Nomenclature of Formations of Claiborne Group, Middle Eocene Coastal Plain of Texas

GEOLOGICAL SURVEY BULLETIN 1251-D

Nomenclature of Formations of Claiborne Group, Middle Eocene Coastal Plain of Texas

By D. HOYE EARGLE

CONTRIBUTIONS TO GENERAL GEOLOGY

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The nomenclature and correlations of the middle Eocene of Texas are updated, with special reference to the Rio Grande embayment

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CONTRIBUTIONS TO GENERAL GEOLOGY

NOMENCLATURE OF FORMATIONS OF THE CLAIBORNE GROUP, MIDDLE EOCENE, COASTAL PLAIN OF TEXAS

By D. Hoye Eargle

ABSTRACT

In the northeastern two-thirds of the Gulf Coastal Plain of Texas the outcropping Claiborne Group (middle Eocene) consists of vertical sequences of alternating marine and nonmarine or near-shore marine units. The marine formations consist mostly of glauconitic fossiliferous clay, and the nonmarine to shallow-water marine formations are blanket sands. Each formation is traceable for hundreds of miles laterally along the outcrop and for several tens of miles downdip. In the Rio Grande embayment of southern Texas, however, the formations, except the Carrizo Sand at the base, differ in lithologic character and fossil content from their equivalent formations to the northeast. Several changes in nomenclature are necessary to make each unit of similar lithologic character a separate formation and to update the stratigraphy of the Rio Grande embayment.

The name Mount Selman is here abandoned for the formation consisting, in ascending order, of the Reklaw, the Queen City Sand, and the Weches Greensand Members, and each of the three members is elevated to the rank of formation. South of the Sabine uplift in Louisiana the Cane River Formation is the equivalent of these units. In the Rio Grande embayment the equivalent of the marine clayey Reklaw is the Bigford Formation, formerly of member rank and consisting chiefly of marine sands with some beds of clay and cannel coal. The overlying beds equivalent to the Queen City and Weches undivided, previously unnamed and consisting chiefly of clay and some cannel coal, are here named the El Pico Clay. The beds equivalent to the Sparta Sand and the clayey Cook Mountain Formation, undivided in the embayment and generally called the Cook Mountain there, were renamed the Laredo Formation in 1938 by Julia Gardner. Although the name has not been widely used, if at all, since 1938, future general use of this appropriate name is recommended. More than half of the Laredo Formation consists of sands. The Yegua Formation, chiefly sand with less clay in the northeast, is chiefly clay with less sand and some banks of oyster shells in the Rio Grande valley.

INTRODUCTION

In its outcrop across a large part of the Gulf Coastal Plain of Texas, the Claiborne Group, middle Eocene, exhibits one of the best known examples of cyclic sedimentation; nonmarine and near-shore blanket sands alternate with glauconitic fossiliferous marine clays and silts. During Claiborne time there were at least three major and fairly rapid marine transgressions followed by generally less rapid regressions of the sea. Each principal lithologic zone, traceable for hundreds of miles laterally and a few tens of miles downdip (fig. 1) and marked by the environment in which it was deposited, is now considered a formation. Acceptance of this concept requires several changes in stratigraphic nomenclature from that previously in use.

This discussion considers chiefly the justification for the terminology proposed and covers only little of the history of past usage. Table 1 shows the former and present nomenclature of the formations.

The changes in nomenclature recommended here are briefly as follows. The Mount Selman Formation is abandoned, and its members—in ascending order in central and eastern Texas, the Reklaw, Queen City, and Weches—are raised to formational rank. The Queen City feathers out in western San Augustine County. South of the Sabine uplift, Weches, Queen City, and Reklaw rocks in Texas are equivalent to Cane River rocks in Louisiana. The name Bigford, once a formation but later the lower member of the Mount Selman in the Rio Grande embayment of southern Texas, is restored in this report to formational rank. The name El Pico Clay is introduced here for the beds once called the Mount Selman Formation in the Rio Grande embayment, but later called the unnamed upper member of the Mount Selman. The name Laredo Formation—introduced by Gardner (1938) but never widely used—is recommended for the beds formerly called the Cook Mountain Formation in the Rio Grande embayment and equivalent to the Sparta Sand and Cook Mountain Formation of eastern and central Texas. The Carrizo Sand, the basal formation, and the Yegua Formation, the uppermost formation of the Claiborne Group, remain unchanged. The lithologic character of the Yegua in the Rio Grande embayment is somewhat different from that to the northeast. The boundaries of the Yegua, having presented some problems in the past, were affirmed in eastern and central Texas by Stenzel (1938) and were corrected in southern Texas by Lonsdale and Day (1937). For south-central Texas, however, the upper boundary has been redefined, and the area has been remapped during the present survey.

The lateral changes within the Claiborne Group from marine-shelf facies northeast of the Rio Grande embayment to fresh- or brackish-water facies and generally thicker units in the embayment are not definitely localized or sharp, but the sediments of the two environments interfinger complexly along the margins of the basin. The northwest-trending axis of the embayment, as defined for this report by the thickest lower Tertiary sediments, lies generally along the Nueces River. The Rio Grande flows along the west edge of the basin, nearly paralleling the strike of the rocks. The east edge of

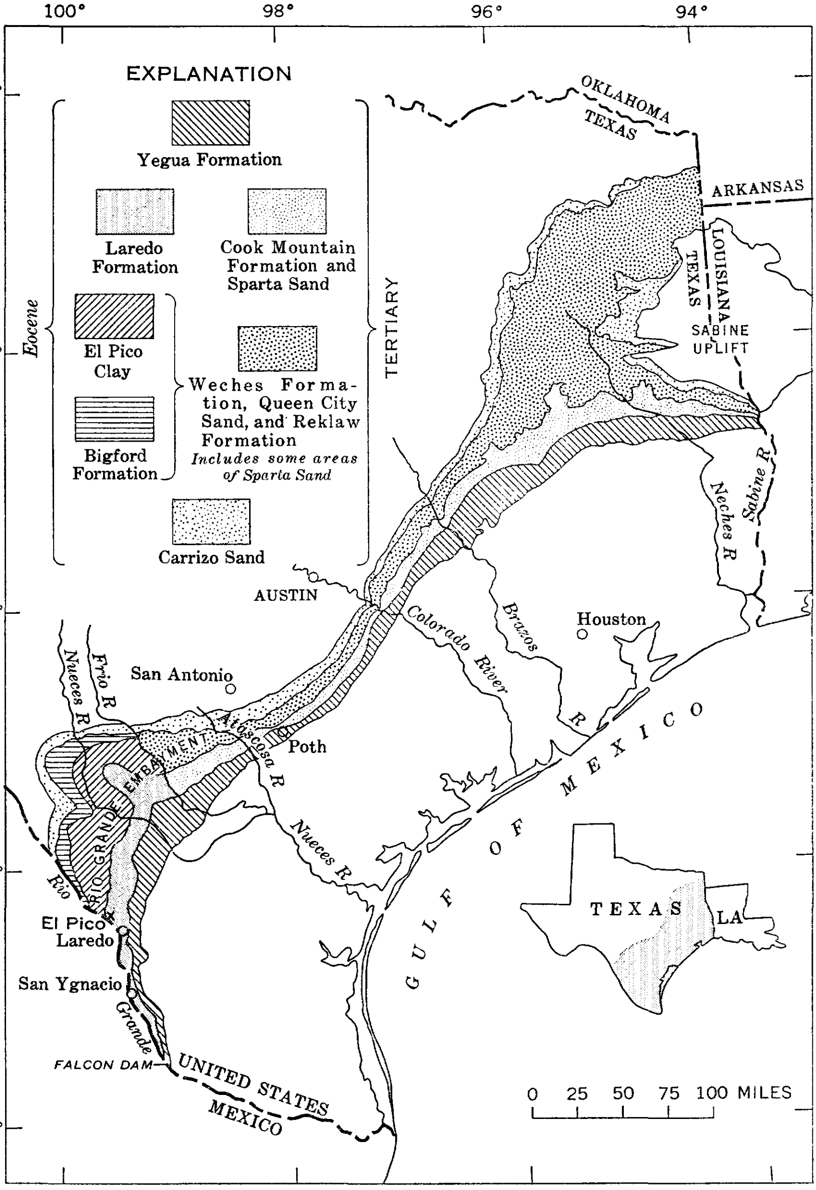

FIGURE 1.—Outcrop area of the Claiborne Group in Texas. Modified from Darton, Stephenson, and Gardner (1937).

TABLE 1.—*Former and present classification of Claiborne Group in Texas*

Former classification				Present classification		
Eastern to central Texas		Rio Grande embayment		South of Sabine uplift	Eastern to central Texas	Rio Grande embayment
Yegua Formation		Yegua Formation		Yegua Formation	Yegua Formation	Yegua Formation
Cook Mountain Formation		Cook Mountain Formation (changed to Laredo Formation by Gardner, 1938)		Cook Mountain Formation	Cook Mountain Formation	Laredo Formation
Sparta Sand				Sparta Sand	Sparta Sand	
Mount Selman Formation	Weches Greensand Member	Mount Selman Formation	Upper unnamed member	Weches Formation	Weches Formation	El Pico Clay
	Queen City Sand Member			Queen City Sand, and Reklaw Formation undivided	Queen City Sand	
	Reklaw Member		Bigford Member		Reklaw Formation	Bigford Formation
Carrizo Sand		Carrizo Sand		Carrizo Sand	Carrizo Sand	Carrizo Sand

the basin, in the area near the Frio River where beds of differing characteristics interfinger and intergrade both laterally and vertically, is ill defined. Studies of well logs of the shallow subsurface made in recent years for water-resource and oil investigations (Alexander and others, 1964; Harris, 1965; Hargis, 1962) have resulted in a better understanding of the stratigraphic relations of formations of the Claiborne Group in southern Texas. Much fieldwork on the outcrop, however, and tracing of units by study of logs and subsurface materials must be done before the boundaries can be defined in detail.

A geologic section, prepared by W. H. Alexander and B. N. Myers (generalized as pl. 6 in Alexander and others, 1964), extends eastward downdip from the outcrop of the Claiborne Group in the Nueces River basin, then northeastward along the strike. The section shows the intertonguing of beds in the Rio Grande embayment, both downdip and laterally along the strike, with those of the shelf deposits to the northeast (fig. 2), and illustrates the necessarily arbitrary definition of limits of stratigraphic units in such instances of interfingering relations.

The cooperation of Dr. V. E. Barnes, Associate Director of the Bureau of Economic Geology, The University of Texas, who, in connection with the Texas Geologic Atlas Project, accompanied the author to the Rio Grande embayment to study outcrops, and who reviewed this paper, is gratefully acknowledged. Dr. P. T. Flawn, Director of the Bureau of Economic Geology, permitted the author to study the core of the San Ygnacio water well (fig. 6) and to obtain samples of the core for fossil determination. Mr. L. H. Henderson, of the International Boundary and Water Commission, furnished the electric log and water-quantity and water-quality data on the San Ygnacio well. W. H. Alexander, Jr., of the U.S. Geological Survey, reviewed with the author subsurface correlations in the Rio Grande embayment and permitted use of work sheets, prepared by him and B. N. Myers (also of the U.S. Geological Survey), showing the intertonguing of beds in the embayment (fig. 2).

The assistance of ranchers along the Rio Grande, especially Mr. A. F. Muller, of La Bota Ranch, and Mr. Emilio Garza, of El Pico Ranch, in permitting fieldwork to be done on their lands and in supplying geographical and historical information on the region northwest of Laredo, is also gratefully acknowledged.

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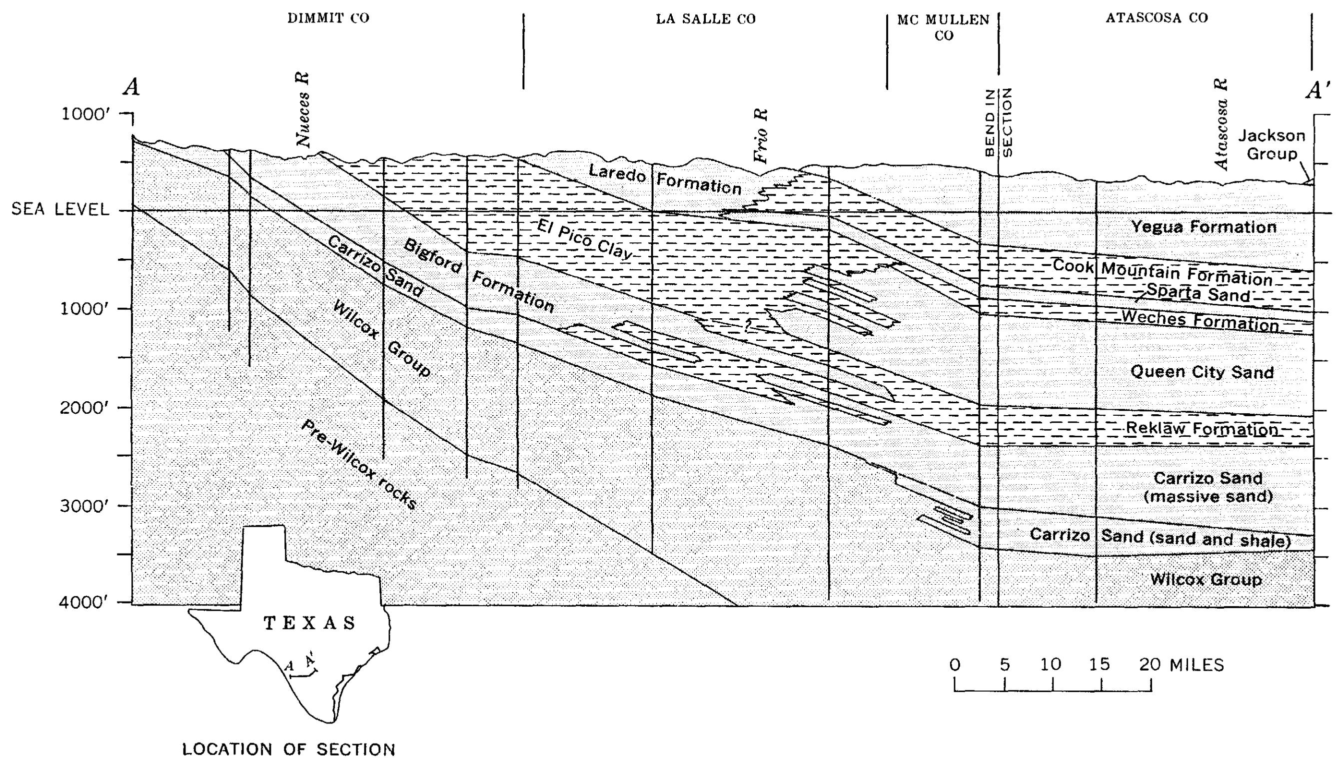

FIGURE 2.—Geologic section A–A', extending eastward obliquely across part of the Rio Grande embayment in southern Texas, then northeastward, shows intertonguing beds of sands (dot pattern) and finer clastics (dash pattern) in formations of Claiborne age, Eocene. Vertical lines indicate the wells used for control. Modified from Alexander, Myers, and Dale (1964).

FORMATIONS OF THE CLAIBORNE GROUP

CARRIZO SAND AND REKLAW FORMATION

The Carrizo Sand, basal formation of the Claiborne Group, is one of the most important aquifers of the updip Gulf Coastal Plain subsurface, and downdip it is a prolifically productive oil reservoir. The Carrizo is traceable from a featheredge north of the Sabine uplift for 500 miles southwestward into the Rio Grande embayment, where it is more than 1,000 feet thick (Alexander and others, 1964), and across the Rio Grande into Mexico.

The Carrizo is generally a massive to crossbedded sand with a few partings of carbonaceous micaceous silty clay or sand which probably was deposited under fluvial conditions, near shoreline (Todd and Folk, 1957). On the surface it unconformably overlies carbonaceous sands, silts, and clays of the Wilcox Group, but in the downdip subsurface its sands are distinguished with difficulty from those of the Wilcox; most geologists in the oil industry consider the Carrizo and Wilcox an indivisible unit.

The Reklaw Formation, which lies conformably on the Carrizo, is mostly marine and consists of even-bedded chocolate-colored shale with thin beds of glauconitic sand and of lignite (Stenzel, 1938, p. 75; Plummer, 1932, p. 625). Stenzel divided the outcropping formation into two members, the Marquez Shale at the top and the Newby Sand at the base. The contact of the marine Newby Sand Member with the underlying nonmarine Carrizo is more apparent on outcrop than it is in the subsurface. The Reklaw is distinguished on electric logs as a zone chiefly of low resistivity indicative of clay (the Marquez Shale Member of the outcrop). Below this zone on most logs is one of moderately nigh resistivity, generally with one or more low-resistivity breaks (fig. 3) followed in depth by a thick zone of very high resistivity. All geologists agree that the lower zone of very high resistivity is Carrizo Sand, and many call that zone the massive Carrizo. It is a unit of coarse massive sand containing fresh water, in contrast to the zones directly above it of finer sand containing water of higher mineral content (W. H. Alexander, Jr., oral commun., 1966). Some consider the top of the first zone of moderately high resistivity to be the top of the Carrizo; others, who consider this first zone to be the basal sand of the Reklaw, place the top of the Carrizo at the top of some lower zone of moderately high resistivity. The writer places the top of the Carrizo at the first principal break from fairly low resistivity to markedly higher resistivity.

From the downdip area to the outcrop the transgressive nature of the Reklaw can be seen in the interfingering of its basal sands and clays with the sands of the Carrizo. Beds of sand near the outcrop

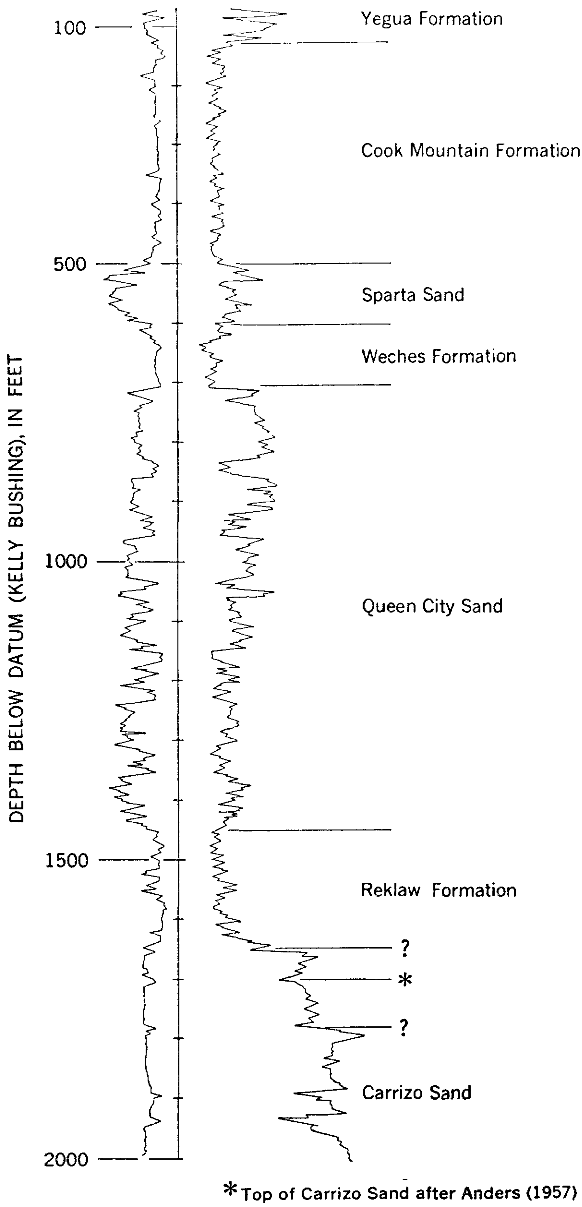

FIGURE 3.—Electrical characteristics of formations of the Claiborne Group as demonstrated on the log of the Poth Water well 3. Three possible contacts of the Carrizo Sand with the Reklaw Formation are indicated.

grade downdip into beds of silt and clay; the stratigraphically higher beds grade into fine materials within a shorter distance downdip than do the lower beds. Thus, as one proceeds up the dip the Reklaw-Carrizo contact moves stratigraphically upward.

Southwestward along the strike the generally clayey nature and marine characteristics of the Reklaw persist on the outcrop almost to the Frio River. Beyond the Frio River, clay beds become much thinner and interfinger with sands. These sands, which contain some fossils and are interbedded with clays, pass laterally westward and southward into the Bigford Formation, the approximate equivalent of the Reklaw.

The Reklaw ranges in thickness from 30 to 130 feet in eastern Texas (Wendlandt and Knebel, 1929, p. 1371). It is about 100 feet thick in Leon County in east-central Texas (Stenzel, 1938); as much as 300 feet thick in Wilson County in south-central Texas (Anders, 1957); and from 200 to 400 feet thick in southern Texas, where it intertongues with the Bigford Formation (Alexander and others, 1964).

BIGFORD FORMATION

The Bigford Formation, the equivalent in the Rio Grande embayment, of the Reklaw, was described by Trowbridge (1923) from exposures along the Rio Grande at the Bigford Ranch in northwestern Webb County, about 45 airline miles northwest of Laredo. The type locality, shown as Cuatralvo Ranch on recent maps, lies north of a 4-mile eastward-flowing reach of the Rio Grande about 20 miles southeast of the Maverick-Webb County line. The Bigford has been traced for about 35 miles in good exposures along the breaks of the Rio Grande from about 9 miles downstream from the Maverick-Webb County line to the vicinity of the old coal mines northwest of Laredo. This unusual length of good exposure is due to the fact that the course of the river nearly parallels the strike along the west flank of the structural basin, the Rio Grande embayment (fig. 1). On the east flank of the embayment the Bigford interfingers with the Reklaw Formation (fig. 2; Getzendaner, 1930, p. 1436). Exact correlation has not been possible in the past because of poor exposures and lack of traceable horizons, but electric logs of wells a short distance downdip have made possible a more certain correlation and have shown the gradation from the predominantly clayey Reklaw northeast of the Rio Grande embayment to the more sandy Bigford in the embayment. (See sections in Harris, 1965.)

The descriptions of the Bigford Formation by Trowbridge (1923, 1932) and the measured sections recorded by Lonsdale (1935) and Lonsdale and Day (1937) give details of the exposures in the outcrop area and adequately describe the lithology and fossil content. Julia

Gardner measured many of the sections and identified the invertebrate fossils for both the Trowbridge and the Lonsdale and Day surveys.

Because of fossil-plant determinations by Berry (1923), Trowbridge considered the Bigford and the underlying Carrizo Sand to be Wilcox in age. Trowbridge (1932, p. 52) suggested, however, that geologists found that field relations and lithologic characteristics showed the Carrizo more directly related to the Claiborne than the Wilcox. Wendlandt and Knebel (1929), Ellisor (1929), and most geologists since that time show the Bigford and the Carrizo to be definitely Claiborne in age. Gardner, as well as most later authors, considered the Bigford the basal member of the Mount Selman Formation in the Rio Grande embayment, but she left the thicker clayey upper part unnamed.

The base of the Bigford is placed at its contact with an underlying massive and highly permeable sand (the Carrizo). The formation consists of sands, some very thin beds of fossiliferous silts and shales, and several coal beds. The shales are brown to gray and gypsiferous, and they make up about 25 percent of the formation along the Rio Grande (Lonsdale and Day, 1937, p. 31). Near the top of the formation is the San Pedro coal, one of the two cannel coals of the once commercially important Webb County coal basin.

The Bigford is reported to be a little more than 650 feet thick along the Rio Grande (Lonsdale and Day, 1937, p. 22) and somewhat thicker in the vicinity of the Nueces River where the structural basin of the Rio Grande embayment centers. Alexander, Myers, and Dale (1964, table 1) show a thickness of 400–800 feet in the Nueces River valley.

QUEEN CITY SAND AND WECHES FORMATION

The Queen City Sand, lying conformably on the Reklaw Formation, is a thick unit of sands and sandy clays that extends from eastern Texas southwestward to the eastern part of the Rio Grande embayment. The Queen City in eastern Texas contains beds of almost pure quartz sand, of sandy clay and greensand, and of lignite and bentonitic clay (Wendlandt and Knebel, 1929, p. 1355). A distinct and traceable bed of glauconite and glauconitic clay in northeastern Texas was called by Wendlandt and Knebel (1929, p. 1355) the Omen Member. In south-central Texas bright-red-weathering beds near the middle of the Queen City, possibly equivalent to the Omen Member, contain local radioactive anomalies (Moxham and Eargle, 1961) that may be placer concentrations of heavy-mineral sands.

South of the Sabine uplift, extending to the Sabine River from about 40 miles west of the river, the Queen City is marine, indistinguishable from the Weches above and the Reklaw below. This undivided section is equivilent to the Cane River Formation in Louisiana.

The Queen City is as much as 480 feet thick in eastern Texas (Wendlandt and Knebel, 1929, p. 1355) and 750 feet thick in the updip subsurface near Poth. Southward, it thickens further and gradually becomes clayey; beyond the Frio River (fig. 2) it is indistinguishable from the overlying Weches as it and the Weches interfinger laterally with the carbonaceous clays of the El Pico.

The Weches Formation in eastern Texas is a relatively thin marine formation consisting chiefly of fossiliferous glauconitic clay with some marl and limestone (Stenzel, 1938). It lies conformably on the Queen City Sand. The weathered outcrop of the Weches contains the principal iron-ore-bearing beds of eastern Texas. The marine character of this formation persists across most of the eastern and south-central part of the State, but the formation becomes gypsiferous carbonaceous sandy clay at the east margin of the Rio Grande embayment.

In eastern Texas the Weches is about 50 feet thick (Wendlandt and Knebel, 1929, p. 1371). In the updip subsurface in south-central Texas, where its thickness can best be determined from well logs, it is about 100 feet thick. Southwest of the Frio River the Weches becomes generally nonmarine and is indistinguishable on well logs from the Queen City below. There, the two formations merge laterally into the El Pico Clay of the Rio Grande embayment.

EL PICO CLAY

El Pico Clay is the name here proposed for the formation in the Claiborne Group that Trowbridge (1923) called the Mount Selman, of Claiborne age, in the Rio Grande region. He found it to be distinct from the underlying Bigford Formation, which, with the Carrizo Sand, he considered to be of Wilcox age. Lonsdale (1935), in his survey of Atascosa and Frio Counties, expanded the Mount Selman to include equivalents of the Bigford in south-central Texas and considered the Mount Selman and underlying Carrizo Sand to be Claiborne in age. Lonsdale and Day (1937) formally designated the Bigford the lower member of the Mount Selman in Webb County, as did Gardner (in Darton and others, 1937). Turner, Robinson, and White (1960) and Alexander, Myers, and Dale (1964) followed Lonsdale and Day in designating as the Bigford the lower of two members, and they have referred to the upper member, here named El Pico, as "post-Bigford beds." The name Mount Selman is not appropriate for the beds in southern Texas because of their distance from the Mount Selman type locality, because the character of the rocks is in almost no way comparable to the Mount Selman of the type locality, and because no purpose would be served by keeping the name. Thus, by describing the Bigford and the El Pico as forma-

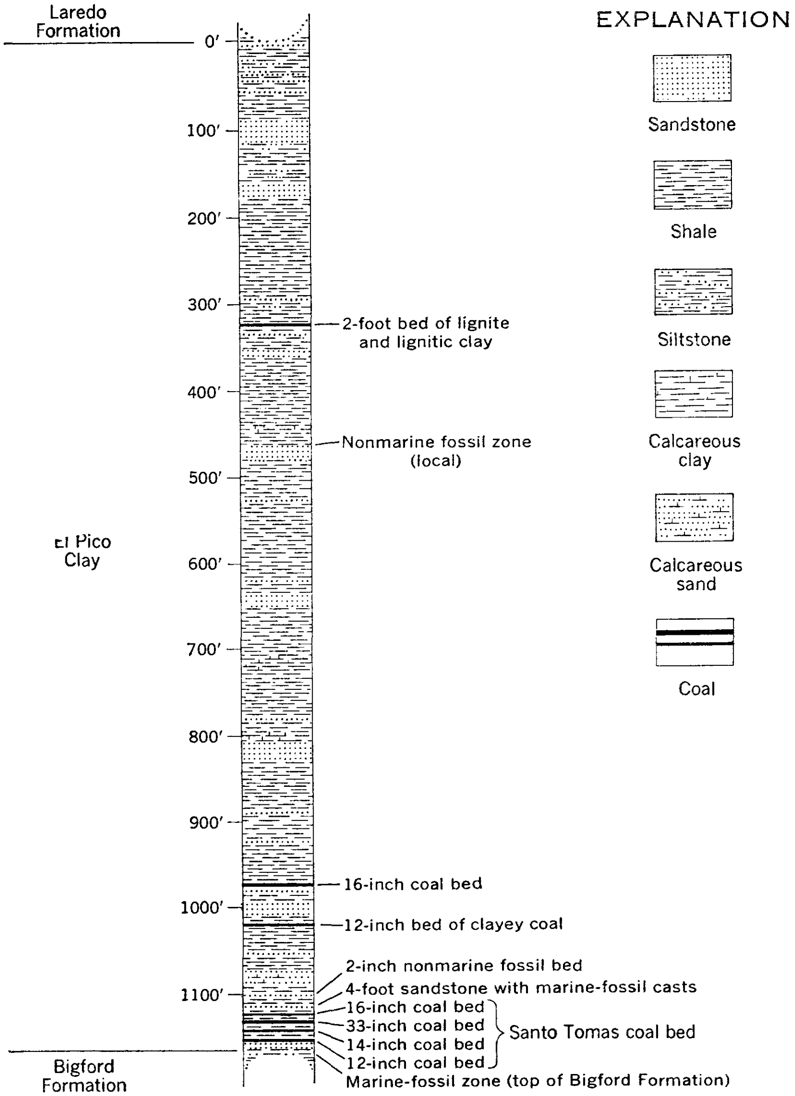

FIGURE 4.—Composite section of El Pico Clay, from sections measured along the Rio Grande in Webb County, Tex. Modified from Lonsdale and Day (1937, fig. 3 and p. 35–37).

tions, the nomenclature is simplified and opportunity is given for more exact definition of units in the Rio Grande embayment.

Type section.—The formation is named for El Pico, a conspicuous mesa-butte in Webb County, about 8½ airline miles northwest of downtown Laredo (fig. 5). El Pico is in the approximate center of a shoe-shaped bend of the Rio Grande (thus, the name of the ranch on which it is located, La Bota, the boot), about three-fourths of a mile from the river, about a mile northwest of the mouth of Sombrerito Creek, and about 2 miles southwest of the bridge where Farm Road (FM) 1472 crosses the creek.

The El Pico Clay is exposed in many places along the breaks of the Rio Grande for at least 25 miles upstream from the mouth of Sombrerito Creek. Trowbridge (1923, 1932) and Lonsdale and Day (1937) recorded many measured sections and fossil identifications by Julia Gardner. A composite section (fig. 4) of the beds that make up this formation, compiled by Londsale and Day (1937, p. 33, 35–37), gives in considerable detail the characteristics of the formation along the Rio Grande and is designated the type section of the El Pico.

Type section of El Pico Clay

[Measured along Rio Grande for 25 miles between Bigford-Laredo contacts (fig. 1). Quoted from Lonsdale and Day (1957, p. 35–37)]

	Ft	*in*
Ledge of fine-grained massive yellow-brown and yellow mottled gray micaceous sandstone	4	0
Soft yellow-brown shale and massive sandstone and alternating shale	5	0
Yellow, gray, and brown clay and shale with iron concretions	21	0
Purple, gray, and brown soft massive sandstone and alternating iron-stained gypsiferous shale	4	0
Hard silty and limy concretionary yellow-gray boulders	1	0
Gray shale and sand	6	0
Deep-brown and dull-green sand and thin-bedded sandstone		6
Soft brown sandstone and alternating gray shale	1	0
Gray and brown iron-stained gypsiferous sandy shale	12	0
Soft rusty-brown thin-bedded sand	1	0
Gray, brown, and yellow laminated iron-stained gypsiferous clay and sandy shale	8	0
Brown, gray-pink, and purplish shale and clay	25	0
Soft fine-grained yellow mottled gray massive sandstone	6	0
Fine-grained brown sandstone forming a soft ledge	6	0
Soft massive yellow-brown sand	7	0
Soft ledge of yellow-brown and gray bedded sandstone	5	0
Soft yellow-brown massive argillaceous sand	10	0
Gray and brown mottled shaly clay	18	0
Purplish-gray and brown gypsiferous iron-stained sandy clay	19	0
Poorly bedded sandstone with a few hard boulders 6 inches in diameter	16	0
Gray, brown, and yellow mottled gypsiferous jointed clay	17	0
Mostly clay covered by river alluvium, about	100	0
Soft massive poorly bedded gray sandstone	4	6
Blue-gray jointed clay	4	0
Soft reddish, rusty-brown, and gray argillaceous sand	4	0
Blue-gray jointed clay	6	0
Soft yellow, brown, and gray argillaceous sandstone		6
Blue-gray shale and jointed clay	6	0
Platy hard crystalline thin blue-gray sandstone		2

Type section of El Pico Clay—Continued

	Ft	in
Bony black coal		7
Blue-black lignitic clay	1	6
Yellow-gray argillaceous sand	2	0
Covered	10	0
Thick-bedded and laminated hard gray sandstone	4	0
Gray clay with some limonite and gypsum, about	15	0
Soft irregularly highly crossbedded gray sandstone	5	0
Medium-hard ripple-marked bedded gray sandstone	3	0
Blue-gray joint clay	3	0
Brown and gray clay and partly covered, about	70	0
Brown and gray clay with some yellow limestone concretions, about	30	0
Brown iron-stained gritty irregular sandstone, with local nonmarine fossils	1	0
Purple, gray, and brown thin-bedded to massive soft fine-grained sandstone	13	0
Sandy gray and brown clay and shale with gypsiferous laminations	4	0
Brown, gray, pink, and purplish mottled gypsiferous clay	46	0
Hard single ledge of massive fine-grained buff and gray sandstone, in places yellow-stained	1	0
Yellow-brown, gray, pink, and purplish clay	30	0
Brown and gray clay, mostly covered	55	0
Brown clay	5	0
Soft ledge of massive gray-brown sandstone	2	0
Gray and brown mottled jointed clay	15	0
Soft massive gray sandstone	12	0
Blue-gray jointed clay	10	0
Brown clay and some yellow concretionary limestone, but mostly covered	120	0
Soft massive ledge of purplish-gray sandstone, stained pink and yellow brown	3	0
Blue-gray and brown gypsiferous clay and a few yellow limestone concretions	29	0
Yellow limestone concretionary bed		6
Soft thin-bedded and crossbedded mealy gray sandstone	17	0
Brown clay	17	0
Clay, slight dip, about	15	0
Brown gypsiferous clay	16	0
Shaly gray and platy buff fine-grained sandstone and some yellow-gray limestone concretions	2	0
Brown gypsiferous clay	7	0
Thin-bedded yellow-brown gritty iron-stained sandstone	3	0
Shaly gray sandstone and shale	3	0
Brown and gray clay	5	6
Very irregular rusty-brown iron-stained sandstone with worm borings		6
Brown iron-stained gritty sandstone	2	0
Brown and gray clay and sandy shale	6	6
Soft gray sand and shaly sand	3	0
Shaly gray and brown sand and clay	13	0
Soft gray sand	3	0
Brown and gray clay, partly covered	53	0
Coal seam, mostly clay		4

Type section of El Pico Clay—Continued

	Ft	in
Brown clay	3	6
Shaly gray sandstone	1	0
Ledge of mealy gray massive sandstone	1	0
Thin-bedded gray sandstone and gray shaly sandstone with alternate gray and brown clay	4	0
Local ledge of hard yellow and gray boulders	1	0
Gray clay	4	0
Gritty yellow mottled iron-stained fine-grained sandstone	1	0
Soft ledge of fine-grained and light purplish-brown to buff-gray bedded sandstone	10	0
Soft fine-grained purplish-gray and brown sand with yellow iron-stained gypsum laminations	4	0
Blue, gray, and brown clay	12	0
Clayey coal bed	1	0
Gray and green-brown clay	32	0
Hard ledge of buff-gray wavy laminated massive fine-grained micaceous sandstone, local	2	0
Greenish-gray and brown-mottled clay	18	0
Medium- to coarse-grained yellow-brown crossbedded and gritty soft sandstone with yellow limestone concretions	17	0
Brown gypsiferous clay	10	0
Wavy bands of gypsum crystals, almost continuous and above clay		6
Soft fine-grained and mealy gray sandstone with gypsum laminations and a few yellow limestone concretions	2	6
Brown and gray gypsiferous clay	9	
Thin hard slaty gray silty sandstone with dwarf fossils, chara seeds, and nonmarine fossils		2
Soft fine-grained and gray thin-bedded yellow-mottled gray and brown sandstone; a few fossils at the base	4	0
Greensih-gray and brown clay	5	6
Santo Tomas zone: Coal, local	1	4
Santo Tomas zone: Gray and brown clay	8	6
Santo Tomas zone: Brown shale and slaty bone coal		6
Santo Tomas zone: Black cannel coal (main Santo Tomas coal)	2	9
Santo Tomas zone: Brown clay	7	
Santo Tomas zone: Brown shaly coal, local	1	2
Brown gypsiferous clay with a little soft brown sandstone at the base	13	0
Coal, local	1	0
Hard massive yellow-stained bluish and purplish-gray sandstone	2	0
Soft shaly and thin-bedded yellow-stained gray sandstone	4	6
Brown clay	4	0

According to Lonsdale and Day (1937, p. 35–37), beds now called the El Pico Clay are 1,165 feet thick along the Rio Grande, and they dip generally east-northeastward 90 feet per mile. Kane and Gierhart (1935) show them to be 1,124 feet thick along the Laredo-Monterrey highway and railroad in Tamaulipas and Nuevo Leon, Mexico, along the west flank of the Rio Grande embayment. In the Nueces River

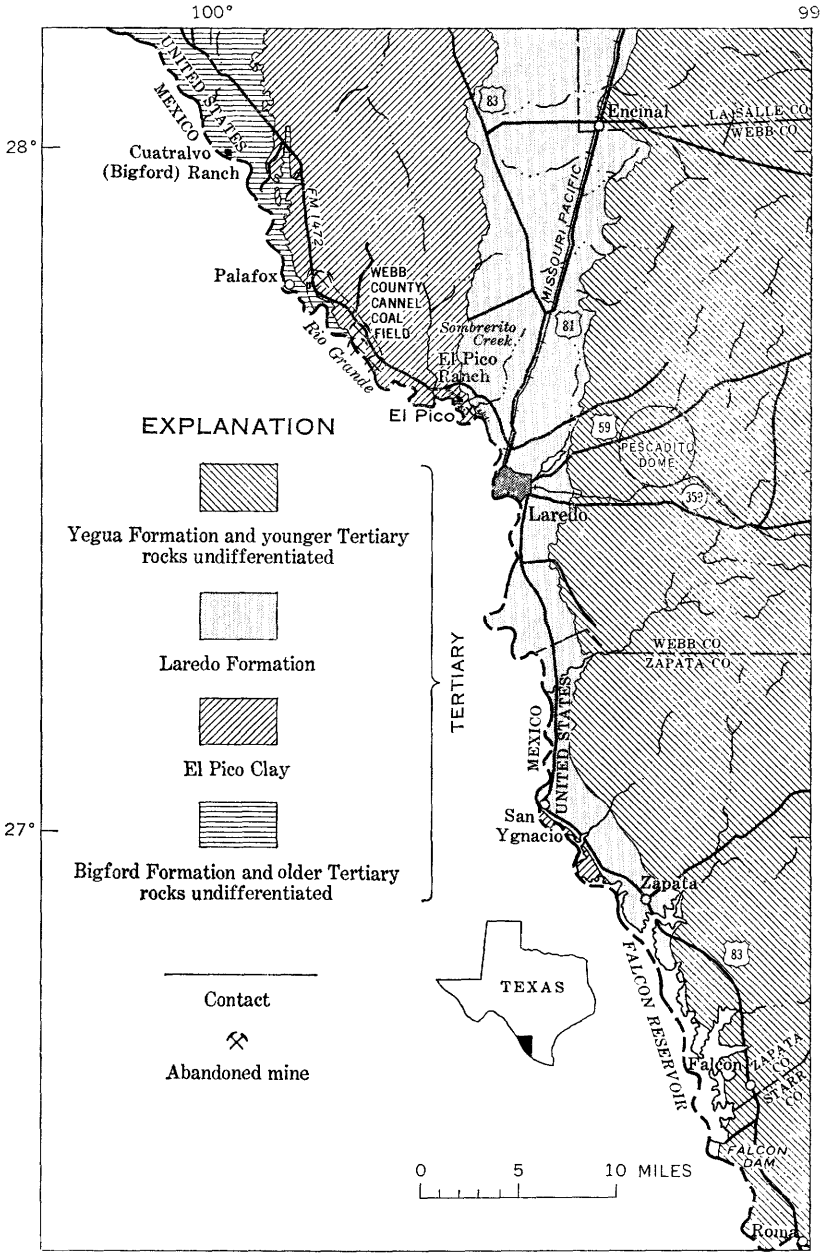

FIGURE 5.—Map showing location of areas studied in the Rio Grande region. Geology modified from Lonsdale and Day (1937), Patterson (1942), and Harris (1965), and by reconnaissance and aerial-photograph interpretation. Rocks overlying Pescadito dome are, in general, older than the surrounding Yegua Formation.

basin the thickness of the El Pico Clay ranges from 700 (Turner and others, 1960) to 900 feet (Alexander and others, 1964).

The El Pico Clay is not well exposed northward from the breaks of the Rio Grande; streams have not deeply dissected the land, and gentle slopes have developed on the clay. A few sections have been recorded from this region, generally measured on flanks of ridges held up by sandstone ledges. The formation crops out along a broad north-trending belt across the Nueces and Frio River valleys, then curves eastward to the east edge of the Rio Grande embayment; there, it merges with the northeast-trending outcrop of the Queen City and Weches.

Along the Rio Grande between Laredo and Palafox (fig. 5) the Santo Tomas coal occurs about 30 feet above the base of the El Pico. The Santo Tomas and the San Pedro (80–90 ft lower, in the Bigford Formation) seams are the principal seams of the once-famous Webb County cannel coal field. Ashley (1918, p. 251) said that this field was "the largest body of cannel coal in the United States if not in the world." He described the Santo Tomas as a low-moisture coal almost as hard as anthracite and highly resistant to weathering; on distillation it yields a much larger proportion of oil (at low temperature) or of gas (at high temperature) than does ordinary bituminous coal. Several large mines operated for many years in the district, but all are now abandoned. No coal of commercial significance has been found north of the Rio Grande region, but some thin beds of coal and lignite and some carbonaceous clays are found in the Nueces River basin.

Section on south slope of El Pico, a small mesa-butte on A. F. Muller's La Bota Ranch, 8½ miles northwest of Laredo, Webb County, Tex.

	Feet
Terrace deposit:	
Gravel cemented with caliche, pebbles as much as 4 in. in diameter, mostly chert, some quartz, quartzite, red porphyry, and hollow siliceous shells that are remnants of partially replaced limestone pebbles	4
Laredo Formation:	
Sandstone, yellowish- to reddish-brown weathering, fine-grained, semi-indurated, medium-thick-bedded, slabby; upper foot is medium gray, highly indurated, glauconitic, calcareous	12
El Pico Clay:	
Sand, light-gray mottled with yellow, very fine grained, soft	6
Sand, silty, shaly, medium-light-gray mottled with yellow and purple	8
Clay, chocolate to pinkish-purple	13
Sand, clayey, yellow-brown to light-gray, soft	17
Sandstone, dark-brown, very fine grained, very ferruginous; weathers platy (exposed in low hills 200 yd southwest of El Pico)	3
Clay, chocolate, laminated, glauconitic; upper part contains conspicuous bands of selenite as much as 1 in. thick	10
Covered slope rising above alluvium of the Rio Grande	10

The upper beds of the El Pico, and especially its contact with the overlying Laredo Formation, are better exposed in the bank of Sombrerito Creek than in the section on the slopes of El Pico.

Section in southwest bank of Sombrerito Creek, eight-tenths of a mile northwest of the confluence of the creek with the Rio Grande, on La Bota Ranch, 8 miles northwest of Laredo, Webb County, Tex.

	Feet
Laredo Formation:	
5. Sandstone, greenish-gray, fine- to medium-grained, moderately indurated, moderately thickly bedded, moderately glauconitic	12±
4. Sand, greenish-gray (weathers light brown), fine-grained, glauconitic; middle 3 ft is gypsiferous chocolate shale	15
El Pico Clay:	
3. Shale, carbonaceous; below 2 ft from top grades downward into sand that is dark gray (weathers pale yellowish brown), fine grained, glauconitic, carbonaceous; sand grades downward into bed 2	6
2. Shale, pale-chocolate to pinkish-brown; upper 2 ft very dark, shaly, easily weathered; grades downward into bed 1	3
1. Sand, shaly, dark- to pinkish-gray; yellow staining along bedding; gypsiferous, carbonaceous, highly glauconitic; grades downward into lighter, less glauconitic, clayey sand	12

The beds in this exposure dip about 2° SE.

The middle part of the formation is excellently exposed on Emilio Garza's El Pico Ranch, 10 miles northwest of Laredo, in high bluffs that rise above the flood plain of the Rio Grande.

Section on El Pico Ranch of Emilio Garza, 10 miles northwest of Laredo, Webb County, Tex.

	Feet
Terrace deposit:	
Gravel cemented with caliche	4
El Pico Clay:	
Sand, shaly, pale-olive to pale-purple, fine-grained, medium- to thin-bedded	14
Sandstone, gray, fine-grained, semi-indurated, thick-bedded, sparsely glauconitic; conspicuous sand-filled cracks ½ in. wide, irregularly distributed	4
Sand, shaly, pale-olive-gray	4
Sand, yellow-olive-gray, fine- to medium-grained, semi-indurated, irregularly crossbedded to massive; interbedded with softer beds; glauconitic; has conspicuous vertical sand-filled cracks or joints	17
Sand, yellow-olive-weathering, fine-grained, soft (a 1-ft bed near base is semi-indurated), massive, glauconitic	11
Shale, silty, pale-chocolate; upper part interbedded with fine sand	22
Sand, shaly, light-gray with yellow staining, fine- to medium-grained ferruginous; polygonal pattern of vertical joints	4
Shale, silty and fine sandy; gray with ferruginous staining; glauconitic	6
Sand, gray to pale-olive, fine- to medium-grained, massive to irregularly bedded; upper 5 ft contains oysters; a zone of calcareous concretions, as much as 2½ ft in diameter, 14 ft from top; holds up low bench in main and tributary valleys; extends to Rio Grande flood plain	28

The formation lies conformably on a conspicuous fossil-bearing sandstone, the uppermost bed of the Bigford Formation, that is well exposed in bluffs above the historic site of Palafox on the Rio Grande, 30 miles northwest of Laredo (Lonsdale and Day, 1937, p. 20).

Logs and cores from wells drilled not far downdip from the outcrop, where complete sections of the El Pico have been penetrated, show the nature of the formation near the outcrop.

In the Laredo Water Works well 1, drilled in the west-central part of the city, 915 feet of mostly clayey beds (from about 215 to 1,130 ft in depth) can be assigned to the El Pico Clay (fig. 6). Beds of sand from about 575 to 610 feet in depth stand out prominently on the log. Perhaps this sand zone is the one that can be traced for a long distance on the surface; it forms a ridge above the surrounding clayey terrain across Webb County and is conspicuous on aerial photographs. A similar light-gray sand is found at about 500 feet in depth near the middle of the El Pico Clay section in the San Ygnacio School well of the International Boundary and Water Commission (fig. 6).

Several exposures of the El Pico Clay have been found on the United States side of the Rio Grande as much as 40 miles southeast of Laredo, several miles south of San Ygnacio (or San Ignacio). A core from the International Boundary and Water Commission's San Ygnacio School well, stored at the Well Sample Library of the Bureau of Economic Geology of The University of Texas at Austin, includes a representative section of the El Pico (fig. 6). The core extends from 387 to 1,749 feet in depth, and is continuous except for several short sections represented only by cuttings. From its top to 1,057 feet (top of the Bigford) the core shows that the unweathered El Pico is a somewhat calcareous smooth light-gray to light-greenish-gray claystone, in part mottled with grayish red, interbedded with gray sandstones that contain biotite and generally abundant plant fossils. A light-gray sand just below the 500-foot depth may correlate with both the bed of similar lithology in the middle of the El Pico in the Laredo well and the bed that forms a conspicuous cuesta on the outcrop. Thin coal beds from a few inches to about a foot thick are found in several places in the core; the thicker ones are in the middle of the El Pico section.

SPARTA SAND AND COOK MOUNTAIN FORMATION

The Sparta Sand extends westward from its type locality in Louisiana as a continuous band of sandy outcrop south of the Sabine uplift. It also caps numerous outliers of resistant ferruginuos rocks of the Weches Formation north and west of the uplift. It is thicker in eastern Texas than it is to the southwest. In east-central Texas the Sparta probably ranges in thickness from 210 to 330 feet (Stenzel, 1938);

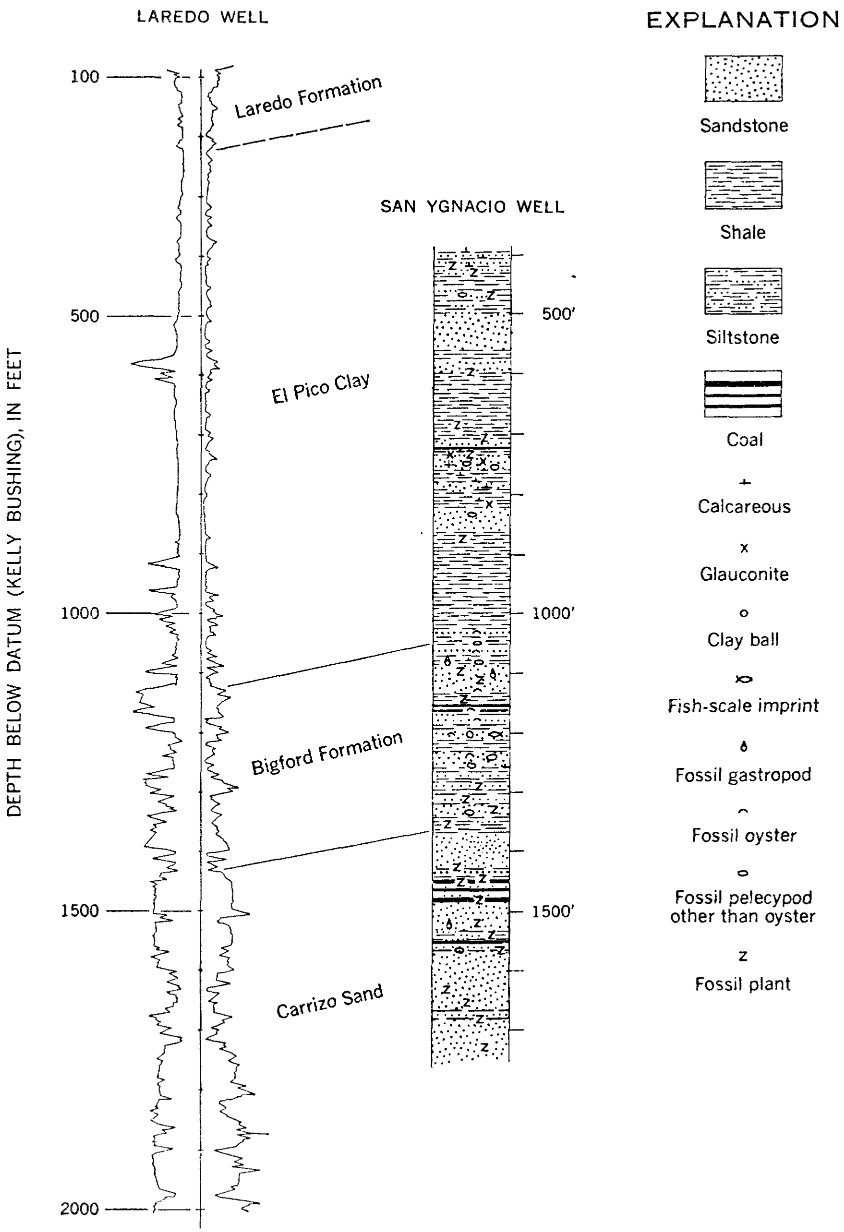

FIGURE 6.—Comparison of the electric log of the Laredo Water Works well 1 with the core log of the International Boundary and Water Commission's San Ygnacio School well, 35 miles south of Laredo.

in the Poth Water well (fig. 3) in south-central Texas it is 90 feet thick. On electric logs of updip subsurface wells the Sparta is one of the most easily recognizable units of the Claiborne. It is a relatively thin zone of high resistivity and self potential bounded by thick zones of low resistivity and self potential, the Weches below and the Cook Mountain above. Downdip about 30-40 miles from the outcrop the Sparta is a fine-grained sediment indistinguishable from the beds above and below.

Plummer (1932, p. 654) considered that the Sparta represents a period that began with the regression of the shoreline of the Weches sea and ended with the transgression of the shoreline of the Cook Mountain sea. Its middle sands, he believed, are flutiatile sediments spread out over a flat terrain. The movements represented by the Sparta Sand probably took place in a relatively short time span.

The Cook Mountain Formation, overlying the Sparta conformably, consists chiefly of marine clays with a few beds of fine sand. The formation has been divided by some authors into several members in eastern Texas, but these members have mostly local significance. In eastern and central Texas the formation ranges in thickness from 125 to 450 feet (Plummer, 1932, p. 658). In south-central Texas, in the Poth Water well (fig. 3), it is 385 feet thick, and it thickens downdip. The downdip thickening of the Cook Mountain, as well as that of the other marine clayey formations, is due in part to the increasing thickness of the prism of sediments toward the Gulf of Mexico, and in part to the changing of facies from sand to clay similar to the formations above and below. Thus, the clayey formations increase in thickness at the expense of the sands separating them.

Southwest of the Atascosa River, sands appear in the Cook Mountain, intertonguing with the clays, and the formation becomes less distinguishable from the Sparta Sand below and the Yegua Formation above. In the Nueces River valley the Sparta and Cook Mountain merge southward into the Laredo Formation.

LAREDO FORMATION

Gardner (1938) gave the name Laredo to the formation in the Rio Grande embayment described previously by Deussen (1924), Trowbridge (1923, 1932), and Lonsdale and Day (1937) as the Cook Mountain Formation, and shown by Darton, Stephenson, and Gardner (1937) with the Cook Mountain and Sparta undifferentiated. In describing it, Gardner pointed out that in the embayment the middle Eocene formations differ in lithologic composition and faunal assemblage from those of central and eastern Texas. More than half of the Laredo consists of sandstones, whereas to the northeast the

Cook Mountain is chiefly clay. Patterson (1942) showed that along the Rio Grande, downstream from Laredo, the section that has been called Cook Mountain consists of three units—thick sandstone members at top and bottom separated by a shale member. Kane and Gierhart (1935) described in some detail the excellent exposures that can be found along the Rio Grande for a distance of about 80 miles where the river, flowing nearly parallel to the strike, crosses and recrosses much of the formation. They stated that the formation constitutes the most fossiliferous part of the Eocene, and that its prominent cuestas of red and brown ferruginous sandstones and red-weathering glauconitic sands, separated by valleys of orange-yellow-weathering clays, make it one of the brightest in color and easiest to identify of all the Eocene formations.

Many exposures of the Laredo Formation along the Rio Grande were recorded by Trowbridge (1932, p. 104–129) and by Lonsdale and Day (1937, p. 42–55). Lonsdale and Day, especially, detailed the sections along the river and listed the fossils. Their composite section of the Laredo (Cook Mountain and Sparta equivalents) shows the formation to be about 620 feet thick in the Laredo area and to range in thickness from 600 to 700 feet in the Nueces River valley.

YEGUA FORMATION

The band of outcrop of the Yegua Formation traverses the entire Gulf Coastal Plain of Texas from the Sabine River to the vicinity of Falcon Dam on the Rio Grande. In about the eastern two-thirds of the State the Yegua is composed principally of sands, with some interbedded clays, thin lignites, and silts of nonmarine origin. In southern Texas it is chiefly clay, with minor beds of sandstone, some thin beds of concretionary limestone, and lenses rich in oyster shells. Much debate has taken place in past years on the boundaries of the outcropping Yegua. Stenzel (1939), in his definitive discussion of the "Yegua Problem," concluded from lithologic and paleontologic evidence that its lower boundary in central Texas is the base of a thick nonmarine sand at the plane of contact with the uppermost marine clay of his Crockett (Cook Mountain) Formation. Most geologists place the subsurface contact in a corresponding position, at the top of the uppermost glauconitic marine clay. Downdip, the basal sands give way to clays, and the contact "moves up" in the section.

Along the Rio Grande, where the Yegua is best known in southern Texas, the basal part of the formation is chiefly clay that lies on highly glauconitic sands of the Laredo (Cook Mountain of Trowbridge, 1932, p. 131, and of Lonsdale and Day, 1937, p. 55). Kane and Gierhart (1935) place two oyster beds, each underlying a ridge-forming sandstone near the Rio Grande both in Mexico and the United States, in the Yegua, but Stenzel (1940, p. 850) believes that it has yet to be proved conclusively that these highly fossiliferous beds do not belong to the underlying Laredo (Cook Mountain).

The upper boundary of the sandy Yegua Formation in eastern and central Texas is placed at the disconformity above which lie sediments reworked by the transgressing Jackson sea (Stenzel, 1940). Locally, where some beds of the upper part of the Yegua are of brackish-marine origin, it is difficult to map the contact. In south-central Texas the upper part of the Yegua contains red-weathering glauconitic sands that are probably bay or lagoonal deposits; the glauconite is of a pale-amber variety, indicating a possible brackish-water origin. The overlying Caddell Formation of the Jackson Group consists of neritic-shelf or open-marine deposits with basal beds locally containing fossiliferous concretions and large abraded oyster shells and rounded boulders, obviously eroded by wave action. Where materials such as these can be found, there is little question about the contact; but generally the Caddell contains volcanic materials, such as ash or bentonitic clay, and these materials, abundant in southern Texas, are indicative of the Jackson.

In southern Texas, however, the location of the contact between the Yegua and Jackson has been disputed. Lonsdale and Day (1937, p. 55) thought that Trowbridge included clays of the lower part of the Jackson with his Yegua; they placed the contact much lower and limited the Yegua to a much narrower outcrop band than did Trowbridge. In Webb County, Lonsdale and Day placed the contact at the base of the lowermost bed of white volcanic ash. The ash is lenticular and grades laterally into ashy sandstone, sandstone, and clay along a slight but distinct escarpment. A silicified tuff exposed south of the Rio Grande and containing an oyster-and-gastropod fauna was placed by Kane and Gierhart (1935, p. 604, 605) in the upper part of the Yegua. This tuff may be the same prominent one that Lonsdale and Day considered the part of the basal Jackson.

A lenticular bed of similar nature, altered volcanic ash, is found in an identical stratigraphic position north of the Frio River in McMullen County. The writer extended its correlation to the Caddell Formation, in the basal part of the Jackson Group, in adjoining counties to the northeast and into the subsurface downdip. The assignment of this bed and its associated beds of sandstone and bentonite to the Jackson Group moves the Yegua-Jackson contact nearly 10 miles to the northwest of the contact shown on the "Geologic Map of Texas" (Darton and others, 1937). The boundary shown on that map is, in the Frio River country, the base of the Whitsett Formation, near the middle of the Jackson Group. Thus, the outcrop band of the Yegua has been narrowed along the Frio and Atascosa Rivers to about the same extent as was done by Lonsdale and Day in the Rio Grande region.

The properties of this bed of indurated tuff north of the Frio River have been investigated for economic purposes by King (1940, p. 143–146), who considered it Yegua. Because it is dense, hard, brittle, and white, and has a conchoidal fracture, King called it kaolin, with some uncertainty; but A. D. Weeks (written commun., 1965) found by X-ray analysis that samples from several locations consist of more than 50 percent zeolite of the variety clinoptilolite, with subsidiary amounts of opal and montmorillonite. Further, the percentage of zeolite in samples increased from northeast to southwest, and the percentages of montmorillonite and opal decreased from northeast to southwest. The firmness and resistance of this bed to weathering make it a good marker for the base of the Jackson in this region of sparse outcrops.

LITERATURE CITED

Alexander, W. H., Jr., Myers, B. N., and Dale, O. C., 1964, Reconnaissance investigation of the ground-water resources of the Guadalupe, San Antonio, and Nueces River basins, Texas: Texas Water Comm. Bull. 6409, 106 p.

Anders, R. B., 1957, Ground-water geology of Wilson County, Texas: Texas Board Water Engineers Bull. 5710, 62 p.

Ashley, G. H., 1918, The Santo Tomas cannel coal, Webb County, Texas: U.S. Geol. Survey Bull. 691–I, p. 251–270 [1919].

Barnes, V. E., Proj. Director, 1966, Geologic atlas of Texas, Texarkana sheet: Texas Univ. Bur. Econ. Geology.

Berry, E. W., 1923, Additions to the flora of the Wilcox group: U.S. Geol. Survey Prof. Paper 131–A, p. 1–22.

Darton, N. H., Stephenson, L. W., and Gardner, J. A., 1937, Geologic map of Texas: U.S. Geol. Survey.

Deussen, Alexander, 1924, Geology of the Coastal Plain of Texas west of the Brazos River: U.S. Geol. Survey Prof. Paper 126, 139 p.

Ellisor, A. C., 1929, Correlation of the Claiborne of East Texas with the Claiborne of Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 10, p. 1335–1346.

Gardner, J. A., 1938, Laredo, a new name for a unit of Cook Mountain age in the Rio Grande region: Washington Acad. Sci. Jour., v. 28, no. 7, p. 297–298.

Getzendaner, F. M., 1930, Geologic section of Rio Grande embayment, Texas, and implied history: Am. Assoc. Petroleum Geologists Bull., v. 14, no. 11, p. 1425–1437.

Hargis, R. N., 1962, Stratigraphy of the Carrizo-Wilcox of a portion of south Texas and its relationship to production, *in* Stapp, W. L., ed., Contributions to the geology of south Texas: San Antonio, South Texas Geol. Soc., p. 129–145.

Harris, H. B., 1965, Ground-water resources of La Salle and McMullen Counties, Texas: Texas Water Comm. Bull. 6520, 96 p.

Kane, W. G., and Gierhart, G. B., 1935, Areal geology of Eocene in northeastern Mexico: Am. Assoc. Petroleum Geologists Bull., v. 19, no. 9, p. 1357–1388; repr. in Am. Assoc. Petroleum Geologists symposium, Gulf Coast Oil Fields, 1936, p. 588–619.

King, P. B., 1940, Clay deposits of the San Antonio area and Morris County, Texas, *in* Clay investigations in the southern States, 1934–35: U.S. Geol. Survey Bull. 901, p. 93–188.

Lonsdale, J. T., 1935, Geology and ground-water resources of Atascosa and Frio Counties, Texas: U.S. Geol. Survey Water-Supply Paper 676, 90 p.

Lonsdale, J. T., and Day, J. R., 1937, Geology and ground-water resources of Webb County, Texas: U.S. Geol. Survey Water-Supply Paper 778, 104 p.

Moxham, R. M., and Eargle, D. H., 1961, Airborne radioactivity and geologic map, Coastal Plain area, southeast Texas: U.S. Geol. Survey Geophys. Inv. Map GP–198.

Patterson, J. M., 1942, Stratigraphy of Eocene between Laredo and Rio Grande City, Texas: Am. Assoc. Petroleum Geologists Bull., v. 26, no. 2, p. 256–274.

Plummer, F. B., 1932, Cenozoic systems in Texas, *in* The geology of Texas, v. 1, Stratigraphy: Texas Univ. Bull. 3232, p. 519–818 [1933].

Stenzel, H. B., 1938, The geology of Leon County, Texas: Texas Univ. Pub. 3818, 295 p.

——— 1940, The Yegua problem: Texas Univ. Pub. 3945, p. 847–910.

Todd, T. W., and Folk, R. L., 1957, Basal Claiborne of Texas, record of Appalachian tectonism during Eocene: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 11, p. 2545–2566.

Trowbridge, A. C., 1923, Tertiary stratigraphy in the lower Rio Grande region [abs.]: Geol. Soc. America Bull., v. 34, no. 1, p. 75.

——— 1932, Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U.S. Geol. Survey Bull. 837, 260 p.

Turner, S. F., Robinson, T. W., and White, W. N., 1960, Geology and ground-water resources of the Winter Garden district, Texas, 1948: U.S. Geol. Survey Water-Supply Paper 1481, 247 p., revised by D. E. Outlaw, W. O. George, and others, 1960.

Wendlandt, E. A., and Knebel, G. M., 1929, Lower Claiborne of East Texas, with special reference to Mount Sylvan dome and salt movements: Am. Assoc. Petroleum Geologists Bull., v. 13, no. 12, p. 1347–1375.