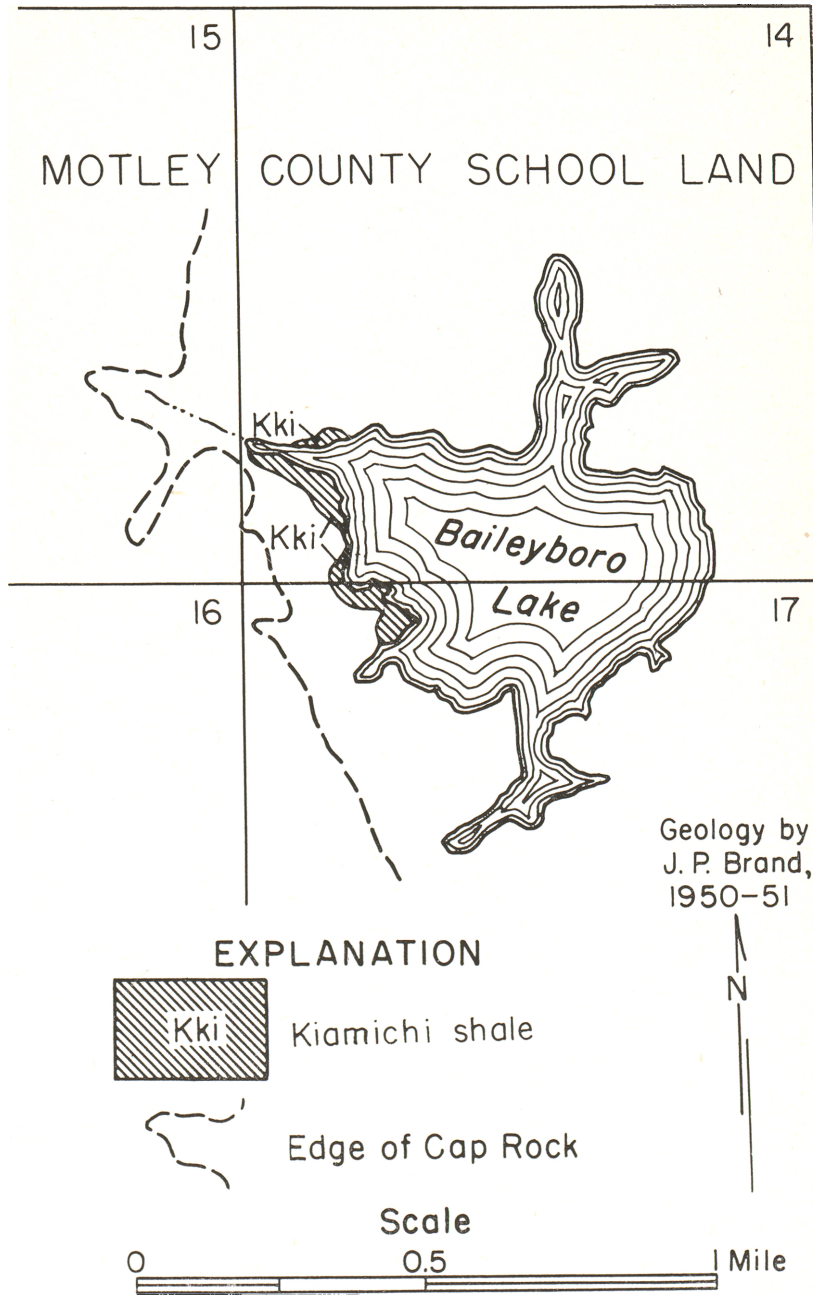
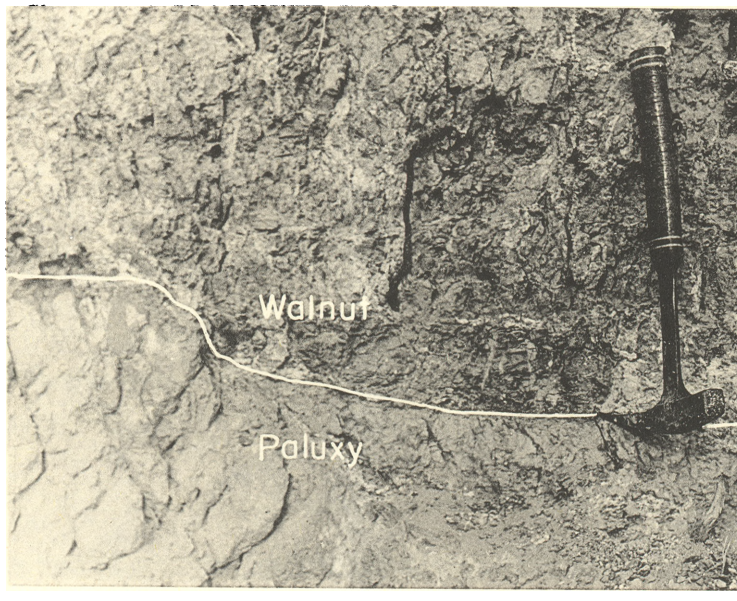
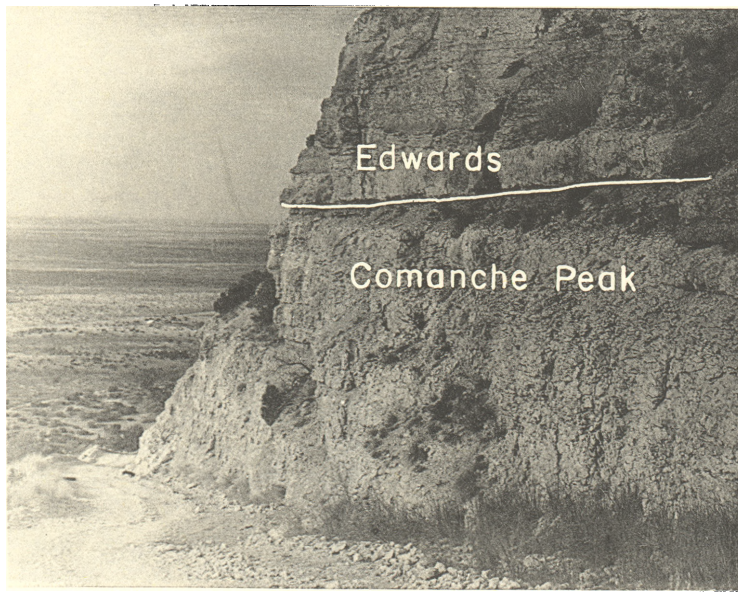


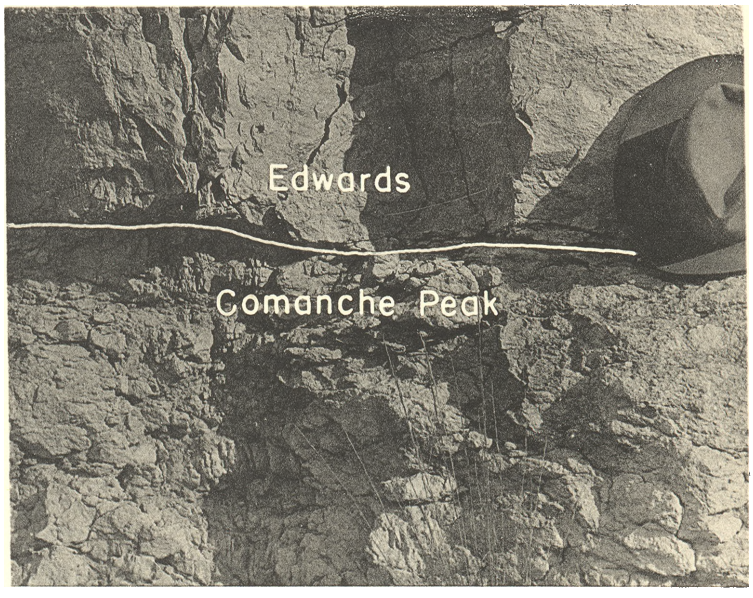
FIG. 14. Cretaceous exposures at Baileyboro Lake, Bailey County, Texas (locality 37).



(A) Disconformity at contact between Paluxy sandstone and Walnut formation in cut along Eppler-Fluvanna road (locality 15). View is from west.



(B) Comanche Peak and Edwards limestones in cut along Eppler-Fluvanna road (locality 15). View is from south.

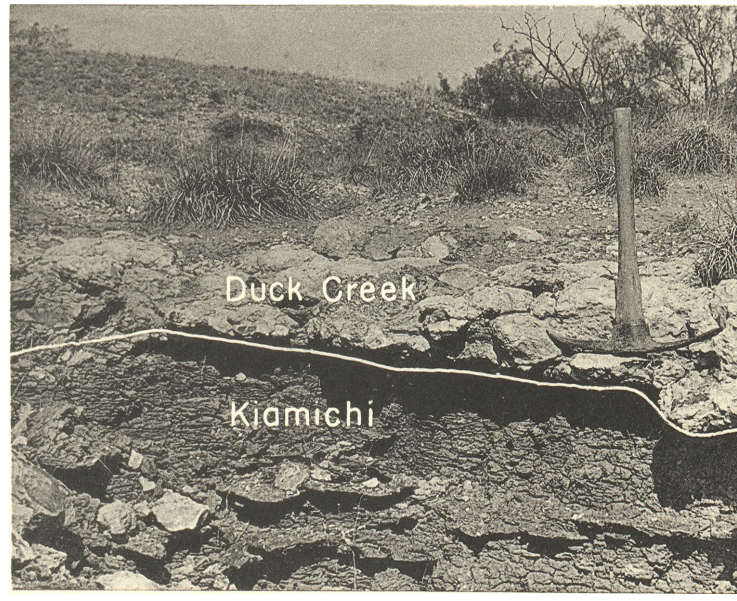


(A) Comanche Peak—Edwards contact in road cut along west side of Gail Mountain (locality 14). View is from west.

(B) Porous strata in Edwards limestone near top of road cut on west side of Gail Mountain (locality 14). View is from west.

(A) Conglomeratic limestone in "Gryphaea navia" zone of Kiamichi shale at locality 32.

(B) Kiamichi shale at mid-western margin of present playa of Guthrie Lake (locality 21). View is from northeast.



(A) Kiamichi—Duck Creek contact at northwest Twin Lake (locality 22). View is from east.

(B) Duck Creek shale at Mound Lake (locality 26).

INDEX

606 599 1361 406

E L & R R RR CO

G C & S F

602 560 1362 1359

E L & R R RR CO

Locality 18

Locality 19

Kcp Kwa Kp Q Rd

J. HAYS

456 1331 1 1360

445 1332 2 276

E L & R R RR CO BLK 1

J HAYS

E L & R R RR CO BLK 9

441 390 275

Fork of Brazos River

Double Mountain

South

LYNN CO.

GARZA CO.

Geology by J. P. Brand, 1950-51

EXPLANATION

Q	Kcp	Kwa	Kp	Rd
Quaternary	Comanche Peak limestone	Walnut formation	Paluxy sandstone	Dockum beds

Scale

0 0.5 1 Mile

Map of portion of eastern Lynn County and western Garza County, Texas, showing locations of Cretaceous exposures along South Double Mountain Fork of Brazos River.