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GEOLOGICAL SURVEY

STRATIGRAPHIC AND HYDROGEOLOGIC FRAMEWORK
OF PART OF THE COASTAL PLAIN OF TEXAS

By

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STRATIGRAPHIC AND HYDROGEOLOGIC FRAMEWORK
OF PART OF THE COASTAL PLAIN OF TEXAS

By

E. T. Baker, Jr.

ABSTRACT

The subsurface delineation of hydrogeologic units of Miocene and younger age and stratigraphic units of Paleocene to Holocene age establishes an interrelationship of these units Statewide across much of the Coastal Plain of Texas. The 11 dip sections and 1 strike section, which extend from the land surface to 7,600 feet (2,316 meters) below sea level, provide continuity of correlation from the outcrop to the relatively deep subsurface. Sand containing water with less than 3,000 milligrams per liter of dissolved solids, which is shown on the sections, serves as an index of water availability of this quality.

INTRODUCTION

This report has been prepared to illustrate the stratigraphic and hydrogeologic framework of a part of the Coastal Plain of Texas from the Sabine River to the Rio Grande. It is the outgrowth of a project that has as its ultimate objective the construction of a digital ground-water flow model, if feasible or desirable, of at least a part of the Miocene aquifers in the Gulf Coastal Plain of Texas. The model would serve as a tool for planning the development of the ground-water supplies. Work on the project is being done by the U.S. Geological Survey in cooperation with the Texas Water Development Board.

During the course of delineating the Miocene aquifers, which is basic to the design and development of the model, the scope of the study was broadened to include delineations of other hydrogeologic units, as well as delineations of stratigraphic units. As a result, units ranging in age from Paleocene to Holocene were delineated (table 1). A relationship of stratigraphic units to designated hydrogeologic units was thus established Statewide.

Eleven dip sections and one strike section are included in this report. The dip sections are spaced about 50 miles (80 km) apart with the most easterly one being near the Sabine River and the most southerly one being near the Rio Grande. Each dip section is about 100 miles (161 km) long and extends from near the coastline to short distances inland from the outcrop of the oldest Miocene formation--the Catahoula Tuff or Sandstone. The strike section, which is about 500 miles (804 km) long (in three segments), extends from the Sabine River to the Rio Grande and joins the dip sections at common control points. This section is from 50-75 miles (80-121 km) inland from the Gulf of Mexico and is essentially parallel to the coastline. The location of the sections and the Catahoula outcrop are shown on figure 1.

The sections extend from outcrops at the land surface to maximum depths of 7,600 feet (2,316 m) below sea level. Selected faunal occurrences, where known or inferred by correlation from nearby well logs, are included. The extent of sand that contains water having less than 3,000 mg/L (milligrams per liter) of dissolved solids was estimated from the electrical characteristics shown by the logs. This information is included on all of the sections.

Although faulting is common in the Coastal Plain and is complex in some areas, all faults have been omitted from the sections to maintain continuity of the stratigraphic and hydrogeologic boundaries. The disadvantage of such omission is, of course, the representation of an unrealistic and simplistic picture of unbroken strata with uninterrupted boundaries. In reality, many of the faults have not only broken the hydraulic continuity of the strata but more importantly have become barriers to fluid flow or conduits for cross-formational flow. The sections are presented in this report as figures 2-15.

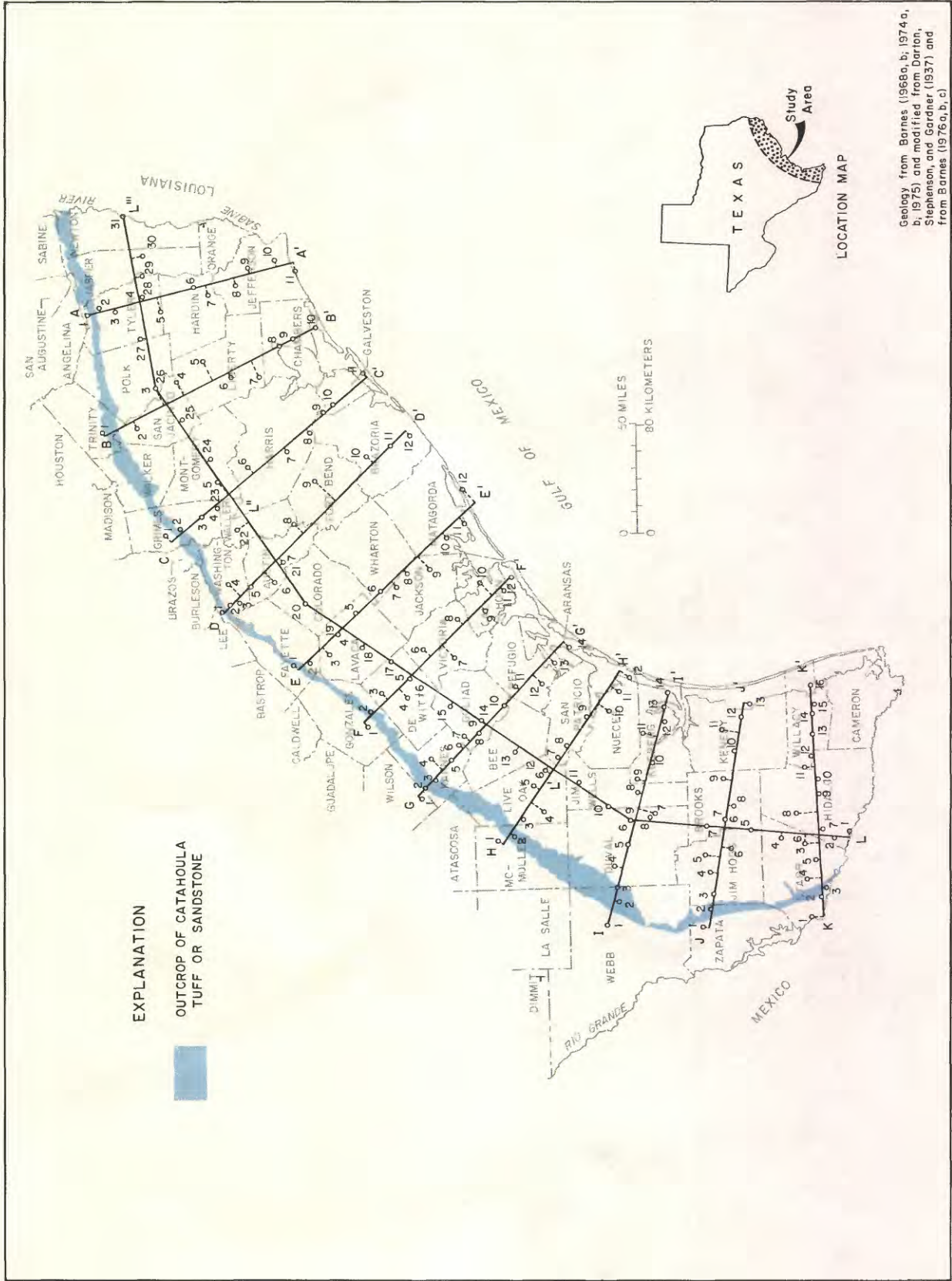


FIGURE 1.-Index map showing location of sections

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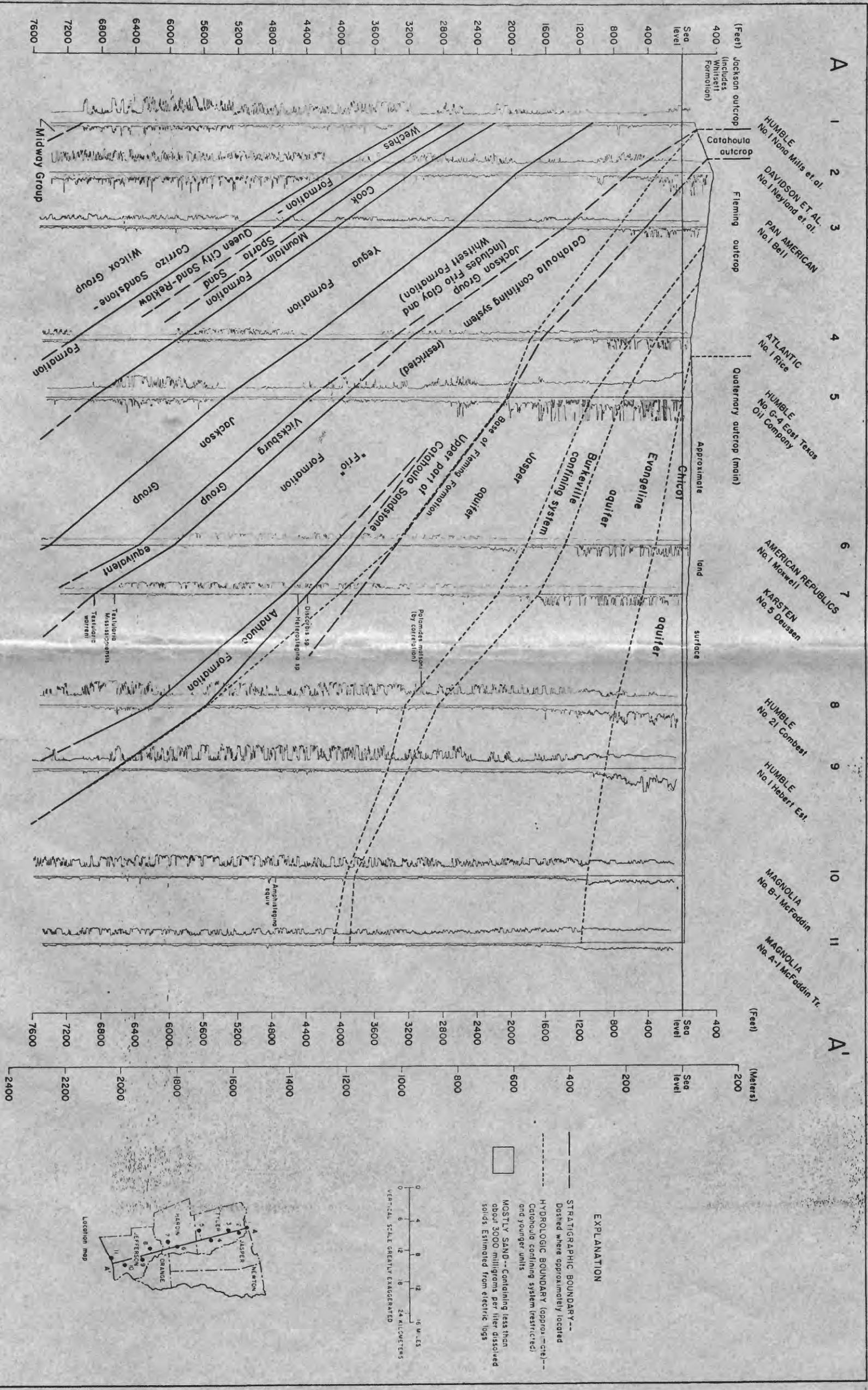


FIGURE 2. Stratigraphic and hydrogeologic section A-A'

Outcrop geology from Barnes (1968a, b)

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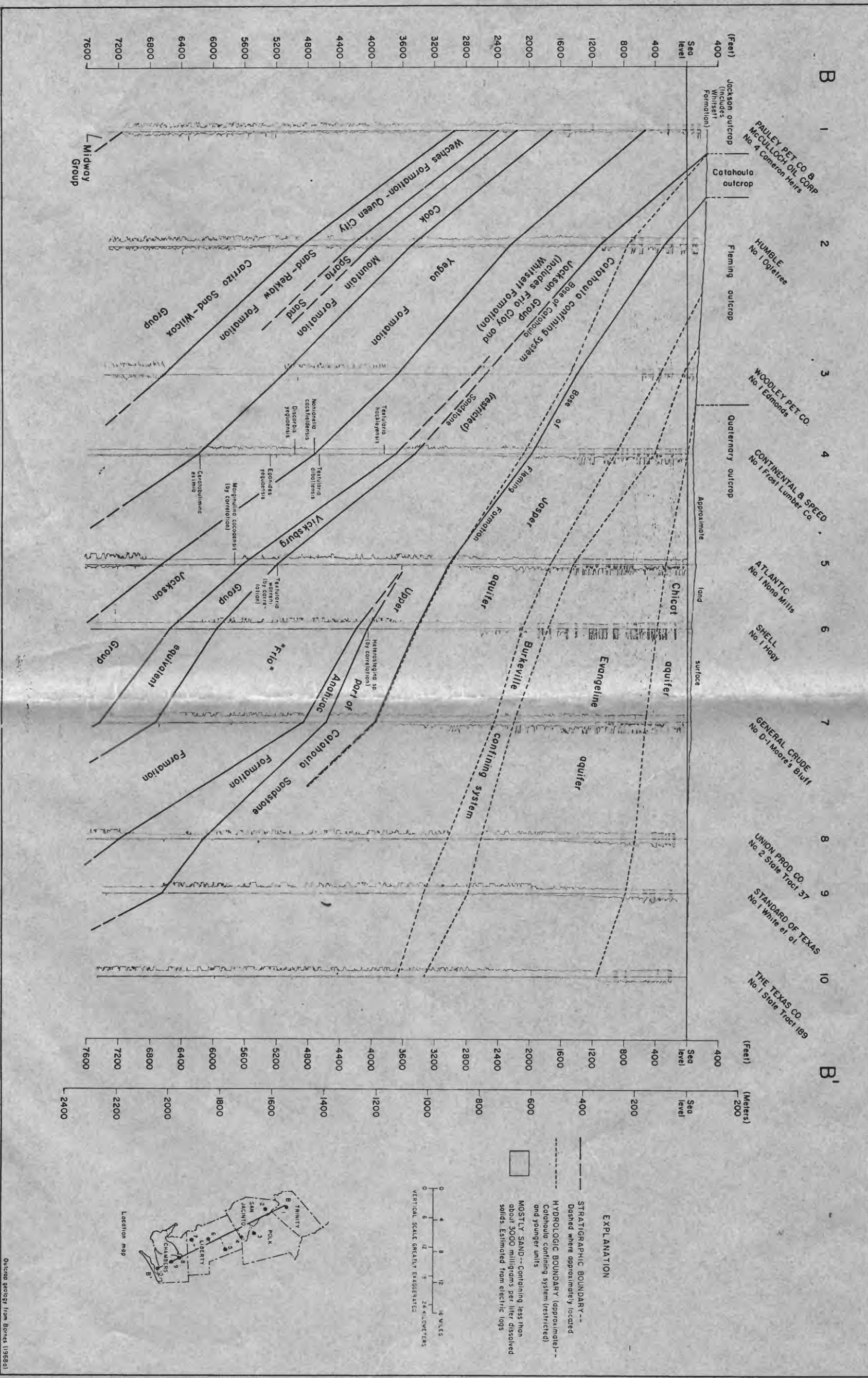


FIGURE 3.-Stratigraphic and hydrogeologic section B-B'

Outline geology from Bonns (1956)

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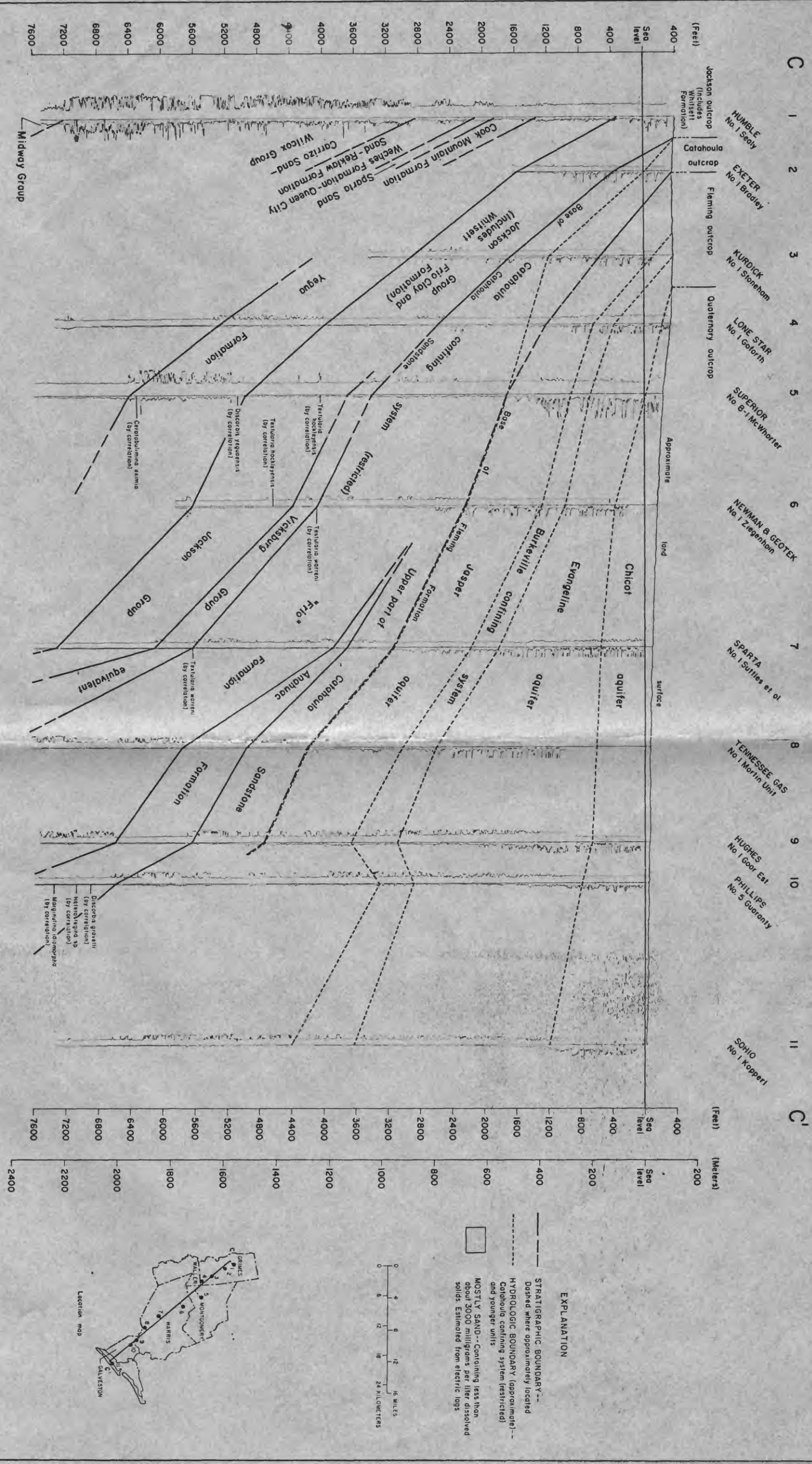


FIGURE 4. Stratigraphic and hydrogeologic section C-C'

Outcrop geology from Dornes (1988a, 1974a)

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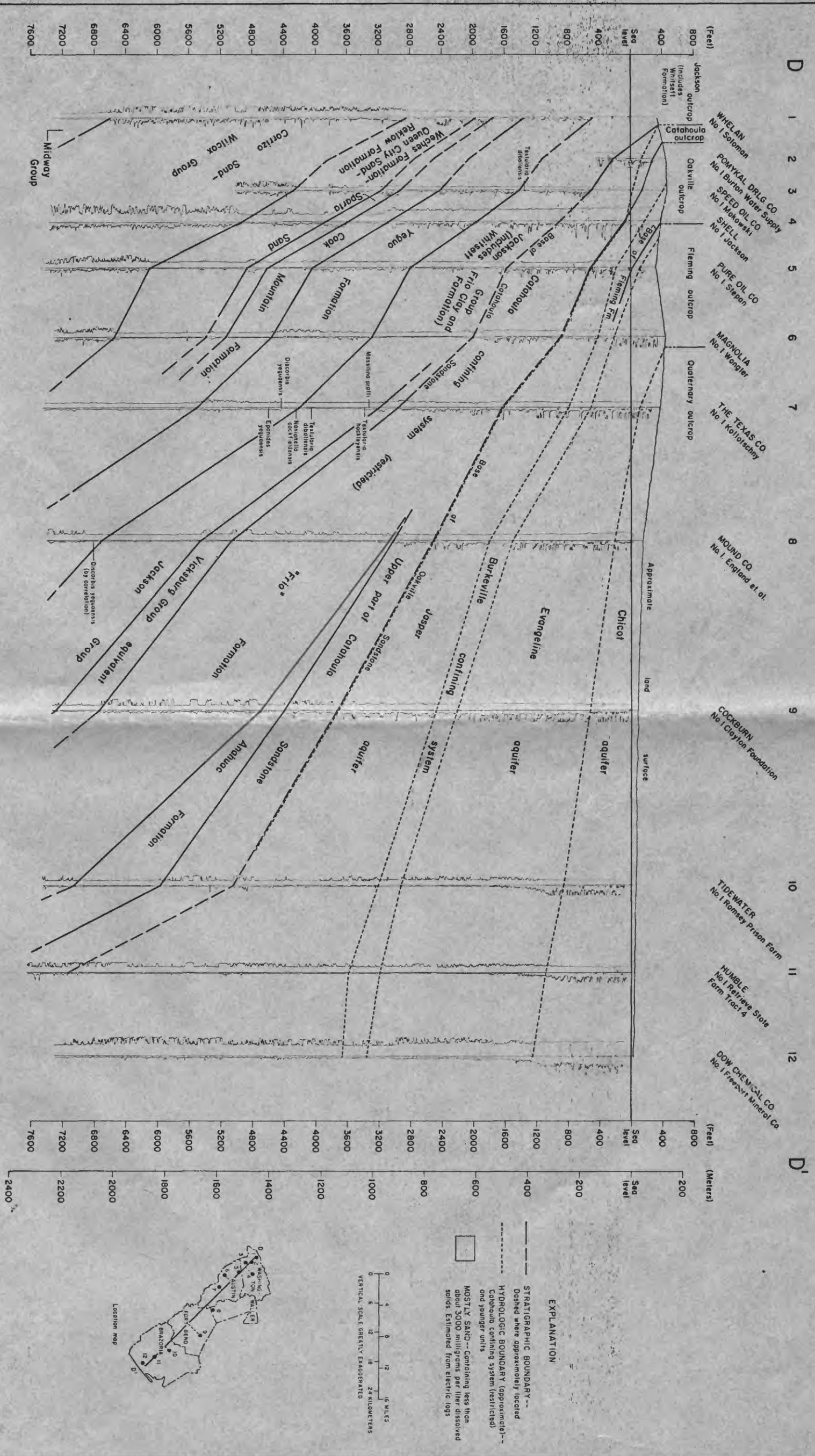


FIGURE 5. Stratigraphic and hydrogeologic section D-D'

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Outcrop geology from Bonnis (1974), (1975)

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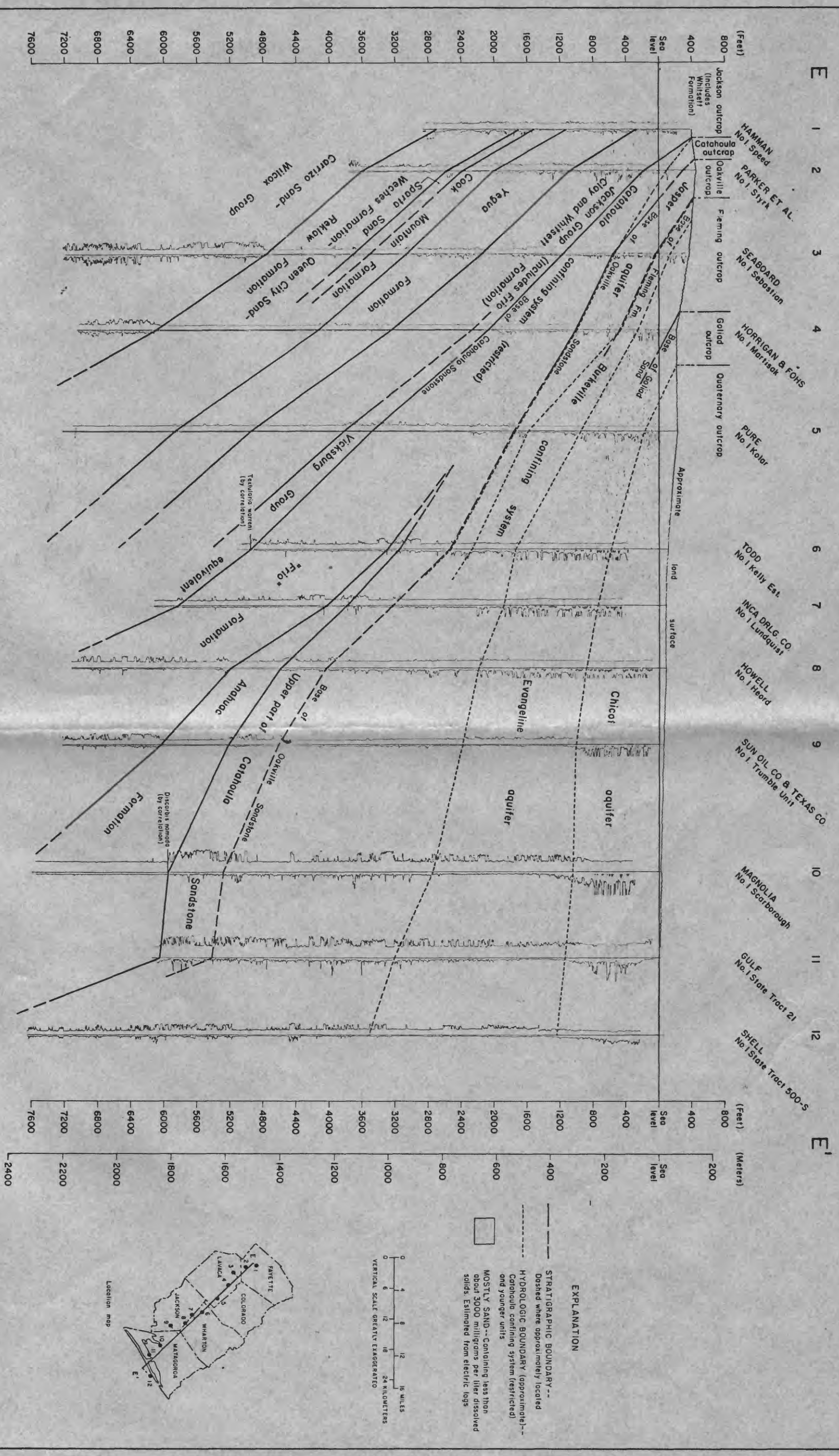


FIGURE 6. Stratigraphic and hydrogeologic section E-E

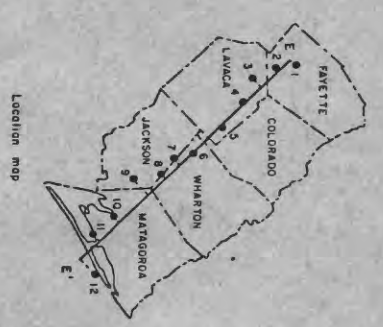
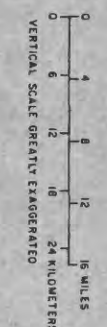
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EXPLANATION

--- STRATIGRAPHIC BOUNDARY --
 Dashed where approximately located

--- HYDROLOGIC BOUNDARY (approximate) ---
 Catchahoula confining system (restricted) and younger units

□ MOSTLY SAND -- Containing less than about 3000 milligrams per liter dissolved solids. Estimated from electric logs



Outcrop geology from Burns (1974b)

77-718

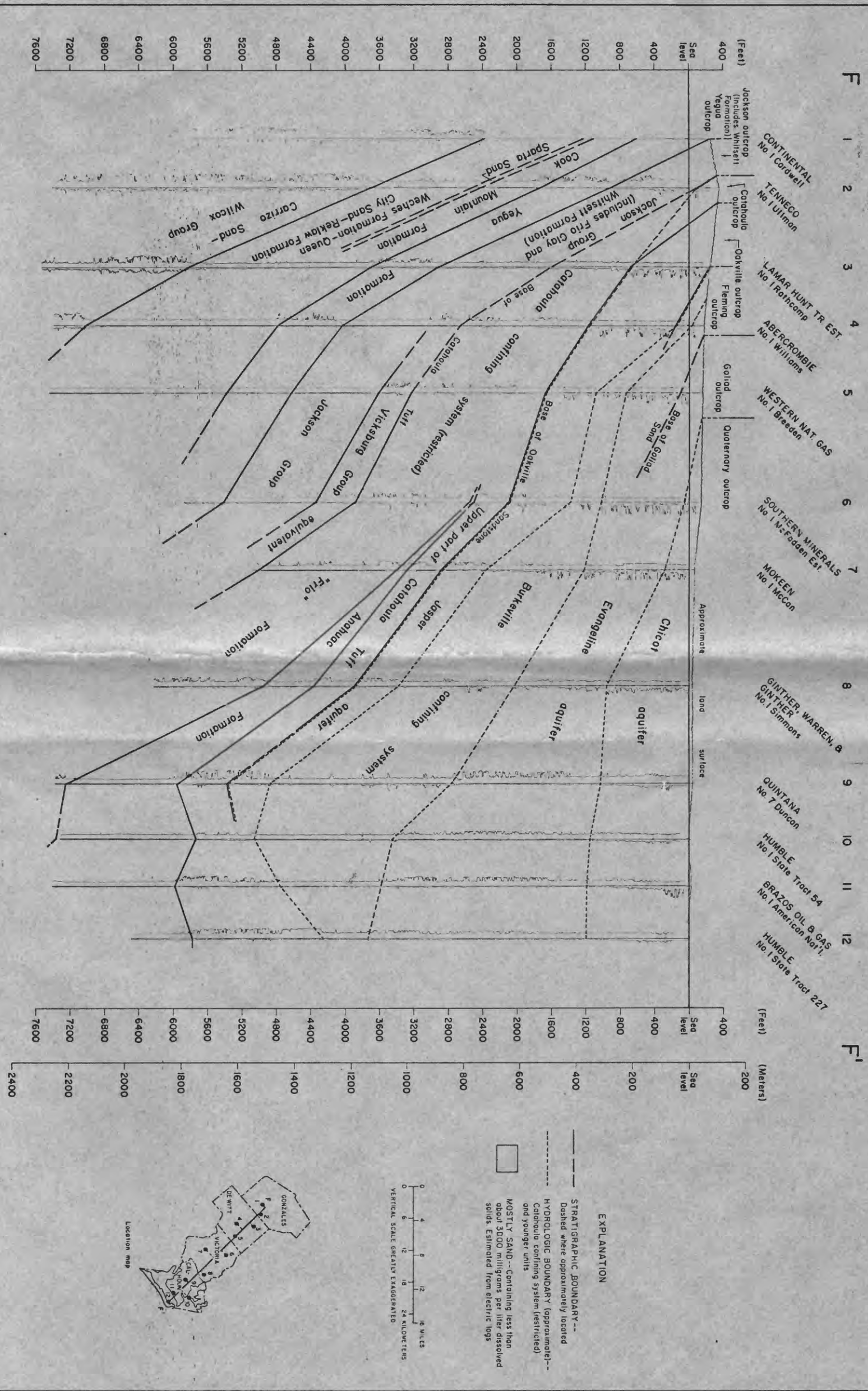


FIGURE 7. Stratigraphic and hydrogeologic section F-F'

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Outcrop geology from Barnes (1974, 1975)

77-7182

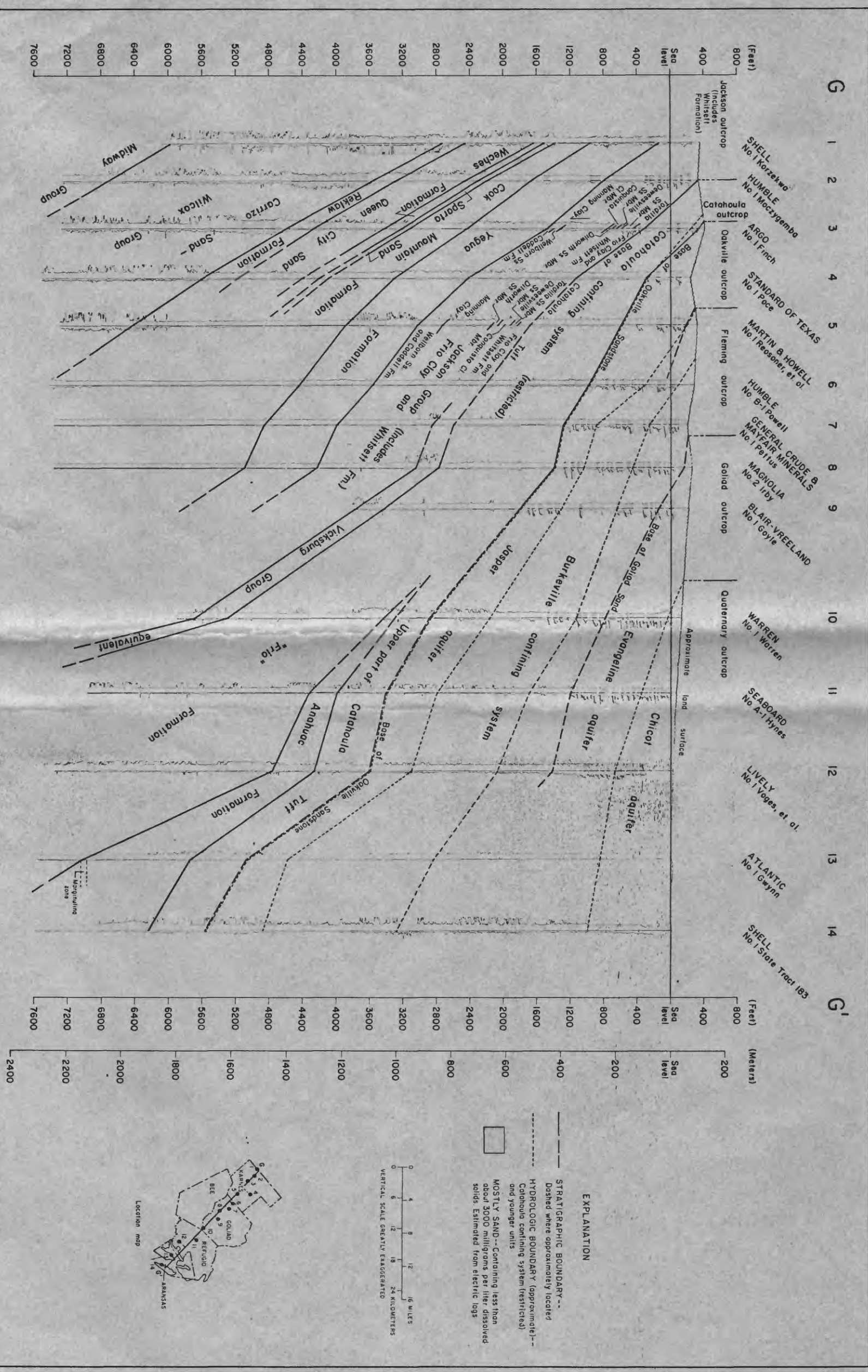


FIGURE 8. Stratigraphic and hydrogeologic section G-G'

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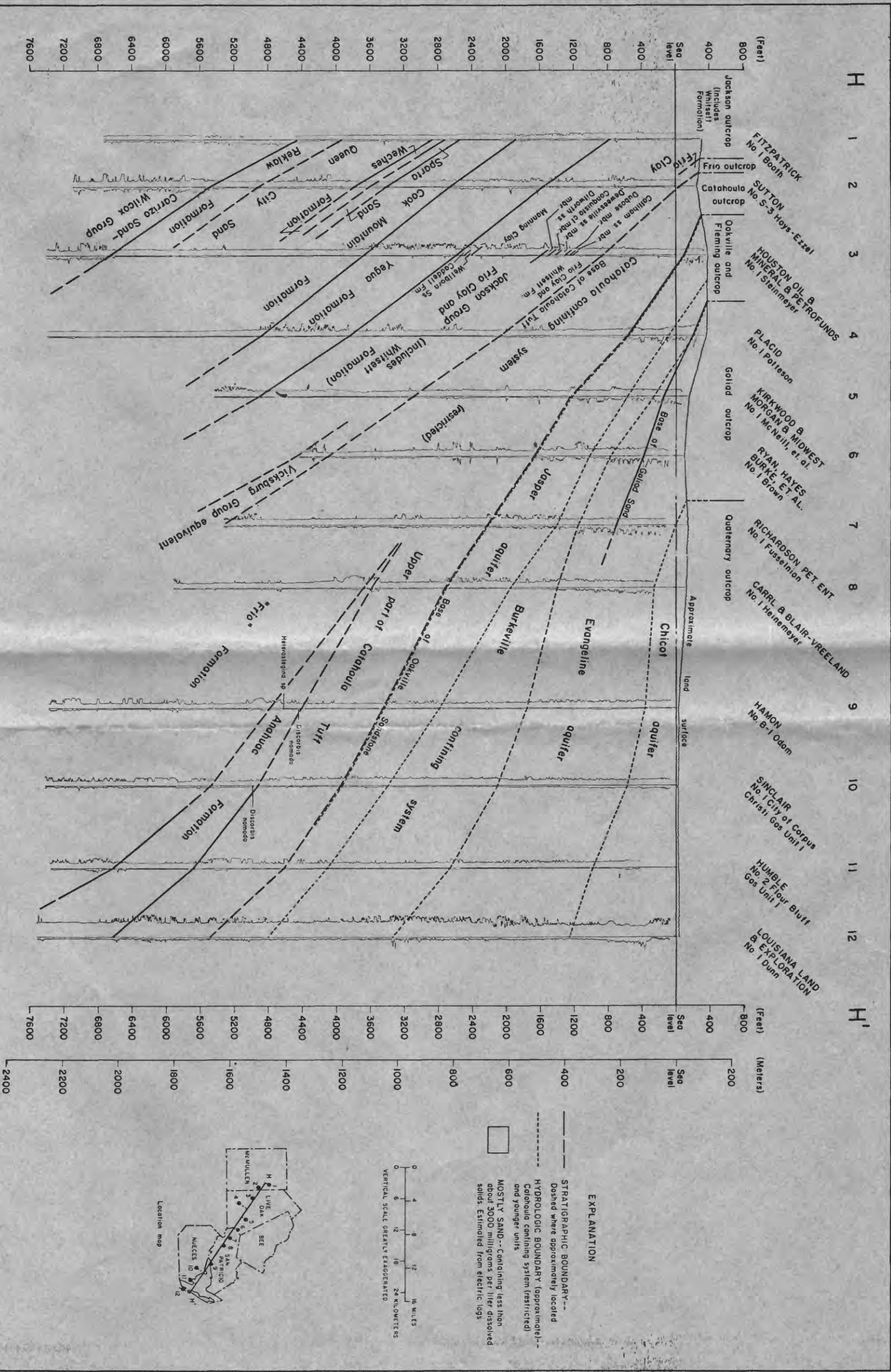
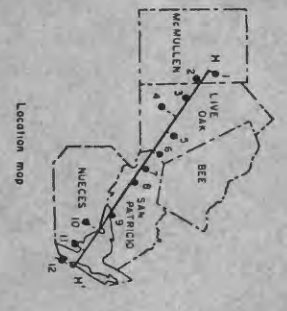


FIGURE 9. Stratigraphic and hydrogeologic section H-H'.

EXPLANATION

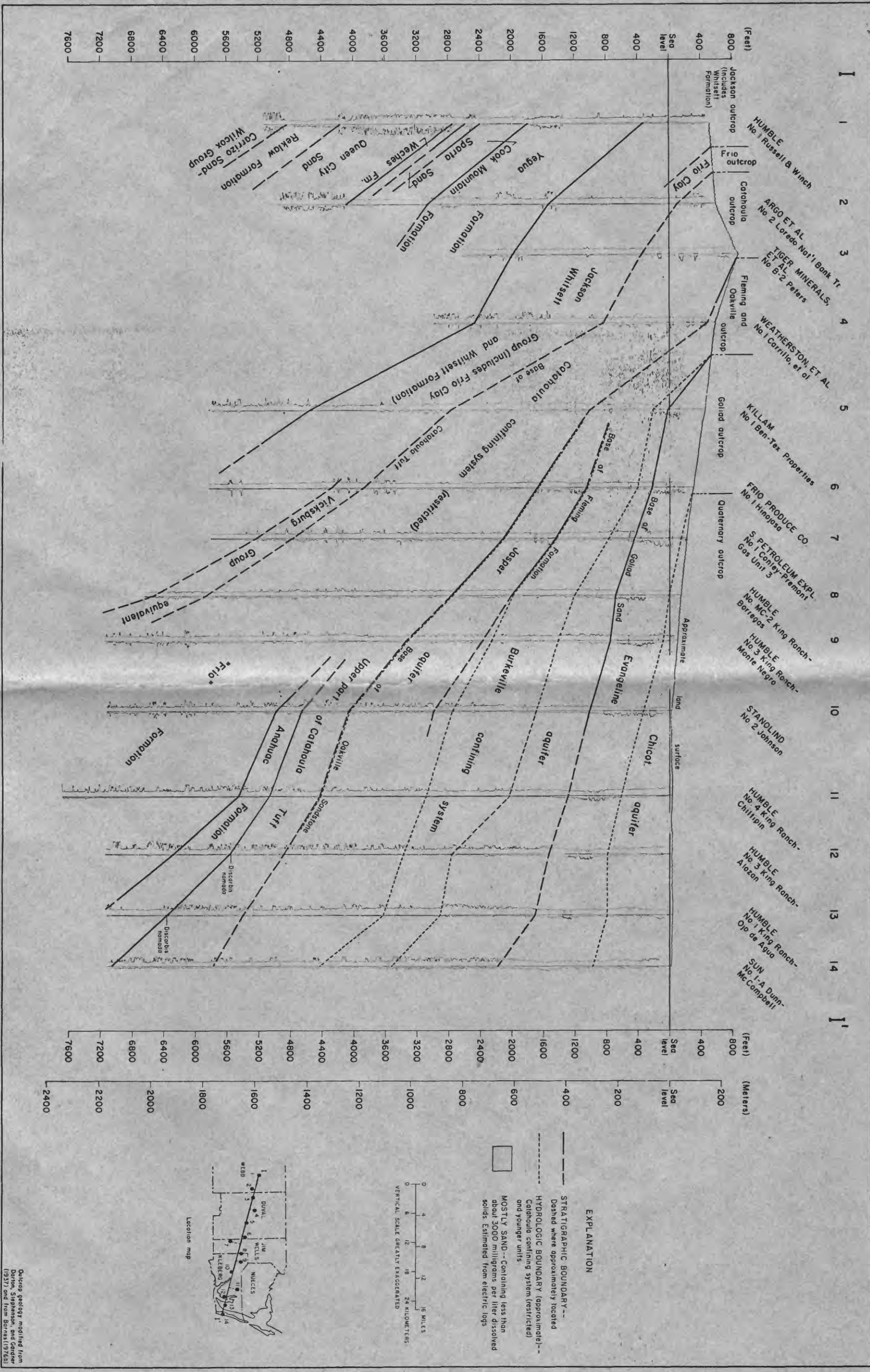
- STRATIGRAPHIC BOUNDARY--
- - - Dashed where approximately located
- HYDROLOGIC BOUNDARY (approximate)--
- - - Colohoula confining system (restricted) and younger units
- MOSTLY SAND--Containing less than about 3000 milligrams per liter dissolved solids. Estimated from electric logs

0 4 8 12 16 MILES
0 4 8 12 16 KILOMETERS
VERTICAL SCALE GREATLY EXAGGERATED



Outcrop geology from Barnes (1975) and modified from Doherty, Thompson, and Conner (1951) and from Barnes (1975).

77-712



(Feet) 800 400 Sea level 400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800 5200 5600 6000 6400 6800 7200 7600

(Meters) 200 400 Sea level 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400

I 1 2 3 4 5 6 7 8 9 10 11 12 13 14 I'

EXPLANATION

STRATIGRAPHIC BOUNDARY--
Dashed where approximately located

HYDROLOGIC BOUNDARY (approximate)--
Calahoula confining system (restricted) and younger units

MOSTLY SAND-- Containing less than about 3000 milligrams per liter dissolved solids. Estimated from electric logs

0 4 8 12 16 MILES
0 4 8 12 16 24 KILOMETERS
VERTICAL SCALE GREATLY EXAGGERATED



Outcrop geology modified from [unclear] (1927) and from Borner (1976)

FIGURE 10. Stratigraphic and hydrogeologic section I-I'

12

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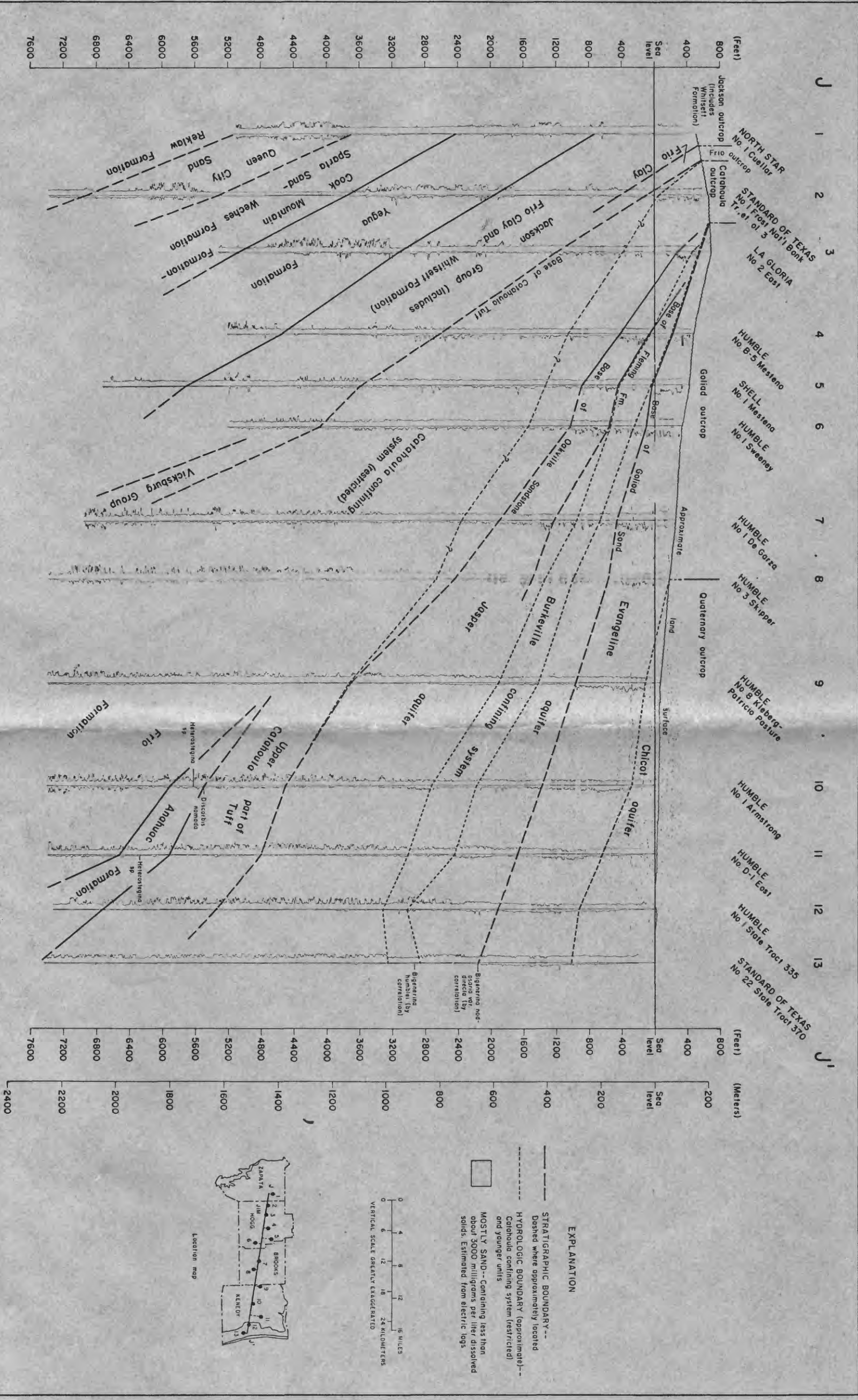


FIGURE 11. Stratigraphic and hydrogeologic section J-J'

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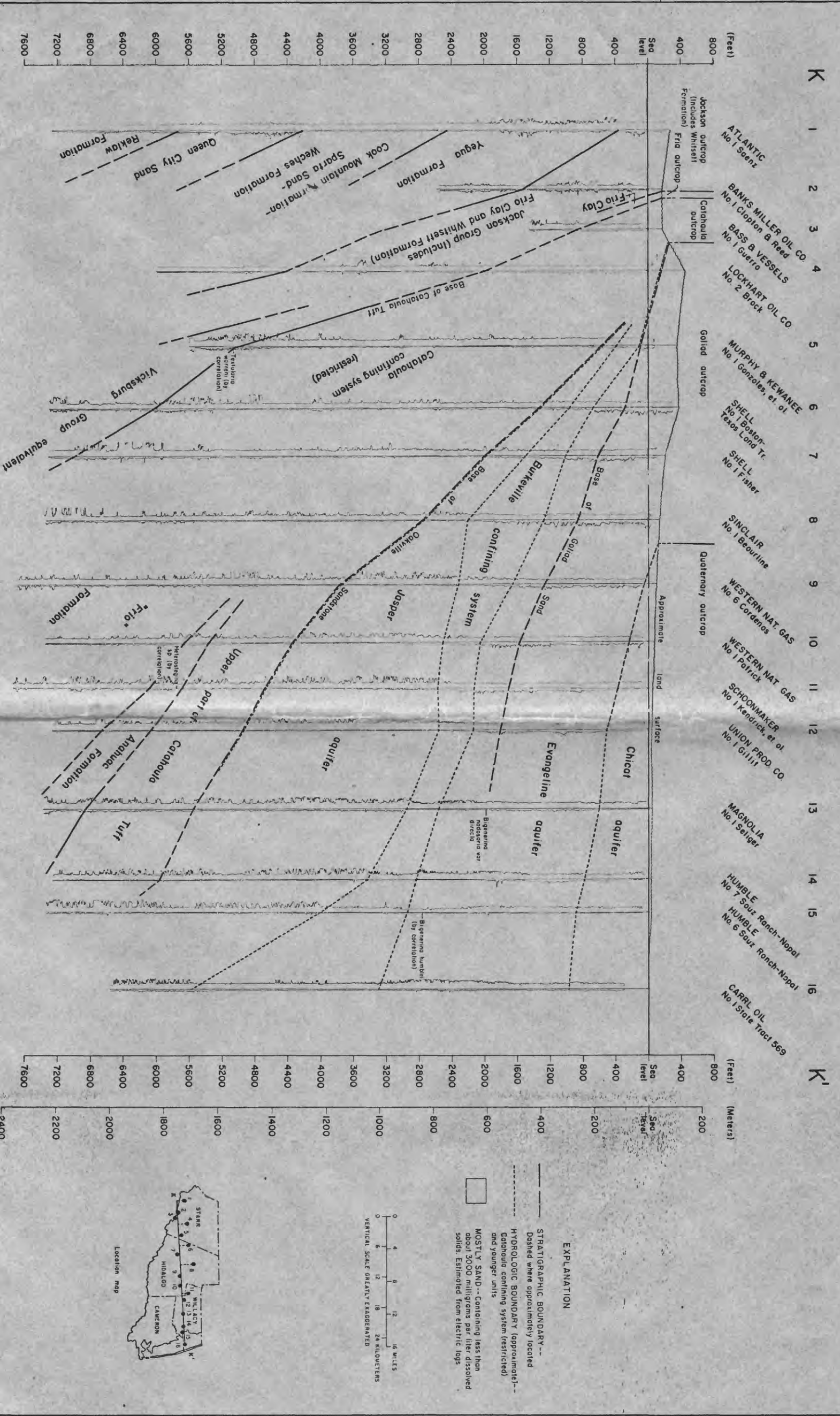


FIGURE 12. Stratigraphic and hydrogeologic section K-K'

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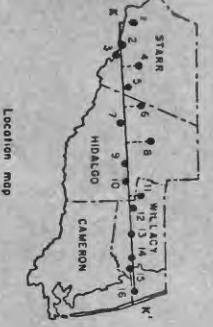
EXPLANATION

STRATIGRAPHIC BOUNDARY--
Dashed where approximately located

HYDROLOGIC BOUNDARY (approximately)--
Catohoula confining system (restricted) and younger units

MOSTLY SAND--Containing less than about 3000 milligrams per liter dissolved solids. Estimated from electric logs

0 4 8 12 16 MILES
0 4 8 12 16 24 KILOMETERS
VERTICAL SCALE ORIGINALLY EXAGGERATED



Outcrop geology modified from Dutton, Shepleton, and Gardner (1937) and from Burns (1935)

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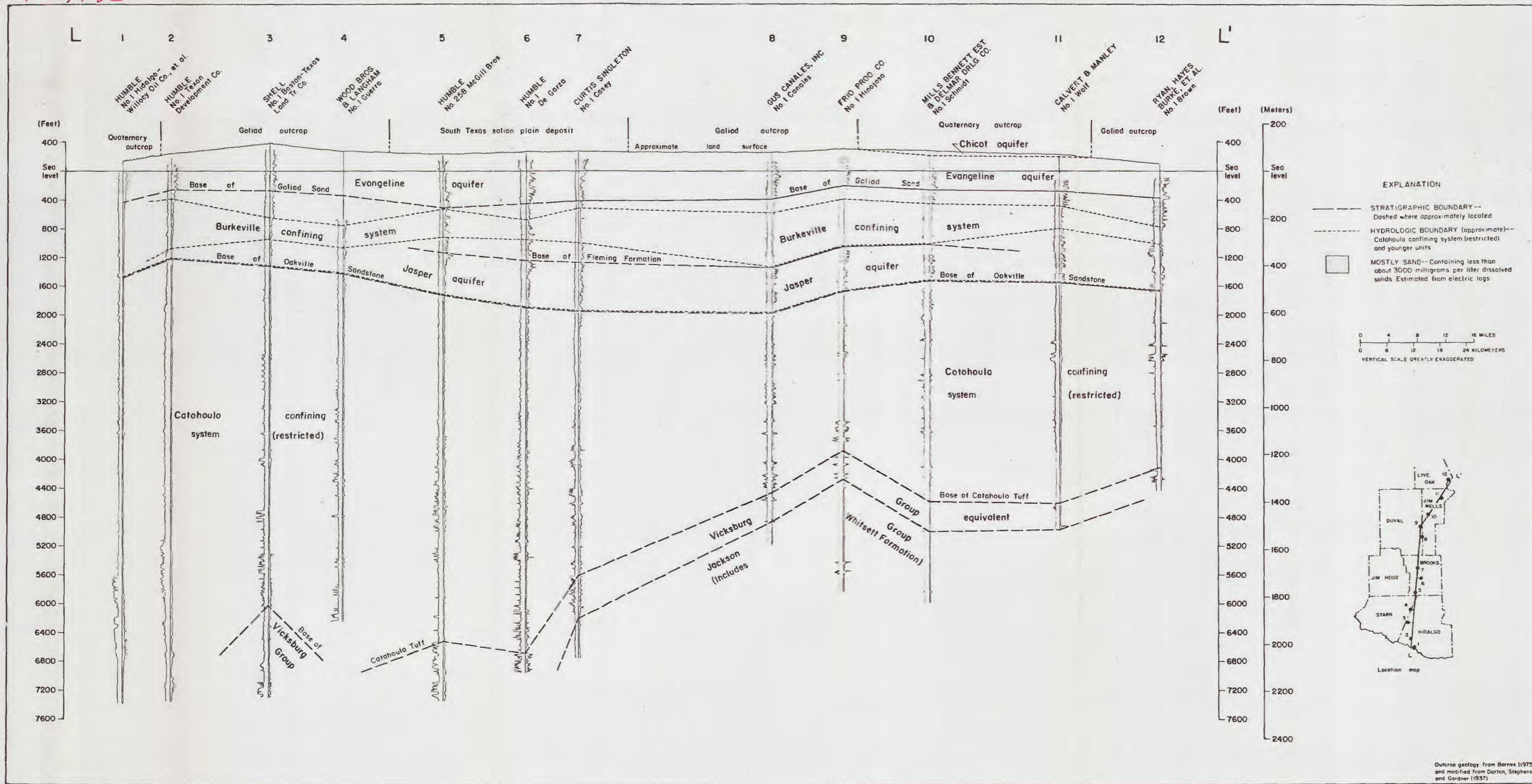


FIGURE 13. Stratigraphic and hydrogeologic section L-L'

Outcrop geology from Barnes (1975) and modified from Darton, Stephenson, and Gardner (1937)

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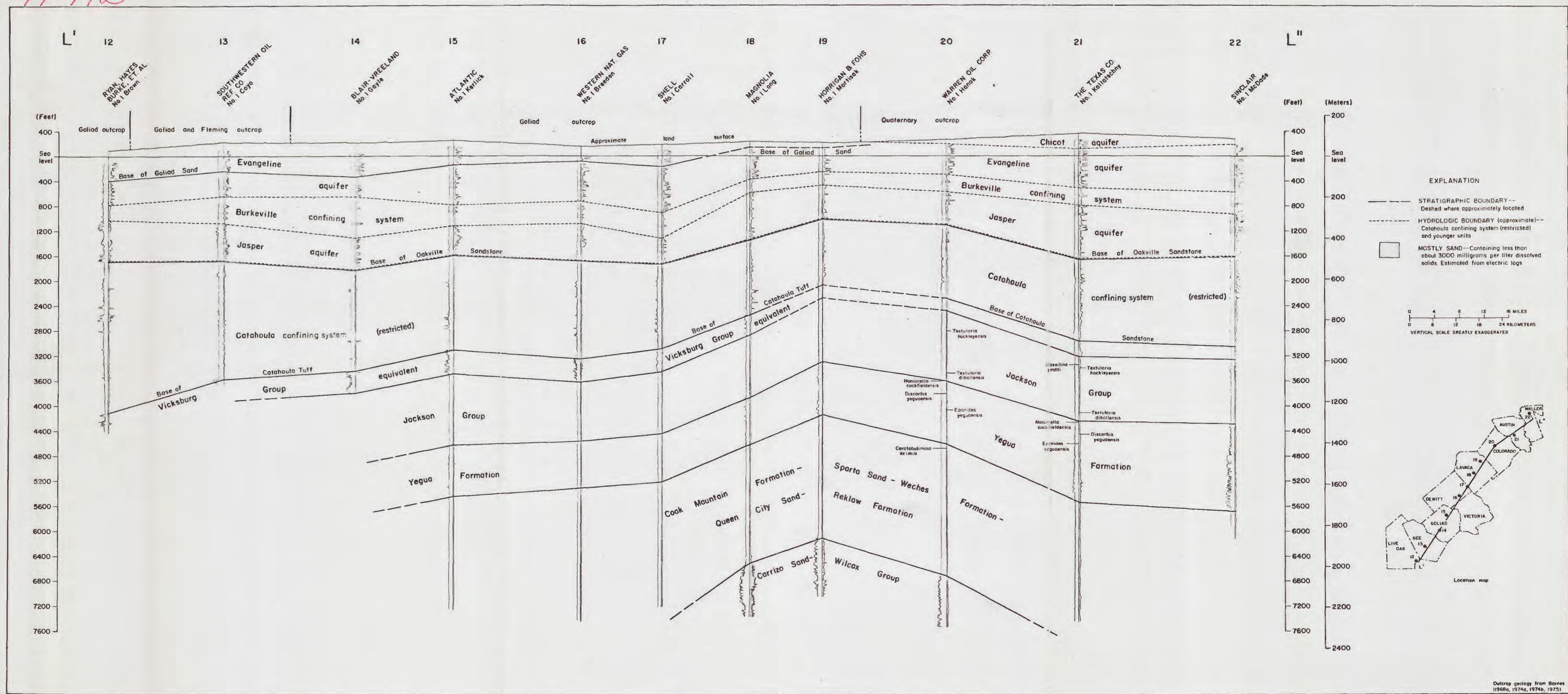


FIGURE 14. Stratigraphic and hydrogeologic section L'-L''

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Outcrop geology from Barnes (1968a, 1974a, 1974b, 1975)

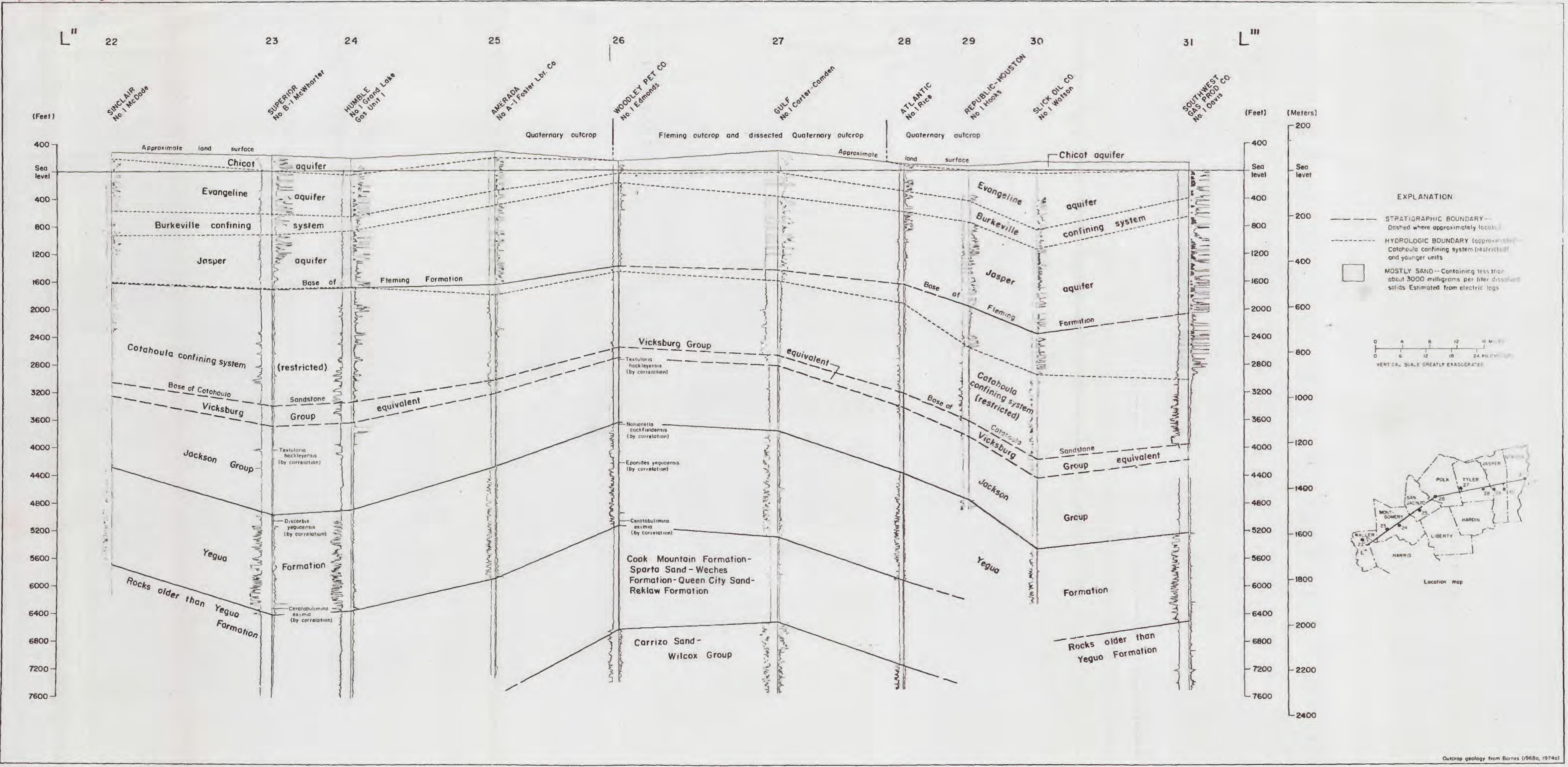


FIGURE 15. Stratigraphic and hydrogeologic section L'-L''

Table 1.--Stratigraphic and Hydrogeologic Framework of Part of the Coastal Plain of Texas

Era	System	Series	Stratigraphic Units	Hydrogeologic Units	Selected Faunal Markers	Remarks
Quaternary	Holocene	Pleistocene	Alluvium	Chicot aquifer		Quaternary System undifferentiated on sections.
			Beaumont Clay			
			Montgomery Formation			
			Bentley Formation Willis Sand			
	Pliocene		Goliad Sand	Evangelina aquifer		Goliad Sand overlapped east of Lavaca County.
			Fleming Formation	Burkeville confining system	<u>Potamides matsoni</u> <u>Bigennerina modosaria var. directa</u> <u>Bigennerina humblei</u> <u>Amphistegina sp.</u>	
	Miocene		Oakville Sandstone	Jasper aquifer		Oakville Sandstone included in Fleming Formation east of Washington County.
			S u b s u r f a c e "Frio" Formation	Catahoula confining system (restricted)	<u>Discorbis nomada</u> <u>Discorbis Gravelli</u> <u>Heterostegina sp.</u> <u>Marginulina idiomorpha</u> <u>Textularia mississippiensis</u>	Catahoula Tuff designated as Catahoula Sandstone east of Lavaca County. Anahuac and "Frio" Formations may be Oligocene in age.
			Surface Frio Clay	Subsurface Vicksburg Group equivalent	<u>Textularia warreni</u>	Frio Clay overlapped or not recognized on surface east of Live Oak County.
			Whitsett Formation	Fashioning Clay Member		Indicated members of Whitsett Formation apply to south-central Texas. Whitsett Formation east of Karnes County may be, in part or in whole, Oligocene in age.
			Jackson Group	Calliham Sandstone Member Tordilla Sandstone Member Dubose Member Deweeseville Sandstone Member Conquista Clay Member Dilworth Sandstone Member		
				Manning Clay		
			Wellborn Sandstone			
			Caddell Formation			
			Yegua Formation			
			Cook Mountain Formation			
Eocene		Sparta Sand	Not discussed as hydrogeologic units in this report.		<u>Marginulina coccoensis</u> <u>Textularia hockleyensis</u> <u>Massillina pratti</u> <u>Textularia dibollensis</u>	
		Weches Formation				
		Queen City Sand				
		Reklaw Formation				
Paleocene		Carrizo Sand				
		Wilcox Group Midway Group		<u>Nonionella cockfieldensis</u> <u>Discorbis yeguaensis</u> <u>Eponides yeguaensis</u> <u>Ceratobulimina eximia</u>		

Acknowledgments

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Metric Conversions

For those readers interested in using the metric system, the metric equivalents of English units of measurements are given in parentheses. The English units used in this report have been converted to metric units by the following factors:

<u>Unit</u>	<u>From</u> <u>Abbrevi-</u> <u>ation</u>	<u>Multiply</u> <u>by</u>	<u>To obtain</u> <u>Unit</u>	<u>Abbrevi-</u> <u>ation</u>
feet	--	0.3048	meters	m
miles	--	1.609	kilometers	km

STRATIGRAPHIC FRAMEWORK
General Features of Deposition and Correlation Problems

Cenozoic sediments that underlie the Coastal Plain of Texas are tens of thousands of feet thick at the coastline. These clastic sediments of sand, silt, and clay represent depositional environments ranging from non-marine at the outcrops of most units to marine where the units may carry a distinctive suite of fossils. Oscillations of ancient seas and changes in amount and source of sediments that were deposited caused facies changes down dip and along strike. For example, a time-stratigraphic unit having age equivalency may consist of sand in one area, sandy clay in a second area, and clay in a third area. Subsidence of the basin of deposition and rising of the land surface caused the stratigraphic units to thicken Gulfward. Growth faults (faults that were more or less continuously active) greatly increased the thickness of some stratigraphic units in short distances. All of these factors contributed to the heterogeneity of the units from place to place, which in turn makes correlation difficult.

Stratigraphic Units

In the discussion to follow, emphasis will be placed on stratigraphic units that are designated in this report as Miocene in age. Many of the correlation problems of the Cenozoic deposits involve these units to a large degree. Also the main thrust of this report is directed at the Miocene in keeping with the ultimate objective of modeling the flow in the Miocene aquifers.

The stratigraphic nomenclature used in this report was determined from several sources and may not necessarily follow the usage of the U.S. Geological Survey.

Pre-Miocene

Delineation of most of the pre-Miocene units of Cenozoic age present relatively few problems of significance. This is especially true of the pre-Jackson units (Midway Group to Yegua Formation). The top of the Carrizo Sand of the Claiborne Group (included with the underlying Wilcox Group on the sections) can be easily delineated, which makes the position of the unit unmistakable in the subsurface. From about the Sabine River to the San Marcos Arch (section F-F', fig. 7, is centered over this structural feature) the top of the Carrizo-Wilcox is about 3,000 feet (914 m) beneath the landward edge of the Catahoula outcrop. Southward from the San Marcos Arch into the Rio Grande Embayment of south Texas, its position steadily increases in depth to more than 7,000 feet (2,134 m) at the western end of section K-K' (fig. 12).

Facies changes occur downdip in the Sparta and Queen City Sands of the Claiborne Group, and where these units grade into clay, delineation on a time-stratigraphic basis is virtually impossible from electrical-log interpretation. The same problem affects the Yegua Formation of the Claiborne Group, although the Yegua remains sandy for greater distances downdip. It can be delineated by lithology on most of the sections in this report. Also, the presence of important faunal markers such as Nonionella cockfieldensis and Ceratobulimina eximia aid in locating the approximate top and base, respectively, of the Yegua, regardless of its lithology.

The delineation of the Jackson Group is significant in establishing the framework for the Miocene units. This is because the outcropping Frio Clay of Oligocene(?) age of south Texas is completely overlapped in Live Oak County by the Miocene Catahoula (or is not recognized on the surface east of this area). The overlap places the Catahoula in contact with part of the Whitsett Formation, the uppermost formation of the Jackson Group in this area. East of the overlap to the Sabine River, careful attention was required to properly separate on the sections the tuffaceous sand and clay interbeds of the Whitsett from the tuffaceous sand and clay interbeds of the overlying Catahoula. From Live Oak County southward, the outcropping Frio Clay separates the Whitsett Formation from the Catahoula Tuff.

The age of the Whitsett, although shown in table 1 as Eocene in south-central Texas, may be at least in part Oligocene in the eastern part of the State. Eargle, Dickinson, and Davis (1975) consider the Whitsett to be Eocene at least from central Karnes County to southern McMullen County. Barnes (1975) likewise considers the Whitsett to be unquestionably Eocene no farther east than central Karnes County. From this area to the Sabine River, Dr. V. E. Barnes (written commun., Apr. 5, 1971) states that the Whitsett may "climb timewise eastward" and be largely Oligocene in east Texas; that the Nash Creek Formation of Louisiana, which is considered to be largely Oligocene, is equivalent to the Whitsett as mapped in Texas near the Sabine River; and the Oligocene vertebrates, which Dr. J. A. Wilson (Dept. of Geologic Sciences, University of Texas at Austin) collected from the Whitsett in Washington County, show that this formation is at least part Oligocene at that site. Because of the probability that the Whitsett is Oligocene, in part or in whole in much of the area, the delineation of the Eocene Jackson Group is shown on the sections to include the Whitsett Formation.

The Frio Clay of Oligocene(?) age has been a controversial unit for decades. Geologists still do not agree on its subsurface equivalents or if it is even a separate stratigraphic unit from the Catahoula. The fact that many geologists have mapped the unit from Live Oak County to the Rio Grande lends support to the existence of the Frio Clay as a formation. The Geologic Atlas of Texas (Barnes, 1976a,b,c) shows that the Frio is mapped separately as a distinct formation from its overlap in Live Oak County to southern Webb County; from there to the Rio Grande, the Frio is undifferentiated from the Catahoula. The Frio outcrop that was used for control at the surface on the dip sections H-H' to K-K' (figs. 9-12) was modified from Darton, Stephenson, and Gardner (1937) and from Barnes (1976a,b,c). East of the overlap in Live Oak County the Frio is presumed to be present in the shallow subsurface beneath the Catahoula with the erosional edge probably only a few miles downdip from the edge of the Catahoula outcrop.

The Frio Clay at the surface has been interpreted by the author to be, at least in part, the nonmarine time-equivalent of the subsurface Vicksburg Group--a marine biostratigraphic unit of Oligocene age that crops out east of the Sabine River and is characterized by the foraminifer Textularia warreni. The relationship is supported by Deussen and Owen (1939, p. 1630) and by the Houston Geological Society (1954). The Vicksburg equivalent east of Karnes County may also be at least a partial time-equivalent of the Whitsett, whose probable Oligocene age in this area may, in itself, indicate an equivalency. Ellisor (1944, fig. 1, and p. 1365) supports this probability and illustrates the relationship in a geologic section. Additionally, this probability is supported by the apparent correlation of the outcrop of the Vicksburg Group in Louisiana near the Sabine River as shown on the geologic map of Louisiana (Wallace, 1946) with the outcrop of the Whitsett Formation as shown on the Geologic Atlas of Texas (Barnes, 1968b). This relationship may be inferred on the dip sections from A-A' to at least F-F' (figs. 2-7) where the Vicksburg equivalent, if projected to the outcrop, would intersect the outcropping Whitsett.

Miocene

The stratigraphic framework of the units that are designated in this report as Miocene in age is complex and controversial, perhaps more so than any other Cenozoic units. Geologists do not agree which units on the surface or in the subsurface are Miocene nor do they agree as to the relationship of the surface and subsurface units. The correct relationship may never be determined because faunal markers, which exist in places in the subsurface, do not extend to the outcrop; and the heterogeneity of the sediments does not facilitate electrical-log correlations.

The outcropping stratigraphic units that are assigned to the Miocene in this report are, from oldest to youngest, the Catahoula Tuff or Sandstone, Oakville Sandstone, and Fleming Formation. The "Frio" Formation, Anahuac Formation, and a unit that is referred to in this report as the upper part of the Catahoula Tuff or Sandstone are assigned by the author as possible downdip equivalents of the surface Catahoula although the Anahuac and "Frio" Formations may be Oligocene in age. Table 1 and the dip sections (figs. 2-12) illustrate this relationship.

The outcrop of the Catahoula, a pyroclastic and tuffaceous unit, has been mapped independently by various geologists with little modification from the Sabine River to the Rio Grande. Darton, Stephenson, and Gardner (1937) modified the unit's name from Catahoula Tuff to Catahoula Sandstone east of Lavaca County where the formation becomes more sandy.

It may be seen on the sections that the thickness of the surface Catahoula increases downdip at a large rate in the subsurface to eventually include, when the Anahuac Formation is reached, the "Frio" Formation which underlies the Anahuac, the Anahuac, and the upper Catahoula unit. Deussen and Owen (1939, figs. 5, 6, p. 1632, and table 1), in a study of the surface and subsurface formations in two typical sections of the Texas Coastal Plain (one in east Texas, the other in south Texas) agree with this relationship. They disagree, however, with these units being Miocene and assign them to the Oligocene. Some oil-company geologists consider the Anahuac and "Frio" as separate formations (unrelated to the Catahoula) in the subsurface and also assign them to the Oligocene. As a consequence of this usage, the upper Catahoula unit of this report is then usually referred to as "Miocene," which term is used instead of, or interchangeably with, Fleming. Holcomb (1964, fig. 2) in a study of the subsurface "Frio" Formation of south Texas places the "Frio" and Anahuac Formations, as well as the surface Catahoula in the Miocene, but does not admit to any Catahoula occurring above the Anahuac. He indicates that the "Fleming Formation" (Oakville Sandstone and Fleming Formation of this report) rests on the Anahuac. Dip sections, especially F-F', G-G', and H-H' (figs. 7-9), show unmistakably that the Catahoula-Oakville contact on the surface can be accurately traced far enough downdip by means of electrical logs to show that the clearly discernible contact is several hundred feet above the Anahuac. For this reason, the upper Catahoula unit above the Anahuac cannot be the Oakville. This contention is supported by Meyer (1939, p. 173) and by Lang and others (1950, plate 1).

The Anahuac Formation, despite the controversial attention it receives, is one of the most discernible formations in the subsurface. This marine biostratigraphic unit carries a rich microfauna of many tens of diagnostic species. These species are categorized into the Discorbis zone, Heterostegina zone, and Marginulina zone, from youngest to oldest. Only a few of the diagnostic species (table 1) are included with the dip sections in this report. The updip limit of the marine facies of the Anahuac ranges in depth from about 2,500 feet (762 m) below land surface in east Texas to about 4,000 feet (1,219 m) in the Rio Grande Embayment in south Texas. The unit is quite sandy south of San Patricio County (south of section H-H', fig. 9) to the Rio Grande in contrast to its shaly character eastward from San Patricio County to the Sabine River.

The Oakville Sandstone and Fleming Formation are composed almost entirely of terrigenous clastic sediments that form sand and clay interbeds. Both formations are basically rock-stratigraphic units that are distinguished and delineated on the basis of lithologic characteristics. Their boundaries in the Coastal Plain of Texas are discernible contacts in some areas and arbitrary ones within zones of lithologic gradation in other areas.

The Oakville Sandstone is most prominent on the surface and in the subsurface in the central part of the Coastal Plain. Here its predominantly sandy character is distinguished from the underlying tuffaceous Catahoula and overlying Fleming, which is composed of clay and slightly subordinate amounts of sand.

The Oakville on the surface has been mapped as a formation from about the Brazos River at the Washington-Grimes County line to central Duval County, where its outcrop is overlapped by the Goliad Sand and remains overlapped to the Rio Grande. Beneath this overlap, the Oakville apparently decreases in thickness or loses its predominance of sand or both. In either case, its position in the shallow subsurface in parts of the Rio Grande Embayment is questionable on dip sections I-I' and K-K' (figs. 10, 12). In the vicinity of the Brazos River, the Oakville grades eastward into the base of the Fleming Formation and loses its identity. The position of the base of the Oakville in the deeper parts of the subsurface has been delineated on some of the sections merely as an approximation.

The Fleming Formation, the uppermost unit of Miocene age in the Coastal Plain, has been mapped on the surface in Texas from the Sabine River to central Duval County. From here, like the Oakville, it is overlapped by the Goliad Sand and remains beneath the Goliad to the Rio Grande.

The Fleming is lithologically similar to the Oakville but can be easily separated from the Oakville in some places by its greater proportion of clay. Plummer (1932, p. 744, 747) described the Lagarto as consisting of 75 percent marl or clay, 15 percent sand, and 10 percent silt, with the clay beds being thicker and more massive and the sand beds being thinner and less massive than those of the Oakville. This description is reasonably accurate in some areas of the outcrop and shallow subsurface where the Fleming is separated from the Oakville. (See sections I-I', J-J', and L-L', figs. 10, 11, and 13.) In other areas, the Fleming on the outcrop and in the shallow subsurface contains a ratio of sand to clay that approximates that of the Oakville. Where the Fleming Formation is not separated from the Oakville and directly overlies the Catahoula, from about Grimes County to the Sabine River, the percentage of sand in the formation increases eastward. In Jasper and Newton Counties, the amount of sand in the section above the base of the Fleming greatly exceeds the amount of clay. This can be seen in wells 30 and 31 on strike section L''-L''' (fig. 15).

Delineation of the base of the Fleming from the surface to the deep subsurface has not been attempted on most of the sections because of complex facies changes. In southeast Texas on sections A-A', B-B', and C-C' (figs. 2-4) an approximate base of the Fleming is shown downdip to short distances beyond the pinchout of the Anahuac. The preponderance of sand above the Anahuac in this area, however, makes any delineation on the basis of electrical logs speculative. Deep wells near the coastline penetrate marine facies of the Fleming which carry a diagnostic fauna. Numerous species, which serve to identify the formation, have been described by Rainwater (1964). Potamides matsoni, Amphistegina sp., Bigenerina humblei, and Bigenerina nodosaria var. directa are faunal markers indicated on some of the sections.

Post-Miocene

Delineation of the stratigraphic units of Pliocene, Pleistocene, and Holocene age has not been attempted. Correlation problems with most of these stratigraphic units are too numerous to solve by using only electrical logs. Delineation of the Pleistocene units--Willis Sand, Bentley Formation, Montgomery Formation, and Beaumont Clay--is exceedingly difficult due to the lithologic similarity of the sediments and lack of paleontological control. The contact at the surface of the basal Quaternary with the Goliad Sand or older units is, however, shown on the dip sections.

The Goliad Sand of Pliocene age overlies the Miocene units in the deep subsurface as well as in places on the surface. Except for a few isolated outcrops, it is otherwise entirely overlapped on the surface east of Lavaca County by Pleistocene deposits. Its inland extent beneath the overlap is presumed to be only several miles southeast from the most downdip exposures of the Fleming Formation. From Lavaca County to the Rio Grande, the width of the Goliad outcrop gradually increases because the Goliad progressively overlaps older units in the Rio Grande Embayment of south Texas.

The Goliad Sand can usually be identified on the surface and in the subsurface by a preponderance of sand except in the far eastern part of the State where sand predominates from the base of the Miocene to the surface. In this area, the identity of the Goliad cannot be established with certainty. Delineation of the base of the Goliad has been made, where outcrop control is available, on the strike and dip sections west of Colorado County. The base of the Goliad has been approximated at about 2,200 feet (671 m) below sea level near the coastline on sections I-I' and J-J' (figs. 10, 11).

HYDROGEOLOGIC FRAMEWORK

The following discussion is restricted to the hydrogeologic framework of five units--Catahoula confining system (restricted), Jasper aquifer, Burkeville confining system, Evangeline aquifer, and Chicot aquifer. A discussion of other hydrologic units of Cenozoic age is beyond the purpose and scope of this report.

The quality of the ground water that is indicated on the sections to be less than 3,000 mg/L of dissolved solids is referred to in this report as fresh to slightly saline water. This terminology follows the classification of Winslow and Kister (1956).

Catahoula Confining System (Restricted)

The Catahoula confining system (restricted) is treated in this report as a quasi-hydrologic unit with different boundaries in some areas than the stratigraphic unit of the same name. Its top (base of the Jasper aquifer) is delineated along lithologic boundaries that are time-stratigraphic in some places but that transgress time lines in other places. Its base, which coincides with the base of the stratigraphic unit, is delineated everywhere along time-stratigraphic boundaries that are independent of lithology. No attempt was made to establish a lithologic (hydrologic) base for the unit, which would have created a distinct hydrologic unit. Such effort would have involved a thorough hydrologic evaluation of pre-Miocene formations, which is beyond the scope of the project.

In many places, the Catahoula confining system (restricted) is identical to the stratigraphic unit, but there are notable exceptions. These departures of the hydrologic boundaries from the stratigraphic boundaries are most prominent in the eastern part of the Coastal Plain near the Sabine River (fig. 15), in places in south Texas (fig. 11), and in numerous places at the outcrop and in the shallow subsurface. In these places, the very sandy parts of the Catahoula Tuff or Sandstone (stratigraphic unit) that lie immediately below the Oakville Sandstone or Fleming Formation are included in the overlying Jasper aquifer. This leaves a lower section from 0 to 2,000 feet (610 m) or more in thickness that consists predominantly of clay or tuff with some interbedded sand to compose the Catahoula confining system (restricted). In most areas, this delineation creates a unit that is generally deficient in sand so as to preclude its classification in these areas as an aquifer. Thus in much of its subsurface extent, the Catahoula confining system (restricted) functions hydrologically as a confining layer that retards the interchange of water between the overlying Jasper aquifer and underlying aquifers.

The amount of clay and other fine-grained clastic material in the Catahoula confining system (restricted) generally increases downdip, until the Anahuac Formation is approached. Below this unit, the "Frio" Formation becomes characteristically sandy and contains highly saline water that extends to considerable depths.

Jasper Aquifer

The Jasper aquifer, which was named by Wesselman (1967) for the town of Jasper in Jasper County, Texas, has heretofore not been delineated farther west than Washington, Austin, and Fort Bend Counties. In this report, a delineation as far downdip as possible has been made of the Jasper from the Sabine River to the Rio Grande.

The configuration of the Jasper aquifer in the subsurface, as shown on the sections, is geometrically irregular. This irregularity is due to the fact that the delineation was necessarily made on the basis of the aquifer being a rock-stratigraphic unit. The hydrologic boundaries were defined by observable physical (lithologic) features rather than by inferred geologic history.

The configuration of the base and top of the Jasper transgresses stratigraphic boundaries along strike and downdip. The lower boundary of the aquifer coincides with the stratigraphic lower boundary of the Oakville or Fleming in some places. In other places the base of the Jasper lies within the Catahoula or coincides with the base of that unit. The top of the aquifer is within the Fleming Formation in places, follows the top of the Oakville Sandstone in other places, and is within the Oakville in still other places.

The Jasper ranges in thickness from as little as 200 feet (61 m) to about 3,200 feet (975 m). The maximum thickness occurs within the region of highly saline water in the aquifer. An average range in thickness of the aquifer within the zone of fresh to slightly saline water is from about 600 to 1,000 feet (183 to 305 m). In the eastern part of the Coastal Plain of Texas the Jasper contains a greater percentage of sand than in the southern part. At the Sabine River, the Jasper attains a thickness of 2,400 feet (732 m) in well 31 on section L''-L''' (fig. 15), where the aquifer is composed almost entirely of sand. Fresh to slightly saline water, as shown on section D-D' (fig. 5), occurs as deep as 3,000 feet (914 m) below sea level.

Delineation of the Jasper aquifer in Louisiana (Whitfield, 1975), in western Louisiana and eastern Texas (Turcan, Wesselman, and Kilburn, 1966), and in Jasper and Newton Counties, Texas (Wesselman, 1967) shows that the thickness of the Jasper at the Sabine River closely approximates that given by the author. For example, the author assigns a thickness of 2,400 feet (732 m) to the Jasper in well 31 on section L''-L''' (fig. 15), and the authors cited above show essentially the same thickness at the site. This agreement in aquifer thickness, however, is contrasted to different interpretations of the stratigraphic composition or age of the aquifer near the Sabine River. The authors cited above restrict the Jasper to a part of the Fleming Formation, whereas this paper redefines the Jasper at its type locality near the Sabine River to include the upper part of the Catahoula of Texas in addition to the lower part of the Fleming of Texas. (This redefinition applies only to the area of the type locality and is thus only locally valid. Elsewhere in the Coastal Plain of Texas the Jasper assumes a different stratigraphic makeup.)

The stratigraphic discrepancies at the Texas-Louisiana border are attributed to different interpretations of the surface geology at the State line. The Palestine quadrangle of the Geologic Atlas of Texas (Barnes, 1968b) shows the Catahoula outcrop to be about 6 miles (9.7 km) wide at the Sabine River, whereas Welch (1942) shows the outcrop in Louisiana to be about 1 mile (1.6 km) wide. A close comparison of the two geologic maps indicates that in Louisiana the Lena, Carnahan Bayou, and at least part of the Dough Hills Members of Fisk (1940) of the Fleming Formation of Kennedy (1892), in addition to the Catahoula of Welch (1942), are equivalent to the Catahoula of Texas. Wesselman (1967) assigned the Carnahan Bayou Member as the basal part of the Jasper, which is reasonable; but this member is Catahoula in age in Texas. As long as the discrepancy in geologic mapping is unresolved, subsurface correlations of the Catahoula-Fleming contact, as well as formation thicknesses, will continue to differ.

Burkeville Confining System

The Burkeville confining system, which was named by Wesselman (1967) for outcrops near the town of Burkeville in Newton County, Texas, is delineated on the sections from the Sabine River to near the Rio Grande. It separates the Jasper and Evangeline aquifers and serves to retard the interchange of water between the two aquifers.

The Burkeville has been mapped in this report as a rock-stratigraphic unit consisting predominantly of silt and clay. Boundaries were determined independently from time concepts although in some places the unit appears to possess approximately isochronous boundaries. In most places, however, this is not the case. For example, the entire thickness of sediment in the Burkeville confining system in some areas is younger than the entire thickness of sediment in the Burkeville in other places.

The configuration of the unit is highly irregular. Boundaries are not restricted to a single stratigraphic unit but transgress the Fleming-Oakville contact in many places. This is shown on sections D-D' to G-G' and J-J' (figs. 5-8 and 11). Where the Oakville Sandstone is present, the Burkeville crops out in the Fleming but dips gradually into the Oakville because of facies changes from sand to clay downdip.

The typical thickness of the Burkeville ranges from about 300 to 500 feet (91 to 152 m). However, thick sections of predominantly clay in Jackson and Calhoun Counties account for the Burkeville's gradual increase to its maximum thickness of more than 2,000 feet (610 m) as shown on section F-F' (fig. 7).

The Burkeville confining system should not be construed as a rock unit that is composed entirely of silt and clay. This is not typical of the unit, although examples of a predominance of silt and clay can be seen in some logs in sections H-H' and I-I' (figs. 9-10). In most places, the Burkeville is composed of many individual sand layers, which contain fresh to slightly saline water; but because of its relatively large percentage of silt and clay when compared to the underlying Jasper aquifer and overlying Evangeline, the Burkeville functions as a confining unit.

Evangeline Aquifer

The Evangeline aquifer, which was named and defined by Jones (Jones, Turcan, and Skibitzke, 1954) for a ground-water reservoir in southwestern Louisiana, has been mapped also in Texas, but heretofore has been delineated no farther west than Washington, Austin, Fort Bend, and Brazoria Counties. Its presence as an aquifer and its hydrologic boundaries to the west have been a matter of speculation. D. G. Jorgensen, W. R. Meyer, and W. H. Sandeen of the U.S. Geological Survey (written commun., March 1, 1976) recently refined the delineation of the aquifer in previously mapped areas and continued its delineation to the Rio Grande. The boundaries of the Evangeline as they appear on the sections in this report are their determinations.

The Evangeline aquifer has been delineated in this report essentially as a rock-stratigraphic unit. Although the aquifer is composed of at least the Goliad Sand, the lower boundary transgresses time lines to include sections of sand in the Fleming Formation. The base of the Goliad Sand at the outcrop coincides with the base of the Evangeline only in south Texas as shown in sections H-H' to K-K' (figs. 9-12). Elsewhere, the Evangeline at the surface includes about half of the Fleming outcrop. The upper boundary of the Evangeline probably follows closely the top of the Goliad Sand where present, although this relationship is somewhat speculative.

The Evangeline aquifer is typically wedge shaped and has a high sand-clay ratio. Individual sand beds are characteristically tens of feet thick. Near the outcrop, the aquifer ranges in thickness from 400 to 1,000 feet (122 to 305 m), but near the coastline, where the top of the aquifer is about 1,000 feet (305 m) deep, its thickness averages about 2,000 feet (610 m). The Evangeline is noted for its abundance of good quality ground water and is considered one of the most prolific aquifers in the Texas Coastal Plain. Fresh to slightly saline water in the aquifer, however, is shown to extend to the coastline only in section J-J' (fig. 11).

Chicot Aquifer

The Chicot aquifer, which was named and defined by Jones (Jones, Turcan, and Skibitzke, 1954) for a ground-water reservoir in southwestern Louisiana, is the youngest aquifer in the Coastal Plain of Texas. Over the years, the aquifer gradually was mapped westward from Louisiana into Texas where, heretofore, its most westerly mapped limit was Austin, Fort Bend, and Brazoria Counties. In this report, the delineation of the Chicot was refined in previously mapped areas and extended to near the Rio Grande by D. G. Jorgensen, W. R. Meyer, and W. M. Sandeen of the U.S. Geological Survey (written commun., March 1, 1976).

It is believed that the base of the Chicot in some areas has been delineated on the sections in this report as the base of the Pleistocene. Early work in southeast Texas indicates that the Chicot probably comprises the Willis Sand, Bentley Formation, Montgomery Formation, and Beaumont Clay of Pleistocene age and any overlying Holocene alluvium (table 1). The problem that arises in this regard is that the base of the Pleistocene is difficult to pick from electrical logs. Thus any delineation of the base of the Chicot in the subsurface as the base of the Pleistocene is automatically suspect. At the surface, the base of the Chicot on the sections has been picked at the most landward edge of the oldest undissected coastwise terrace of Quaternary age. In practice, the delineation of the Chicot in the subsurface, at least on the sections in southeast Texas, has been based on the presence of a higher sand-clay ratio in the Chicot than in the underlying Evangeline. In some places, a prominent clay layer was used as the boundary. Differences in hydraulic conductivity or water levels in some areas also served to differentiate the Chicot from the Evangeline.

The high percentage of sand in the Chicot in southeast Texas, where the aquifer is noted for its abundance of water, diminishes southwestward. Southwest of section G-G' (fig. 8) the higher clay content of the Chicot and the absence of fresh to slightly saline water in the unit is sharply contrasted with the underlying Evangeline aquifer that still retains relatively large amounts of sand and good quality water.

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