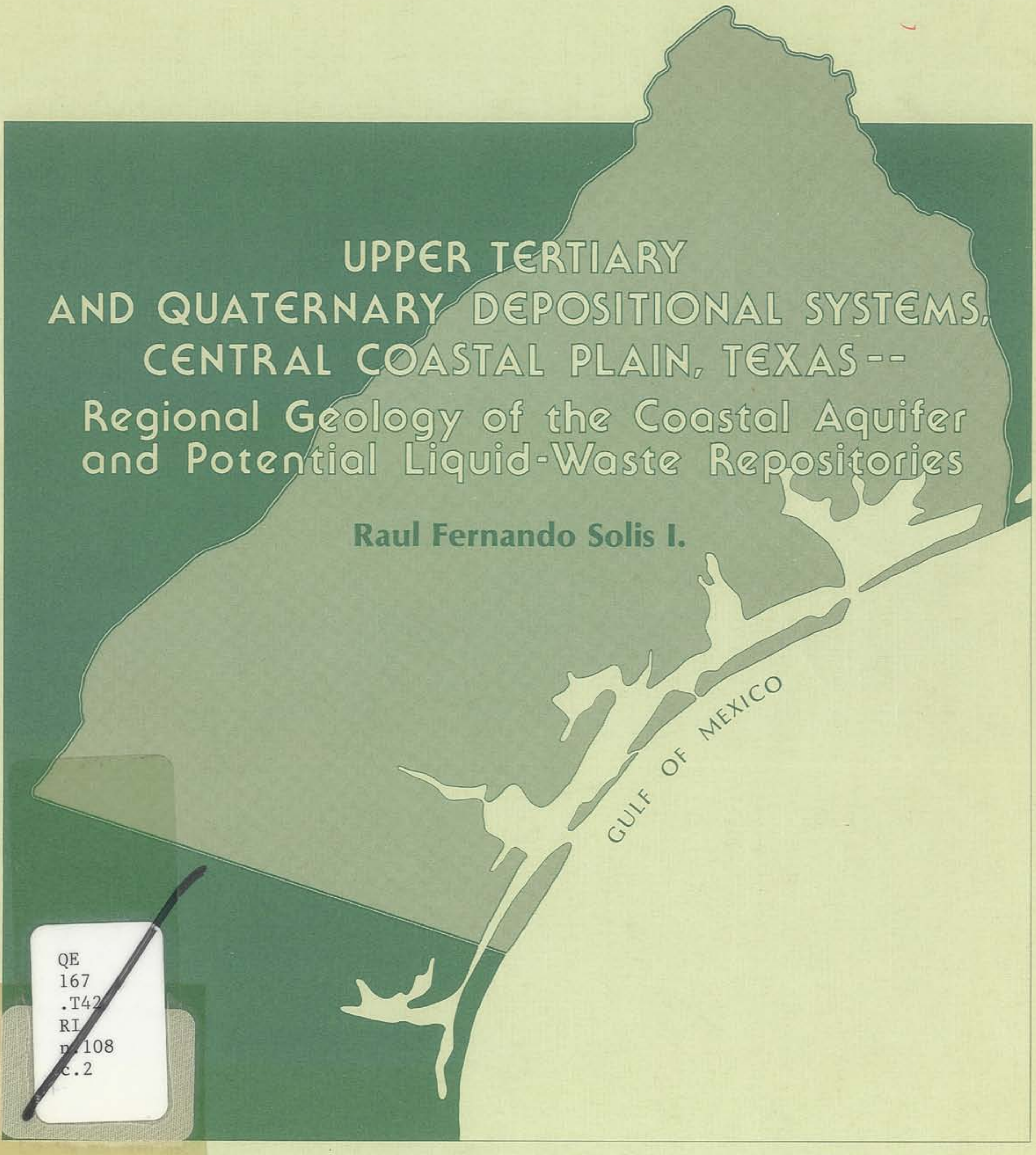
REPORT OF INVESTIGATIONS NO. 108
BUREAU OF ECONOMIC GEOLOGY • W. L. FISHER, DIRECTOR • THE UNIVERSITY OF TEXAS AT AUSTIN • AUSTIN, TEXAS 78712
1981

UPPER TERTIARY AND QUATERNARY DEPOSITIONAL SYSTEMS, CENTRAL COASTAL PLAIN, TEXAS--

Regional Geology of the Coastal Aquifer and Potential Liquid-Waste Repositories

Raul Fernando Solis I.



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Regional Geology of the Coastal Aquifer and Potential Liquid-Waste Repositories

Raul Fernando Solis I.*

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ABSTRACT

Upper Miocene, Pliocene, and Pleistocene deposits in the subsurface of the central Coastal Plain of Texas were subdivided into six operational units comprising the surface-defined Fleming, Goliad, Willis, Lissie, and Beaumont Formations. These sedimentary units constitute the last major depositional episodes in the northwestern Gulf Coast Basin. Late Miocene deposition is represented by transgressive shelf and shallow-marine shales overlain by progradational clastics of the upper part of the Lower Fleming, Upper Fleming, and Lower Goliad-Willis units. A minor Pliocene transgressive event is represented by downdip marine embayment facies of the Upper Goliad-Willis unit. Finally, Pleistocene highstand fluviodeltaic progradation (Lissie and Beaumont units) terminated pre-Holocene sedimentation.

Interpretation of sediment distribution, established by constructing a series of net- and percentage-sand maps for each unit, permits delineation of the following main depositional systems: fluvial braided-meanderbelt and floodbasin; fluviodeltaic system; lagoon; large marine embayments; small bayhead deltas; thick wave-dominated deltas; strandplain; and thick, stacked coastal barriers. Western fluviodeltaic systems were consistently less active than the eastern ones, which deposited greater volumes of sand.

Inherited, subtle structural influence of the deeper seated San Marcos Arch had some effect on sediment distribution and paleogradients. Shallow extensions of the deeper Vicksburg, Frio, and Miocene fault systems display respectively decreasing (from 400 ft, 122 m) displacements in the section studied. Faults clearly played a central role in the distribution of fluvial, deltaic, and strike-oriented coastal sands.

Most sands in the updip parts of the operational units contain fresh water, whereas those of downdip areas contain predominantly brackish to saline waters. The area with greatest reservoir potential for fresh water includes Victoria, Jackson, Wharton, and Colorado Counties. Possible use of sealed, thick coastal sands in the Lower Fleming unit for the disposal of industrial and municipal liquid waste is recommended.

INTRODUCTION

This report delineates the distribution of sediments of late Tertiary to Quaternary age in the subsurface of the central part of the Texas Coastal Plain and infers sediment dispersal trends, geometry, and distribution of facies within these depositional systems. The sediments interpreted herein comprise the subsurface equivalents of the Fleming Formation (upper Miocene), the Goliad and Willis Formations (Pliocene), and the Lissie and Beaumont Formations (Pleistocene).

Generally, the section investigated constitutes the last major regressive depositional sequence in the Gulf Coast Basin following deposition of upper Miocene coastal marine shales (lowermost Fleming). Outcrops of these formations have been studied by numerous investigators, but limited information is available on their subsurface stratigraphic equivalents.

The area of study (fig. 1) is in the central part of the Texas Coastal Plain between the Colorado River (to the northeast) and Kleberg and southern Jim Wells and Duval Counties (to the southwest). The inland boundary is the surface contact of the Oakville and

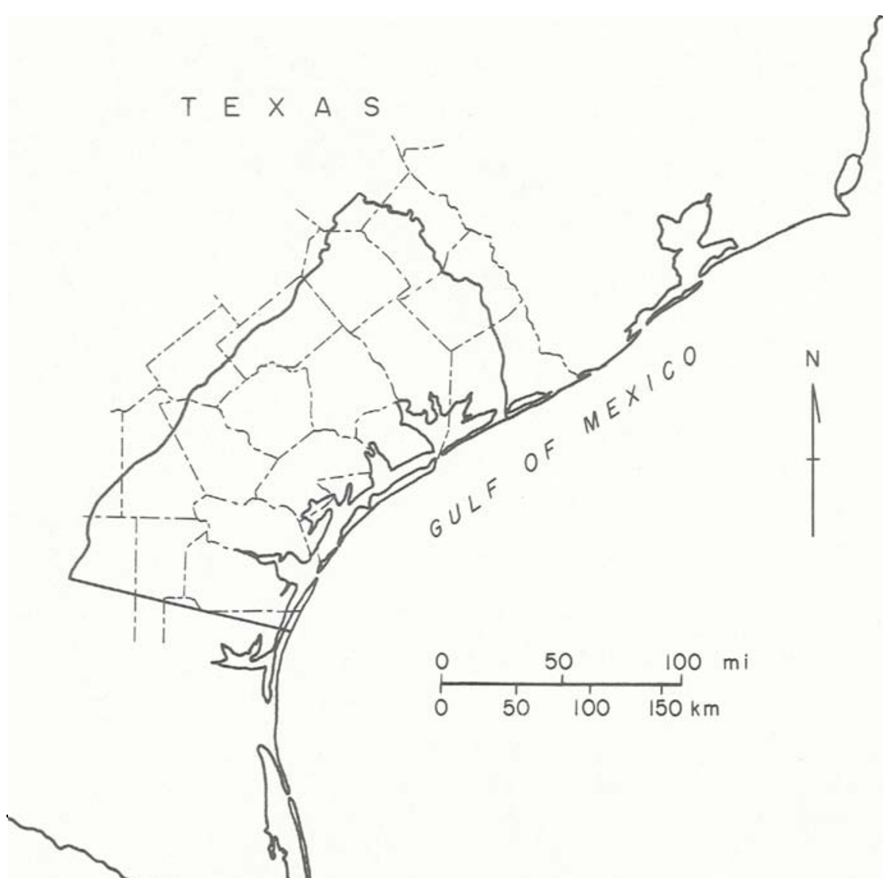


Figure 1. Location of the study area.

Fleming Formations, and the downdip limit is the Gulf coastline. The average width of the area is 90 mi (145 km), and the total area is 13,050 mi^2 (33,782 km^2).

The goal of this study was to determine the subsurface distribution of upper Miocene, Pliocene, and Pleistocene sediments, sand-dispersal patterns, depositional systems, and constituent facies within this upper Cenozoic sequence to obtain a better explanation of the depositional history of the younger strata beneath the central Coastal Plain of Texas. The study also attempted to determine the relationship between depositional systems, faulting, and fresh ground water and shallow gas or petroleum accumulations. Finally, it evaluated the potential for liquid-waste disposal in the subsurface of the area.

METHODOLOGY

The stratigraphic sequence studied was subdivided into the following six operational units, which correspond approximately to the equivalent surface formations (from oldest to youngest): Lower Fleming, Upper Fleming, Lower Goliad-Willis, Upper Goliad-Willis, Lissie, and Beaumont (table 1).

Most of the subsurface data used in this study are electric log records from oil and water wells (fig. 2). Sources of log data were the Texas Department of Water Resources, the Bureau of Economic Geology, and Shell Oil Company. A total of 1,500 well logs was used.

Table 1. Stratigraphic subdivisions of upper Tertiary and Quaternary strata, central Coastal Plain, Texas.

Series	Group	Surface Formation*	Subsurface Operational Unit	
PLEISTOCENE	HOUSTON	Beaumont	Beaumont	INTERVAL STUDIED
		Lissie	Lissie	
PLIOCENE	CITRONELLE	Willis Goliad	Upper Goliad-Willis	
			Lower Goliad-Willis	
UPPER MIOCENE	FLEMING	Fleming	Upper Fleming	
			Lower Fleming	
LOWER MIOCENE		Oakville	Oakville	
			Lower Oakville or Anahuac Sand (downdip)	
UPPER OLIGOCENE		-----	Anahuac Shale (downdip)	

*Modified from Doering (1935).

A base map at a scale of 1:250,000 was prepared from the Corpus Christi, Laredo, Crystal City, Beeville, and Seguin topographic sheets published by the U. S. Geological Survey. Five strike and 20 dip sections were constructed (fig. 2), of which 7 dip and 2 strike sections are included in this report. Reference data pertaining to wells belonging to these sections are listed in Appendix D. The remaining cross sections, well information, and stratigraphic numerical data (derived from correlation) are on open file at the Bureau of Economic Geology.

Operational stratigraphic units were subdivided on the basis of an extensive lithostratigraphic correlation of all wells in the area and by correlation of these units with equivalent formations in outcrop. Published paleontological information refers mainly to continental fauna; some marine paleontological information was available for the lower downdip part of the sequence (Lower Fleming). Operational units are informal stratigraphic units that closely correspond to time-stratigraphic units. This stratigraphic approach was necessary because of inadequate to absent foraminiferal information and unavailable seismic-stratigraphic data. The base of the sequence studied is the top of a marker bed, the Oakville Sandstone, which can be traced over most of the area.

The stratigraphic framework established by the construction of 25 cross sections (fig. 2) was essential for the overall correlation of wells and units throughout the area. This framework was the basis for a series of maps and figures that depict the distribution of sediments and depositional settings and environments. Two maps were prepared for each operational unit: a net-sand map and a sand-percentage map. These maps display the absolute sand content and the sand/shale ratio expressed in sand percentages. Contour intervals were set at 20, 50, and 100 ft (6, 15, and 30.5 m) and 10 percent, respectively. The net-sand and sand-percentage maps were used to construct a third set of interpretive maps that depict the depositional trends and systems for each operational unit. Well control and location of stratigraphic cross sections are shown in figure 2. Other maps depict structural elements, namely faults and salt domes (courtesy of Geomap), and formation outcrops (Barnes, 1974, 1975, 1976), as well as the base of the interval studied (the boundary between the base of Fleming shales and top of Oakville sands and its downdip coastal equivalent).

The investigation of the fresh-water aquifer in the area includes a series of figures that illustrate the net-sand thickness of fresh-water sands and the position of the base of the aquifer. Finally, a map was prepared to show the most favorable zone for the disposal of liquid wastes in the subsurface.

REGIONAL SETTING

The central coastal area of Texas is located in the northwestern part of the regional structural province of the Gulf Coast Basin (fig. 1). The Gulf Coast Basin has been asymmetrically infilled by Cenozoic terrigenous sediments. Main depocenters were located in

Texas in the Eocene to Oligocene and in Louisiana during the Miocene, Pliocene, and Pleistocene. Williamson (1959) recognized about 20,000 ft (6,100 m) of Eocene sediments in offshore Texas versus 5,000 ft (1,525 m) beneath the Mississippi Delta in Louisiana, and about 16,000 ft (4,880 m) of Oligocene sediments in offshore Texas compared with only 5,000 ft (1,525 m) in offshore Louisiana. Rainwater (1964) estimated more than 10,000 ft (3,050 m) of Miocene sediments in offshore Texas, whereas more than 20,000 ft (6,100 m) were estimated in Louisiana. Shinn (1971) estimated nearly 3,000 ft (915 m) of Pliocene and Pleistocene sediments several miles offshore of Texas and approximately 15,000 ft (4,575 m) in front of and beneath the Mississippi Delta. Woodbury and others (1973) estimated 18,000 to 20,000 ft (5,490 to 6,100 m) for the same section in front of and beneath the Mississippi Delta. In summary, the total thickness of Cenozoic sediments is estimated to be about 50,000 ft (15,250 m) in offshore Texas and almost 45,000 ft (13,725 m) in offshore Louisiana.

The Cenozoic history of the northwestern Gulf Coast Basin was characterized by a series of clastic, regressive depositional events interrupted and separated by deposition of alternating, transgressive marine shales. Growth faulting normally accompanied the deposition of those regressive clastic wedges (fig. 3).

The thick wedge of clastic sediments underlying the Coastal Plain of Texas crops out in subparallel belts across the plain. The surface expression of the Oakville and younger formations is relatively simple: (1) an inland plain, underlain by deposits of the Oakville and Fleming Formations, exhibits elevations up to 500 ft (152.5 m) above sea level and consists of rolling hills, cuestas, and valleys, which have been dissected by rivers such as the Nueces, Aransas, San Antonio, Guadalupe, and Colorado; (2) a middle coastal plain, underlain by the Goliad and Willis Formations, is expressed as gentle rolling hills, gentle cuestas (Goliad cuesta), relatively shallow valleys, and generally flat topography with elevations ranging between 200 and 350 ft (61 and 107 m) above sea level (Doering, 1935); and (3) a low coastal plain underlain by the Lissie and Beaumont Formations is an essentially flat fluvial and deltaic plain composed of floodbasin muds cut extensively by meandering rivers and abandoned meanderbelt deposits at elevations that range between sea level and about 100 ft (30.5 m) above sea level.

SURFACE GEOLOGY: A SUMMARY

The surface geology of the Coastal Plain of Texas has been studied by a number of investigators. The basic geological framework and definition of formations was established by Dumble and Kennedy during the last decade of the 1800's and by Hayes, Udden, Dall, and Deussen early in the 1900's. Evolution of the stratigraphic nomenclature is presented in table 2. In the area of study, outcrops of the Oakville to Beaumont Formations extend as strike-oriented belts that become progressively younger toward the Gulf (fig. 4).

Table 2. Evolution of nomenclature, upper Tertiary and Quaternary formations, central Coastal Plain, Texas.

<table>
<tr><th>Hayes and Kennedy, 1903</th><th colspan="2">Deussen, 1914, 1924</th><th>Barton, 1930</th><th colspan="2">Plummer, 1932</th><th>Weeks, 1933</th><th colspan="2">Doering, 1935</th><th>Fisk, 1938; Bernard, 1950</th><th>Bernard and others, 1962</th><th colspan="2">Tipsword, 1962</th></tr>
<tr><td rowspan="2">Beaumont</td><td colspan="2" rowspan="2">Beaumont</td><td rowspan="5">Beaumont</td><td colspan="2" rowspan="2">Beaumont</td><td rowspan="2">Beaumont</td><td colspan="2" rowspan="2">Beaumont</td><td>Prairie</td><td>Beaumont</td><td rowspan="5">Houston</td><td rowspan="3">Beaumont</td></tr>
<tr><td rowspan="3">Montgomery</td><td rowspan="3">Unnamed Second Terrace</td></tr>
<tr><td rowspan="3">Columbia</td><td colspan="2" rowspan="3">Lissie</td><td colspan="2" rowspan="3">Lissie</td><td rowspan="3">Upper Lissie</td><td colspan="2" rowspan="3">Lissie</td></tr>
<tr><td rowspan="2">Lissie</td></tr>
<tr><td>Bentley</td><td>Lissie</td></tr>
<tr><td rowspan="3">LaFayette</td><td rowspan="2">Uvalde</td><td rowspan="4">Reynosa</td><td rowspan="4">Lissie</td><td rowspan="4">Citronelle</td><td>Unnamed Pliocene Sand</td><td>Lower Lissie</td><td rowspan="4">Citronelle</td><td>Willis</td><td rowspan="4">Williana</td><td>Willis</td><td rowspan="4">Citronelle</td><td>Willis</td></tr>
<tr><td rowspan="3">Goliad</td><td rowspan="3">Upper Lagarto or Reynosa</td><td rowspan="3">Goliad</td><td rowspan="3">Goliad</td><td rowspan="3">Goliad</td></tr>
<tr><td rowspan="2">De Witt</td></tr>
<tr><td rowspan="2">Frio Clays</td></tr>
<tr><td rowspan="2">Fleming Clay</td><td rowspan="2">Lagarto Lapara</td><td rowspan="3">Fleming</td><td rowspan="3">Fleming</td><td rowspan="2">Lagarto</td><td rowspan="2">Lower Lagarto</td><td rowspan="3">Fleming</td><td rowspan="2">Lagarto</td><td rowspan="3"></td><td rowspan="3"></td><td rowspan="3">Fleming</td><td rowspan="2">Lagarto</td></tr>
<tr><td rowspan="2">Fayette Sands</td></tr>
<tr><td colspan="2">Oakville</td><td>Oakville</td><td>Oakville</td><td>Oakville</td><td>Oakville</td></tr>
</table>

Figure 2. Well control and location of cross sections. For identification of wells on cross

sections, see Appendix D. Names of other wells on file, Bureau of Economic Geology.

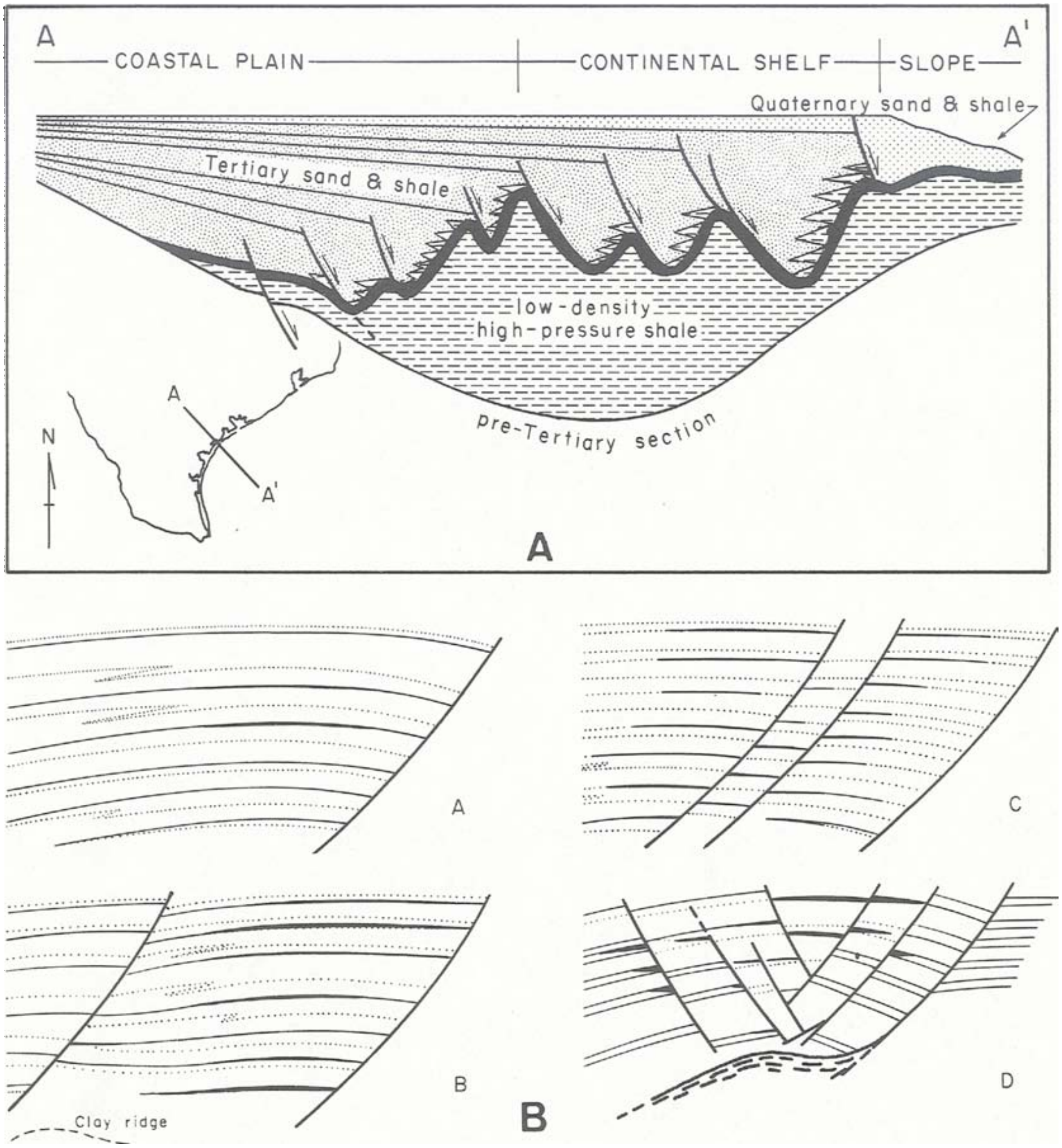


Figure 3. Depositional and structural style exhibited by delta systems. A. Diagrammatic cross section across Texas part of northern Gulf of Mexico Basin. After Bruce (1973). B. Growth-fault patterns in the Tertiary Niger delta system. After Weber (1971).

OAKVILLE FORMATION

Initially defined by Dumble (1894), the Oakville Formation is a thick (200 ft, 61 m, in East Texas and more than 500 ft, 152.5 m, in South Texas), fine- to coarse-grained and partially consolidated sandstone containing intercalations of silt and clay beds. This sand, which in areas exhibits crossbedding, is composed of quartz (40 percent), chert (25 percent), and considerable amounts of feldspar and calcite cement. In addition, silicified wood and reworked Cretaceous fossils are reported. The Oakville Sand becomes more clayey northeast of Grimes County (Plummer, 1932). The Oakville dips at about 50 ft per mi (15.25 m per km) (Weeks, 1945). Galloway (1979a) studied genetic facies, hydrology, and uranium mineralization of the Oakville in outcrops and at mining sites. He recognized a George West axis and a New Davy fluvial sand axis in Live Oak and De Witt-Karnes Counties and discussed their relationship to uranium ore occurrences.

FLEMING FORMATION

Kennedy (1892) first applied the name Fleming Formation to sediments lying above the Catahoula Formation and below the Lissie Formation. Later, Dumble designated the same interval as Lagarto, but excluded the Oakville Sand. Because of prolonged

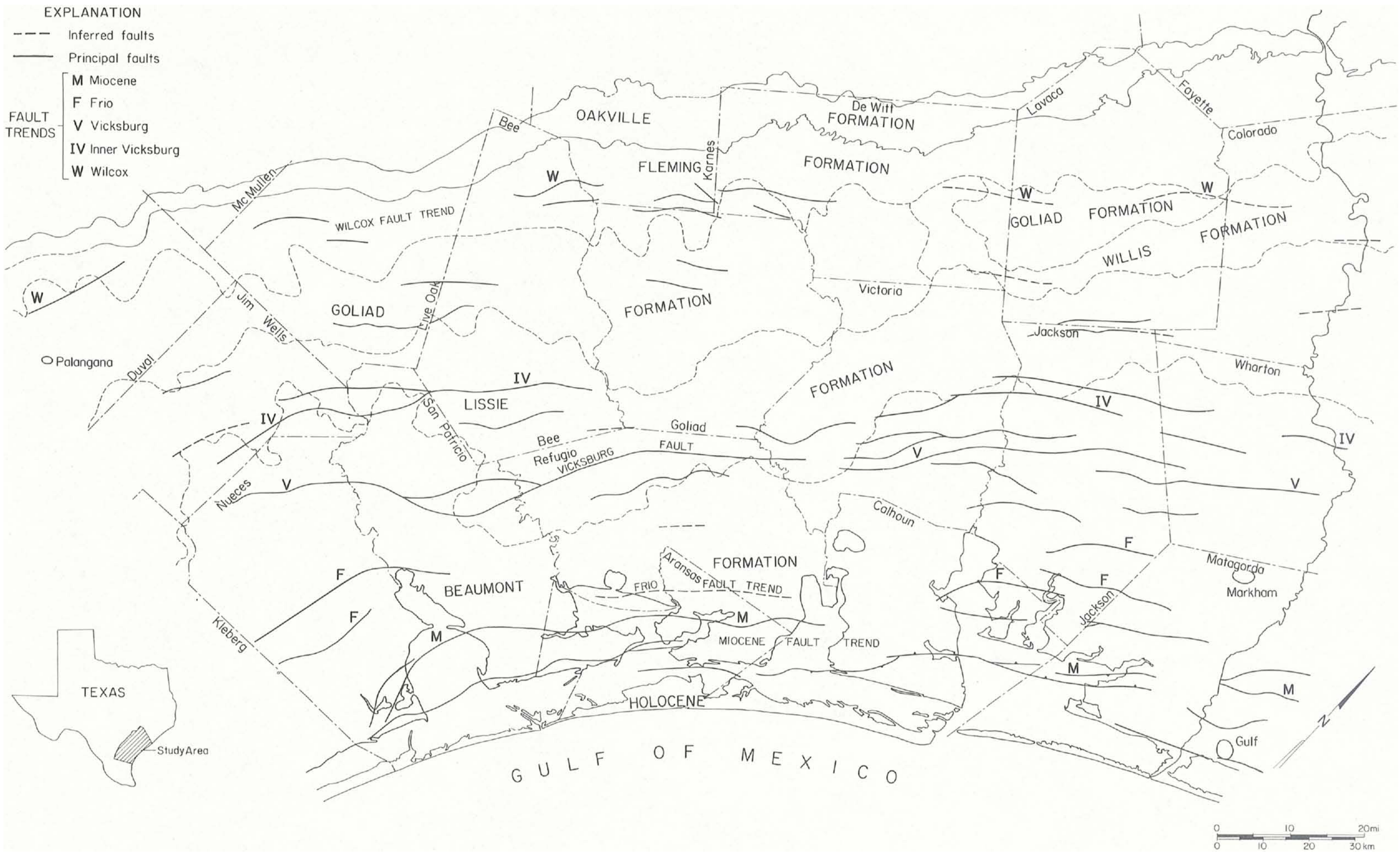


Figure 4. Geological and structural setting showing principal faults and outcrops of stratigraphic units. Fault data courtesy of Geomap.

use of the name Lagarto, Plummer (1932, p. 740) proposed this name for a sequence of 500 to 1,000 ft (152 to 305 m) of clays between the base of the Lapara sands (presently Goliad) and the top of the Oakville Sand. Fleming and Lagarto are equivalent designations used in both the surface and the subsurface; however, the name Fleming is currently more widely used, and the name Lagarto is being abandoned.

The Fleming Formation overlies the Oakville Sand and is in turn overlain unconformably by the Goliad and Willis Formations (Doering, 1935, p. 660). It dips toward the Gulf at 25 to 50 ft per mi (7.6 to 15.2 m per km). Doering (1935) estimated a maximum thickness of 1,200 ft (366 m) near the outcrop. The average width of the Fleming outcrop in the area of study is about 15 mi (24 km).

Fleming sediments at the surface consist of ocher to yellowish, green and gray calcareous shales and clays containing minor amounts of feldspar crystals, chert, and reworked Cretaceous fossil fragments. Clays contain thin intercalations of light-brown, gray, and yellowish calcareous sands composed of medium-grained sand that in places exhibits crossbedding. Fleming sediments weather into rich dark clayey soils. In South Texas, the Fleming is covered by caliche crusts that occur at or near the surface. Important Miocene vertebrate fauna has been described by several workers; biostratigraphy of the unit is further detailed in Appendix D.

GOLIAD FORMATION

The name Goliad was first used by Howeth and Martin (Plummer, 1932, p. 750). Plummer (1932, p. 752-753) subdivided the formation into three members: (1) Lapara sand (lowest unit), a coarse and conglomeratic crossbedded sand containing clay lentils and calcareous concretions, bone fragments, and fossilized wood. Its type locality is Lapara Creek in Live Oak County. (2) Lagarto Creek beds, consisting of reddish and pinkish, mottled, limy clays. The type locality is Lagarto Creek in Live Oak County, where 50 ft (15 m) of section were measured. (3) Labahia beds (uppermost unit), composed of grayish, white, fine to coarse crossbedded sands that include a middle unit of greenish to gray, pink, or reddish calcareous clay. The type locality of this unit is near La Bahia Mission, along the San Antonio River in southern Goliad County; about 10 ft (3 m) of section were measured here by Howeth and Martin (Plummer, 1932).

In the area of study, the Goliad Formation crops out in a belt 10 to 20 mi (16 to 32 km) wide and dips toward the Gulf at 15 to 20 ft per mi (4.6 to 6.0 m per km). The average thickness of the Goliad at the surface is estimated to be 250 ft (76 m) (Plummer, 1932). The Goliad Formation lies unconformably over clays of the Fleming Formation and is in turn overlain by deposits of the Lissie Formation. Goliad sediments have been described in the following general terms: light-gray, medium- to coarse-grained unconsolidated sands, locally well bedded and crossbedded. The Goliad includes pinkish or greenish calcareous clays, marls, clayey sands, and cherty conglomerates at the base (Plummer, 1932; Barnes, 1975). Goliad outcrops are covered by caliche crusts over wide areas of South Texas. In the Central Coastal Plain, Goliad sediments contain vertebrate fossils and reworked Cretaceous invertebrates (Quinn, 1952, 1955; Wilson, 1962). In addition, subsurface concentrations of uranium occur near Lake Corpus Christi in Live Oak County and at the Palangana dome in Duval County.

Doering (1935, p. 659) determined that a close lateral relationship exists between Goliad and Willis sediments.

WILLIS FORMATION

The name Willis was first introduced by Doering (1935) after the town of Willis in Montgomery County to describe a sequence of sands and gravelly sands overlying Fleming sediments in southeast Texas and southern Louisiana. Willis sediments were described under the name of the De Witt Formation by Deussen (1914); Dumble (1918) called them the LaFayette Gravel. Bailey (1923) named them the Lower Lissie, and the formation was mapped by the U. S. Geological Survey as undifferentiated Lissie and Reynosa (Darton, 1932; Trowbridge, 1932).

These continental unfossiliferous sands were called unnamed Pliocene or Upper Citronelle sands by Plummer (1932, p. 761) (table 2 of this report). He described the Willis as consisting of reddish, coarse and gravelly sands and subordinate clays attaining a maximum surficial thickness of about 350 ft (107 m). Apparently, the Willis Formation partly grades to the southwest into the Goliad Formation (fig. 4) (Doering, 1935, p. 659). Willis beds rest unconformably on clays, which are, in part, Fleming and Goliad (Doering, 1935). Doering subdivided 85 ft (26 m) of exposed Willis into three members: Willis gravelly sand (lowest unit), Willis ferruginous sand, and Hockley Mound sand. Outcropping beds of the Willis Formation dip toward the coast at 15 to 20 ft per mi (4.6 to 6.0 m per km) (Doering, 1935, p. 669).

LISSIE FORMATION

The Lissie Formation was first studied by McGee (1891) as part of the LaFayette Formation. Later Hayes and Kennedy (1903) and Veatch (1906) described its sediments as Columbia sands (table 2).

The name Lissie was first used in 1914 by Deussen, after the town of Lissie in Wharton County. The formation's outcrop is a belt 10 mi (16 km) wide in the southwest part of the area of study and about 20 mi (32 km) wide in the northeast (fig. 4). Lissie sediments extend into the subsurface, dipping 5 to 20 ft per mi (0.9 to 3.8 m per km) (Doering, 1935). The Lissie section includes all sediments below the Beaumont Formation and above the Goliad sands. Maximum outcrop thickness is estimated to be about 600 ft (183 m) in East Texas and 400 ft (122 m) in South Texas (Plummer, 1932).

Lissie sediments consist of reddish, orange, and gray fine- to coarse-grained and crossbedded sands that contain intercalations of clays and sandy clays. They include abraded fossils and lentils of gravel of varied composition. In the subsurface, Lissie floodbasin sediments are bluish and greenish gray. Lissie sediments are described in the Crystal City-Eagle Pass, Seguin, and Beeville-Bay City sheets of the Geological Atlas of Texas (Barnes, 1974, 1975, 1976) as consisting of sands, silts, clays, and minor amounts of gravel. The upper part, locally, is calcareous and includes calcareous concretions and iron-manganese nodules. Sediments were deposited as meanderbelt, levee, crevasse splay, and floodbasin facies (Barnes, 1974).

BEAUMONT FORMATION

The Beaumont Formation was named by Hayes and Kennedy (1903) to describe clays overlying the Columbia sands (now Lissie) and underlying the recent Port Hudson silts in the area of Beaumont in Jefferson County (table 2). Bailey (1923) mapped the Lissie and Beaumont Formations in Colorado County. Barton (1930) studied characteristics of deltaic sedimentation on the Coastal Plain. Plummer (1932) discussed the general regional geology of this formation (table 2). Metcalf (1940) concluded that Lissie and Beaumont Formations represent mostly fluvial deposition of the ancestral Colorado and Brazos Rivers. Fisk (1938, 1944) subdivided Pleistocene sediments in Louisiana into four formations represented by terraces: Williana (equivalent to the present Goliad-Willis), Bentley, Montgomery, and Prairie (equivalent to the present Lissie-Beaumont) (table 2) and proposed a correlation of these terraces with glacial and interglacial stages of the American Pleistocene. More recently, the Bureau of Economic Geology published detailed surface geological maps of the Corpus Christi, Port Lavaca, and Bay City-Freeport sheets as part of the *Environmental Geologic Atlas of the Texas Coastal Zone* (Brown and others, 1976; McGowen and others, 1976a, b).

In the area of study, the Beaumont Formation crops out along strike as a low plain 30 to 40 mi (48.3 to 64.4 km) wide (fig. 4). It dips gulfward between 1.5 and 5 ft per mi (0.3 and 0.95 m per km). Maximum thickness in the area of study and beneath the coastline is estimated to be about 500 ft (152.5 m) (figs. 5 to 13).

The Beaumont Formation consists of clays, silts, and sands deposited as meanderbelt, floodbasin, crevasse splay, levee, deltaic, barrier bar, and lagoon facies (Plummer, 1932; Achalabhuti, 1973; Barnes, 1974; McGowen and others, 1976a, b; Brown and others, 1976). It weathers into rich, dark soils crossed by meandering, low sand ridges. Clays are bluish gray and include calcareous nodules.

TECTONIC SETTING

The area of this study lies within the western region of the Gulf Coast Basin and shares part of the regional structural elements of that basin. Miocene, Pliocene, and Pleistocene sediments constitute the youngest Cenozoic fluviodeltaic progradational systems. Each progradational event was terminated by transgressive (marine shale) depositional episodes. Collectively, the deltaic systems progressively shifted basinward during the late Tertiary (fig. 3).

Deltaic depocenters such as those of the Wilcox, Vicksburg, Frio, Miocene, and offshore Pleistocene produced complex strike-oriented growth-fault systems and associated structures. These structural mechanisms created favorable conditions for hydrocarbon traps.

GROWTH FAULTS

Origin and mechanisms of contemporaneous faulting have been studied by Hardin and Hardin (1961), Ocamb (1961), Hamblin (1965), Carver (1968), Shelton (1968), Cloos (1968), Weber (1971), and Daily (1976). Bruce (1973) considered the effects of sediment loading and the development of rising "shale masses" under high fluid pressures beneath the Gulf Coast Basin deltaic depocenters. He also discussed the mechanics of growth faults and associated structures.

The area of study is crossed by dominantly strike-oriented growth-fault systems (fig. 4): Wilcox-Vicksburg, Frio, and Miocene. These fault systems affected mainly the lower stratigraphic units of this study; some vertical displacement can be recognized (in dip sections) in the shallower Goliad-Willis units. Faulting strongly influenced the sediment distribution of the formations studied. Growth-fault influence on deposition is discussed in the section of this report entitled "Sediment Distribution and Depositional Systems."

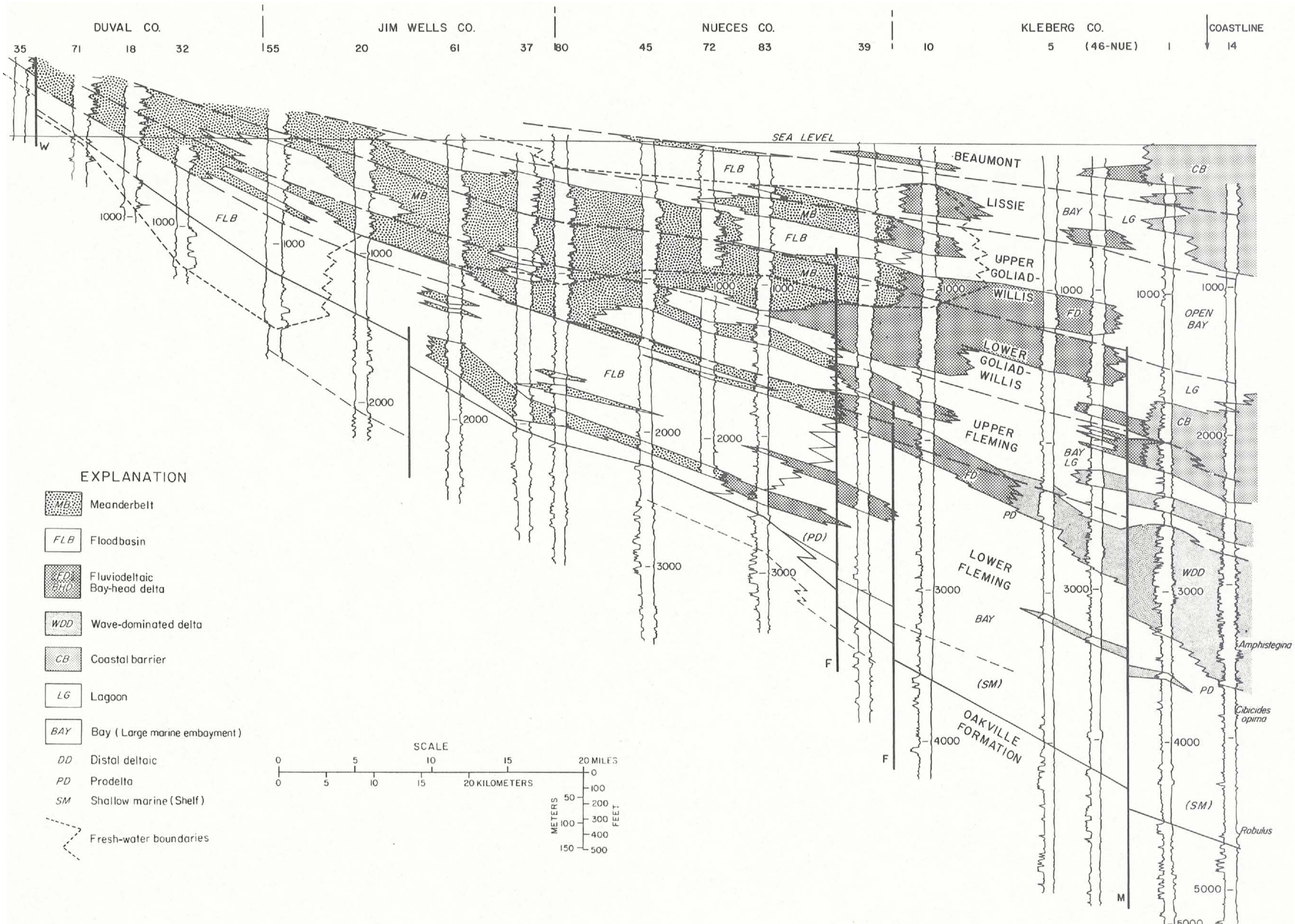


Figure 5. Dip cross section 1. Fault data courtesy of Geomap. See Appendix D for well names.

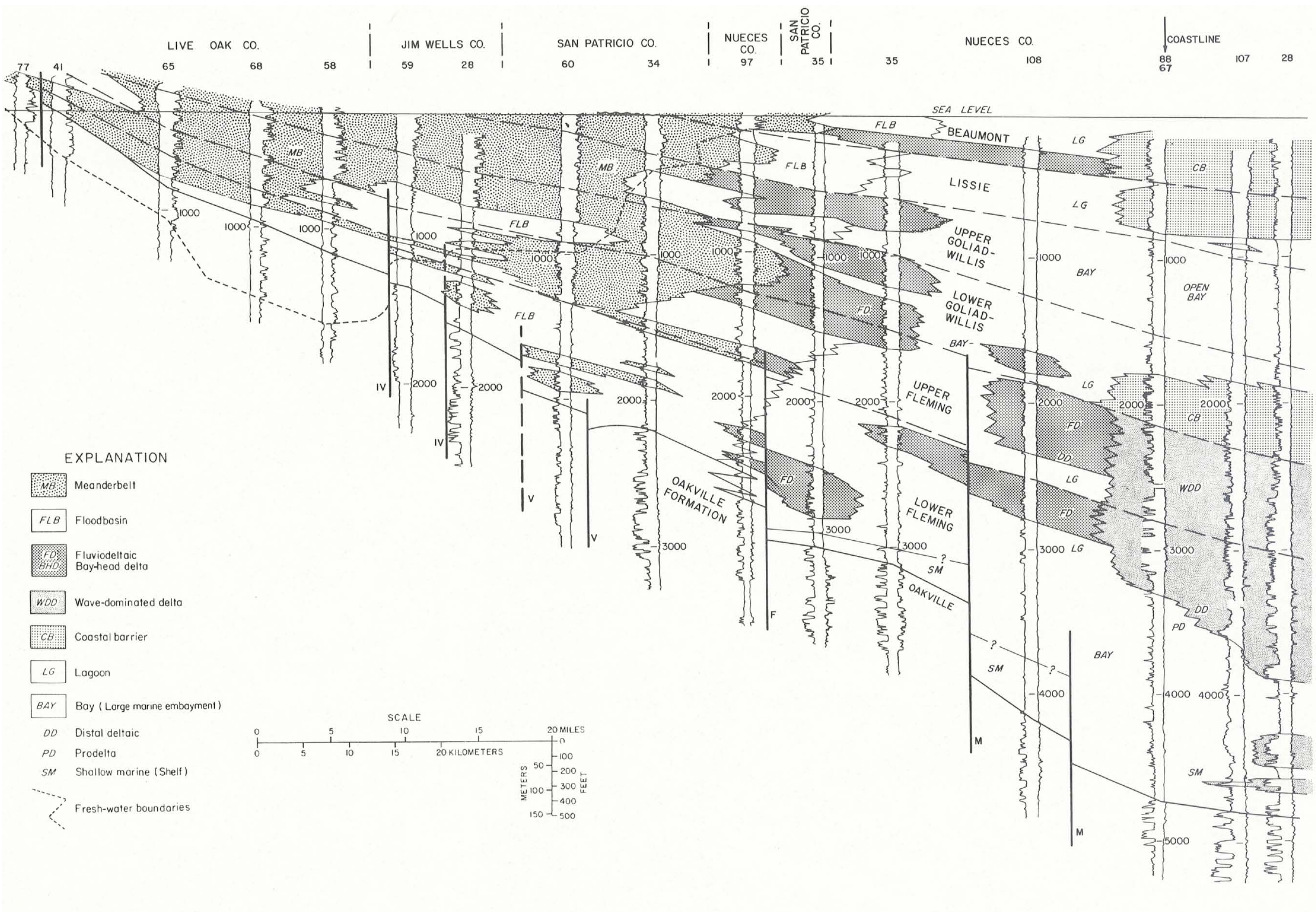


Figure 6. Dip cross section 4. Fault data courtesy of Geomap. See Appendix D for well names.

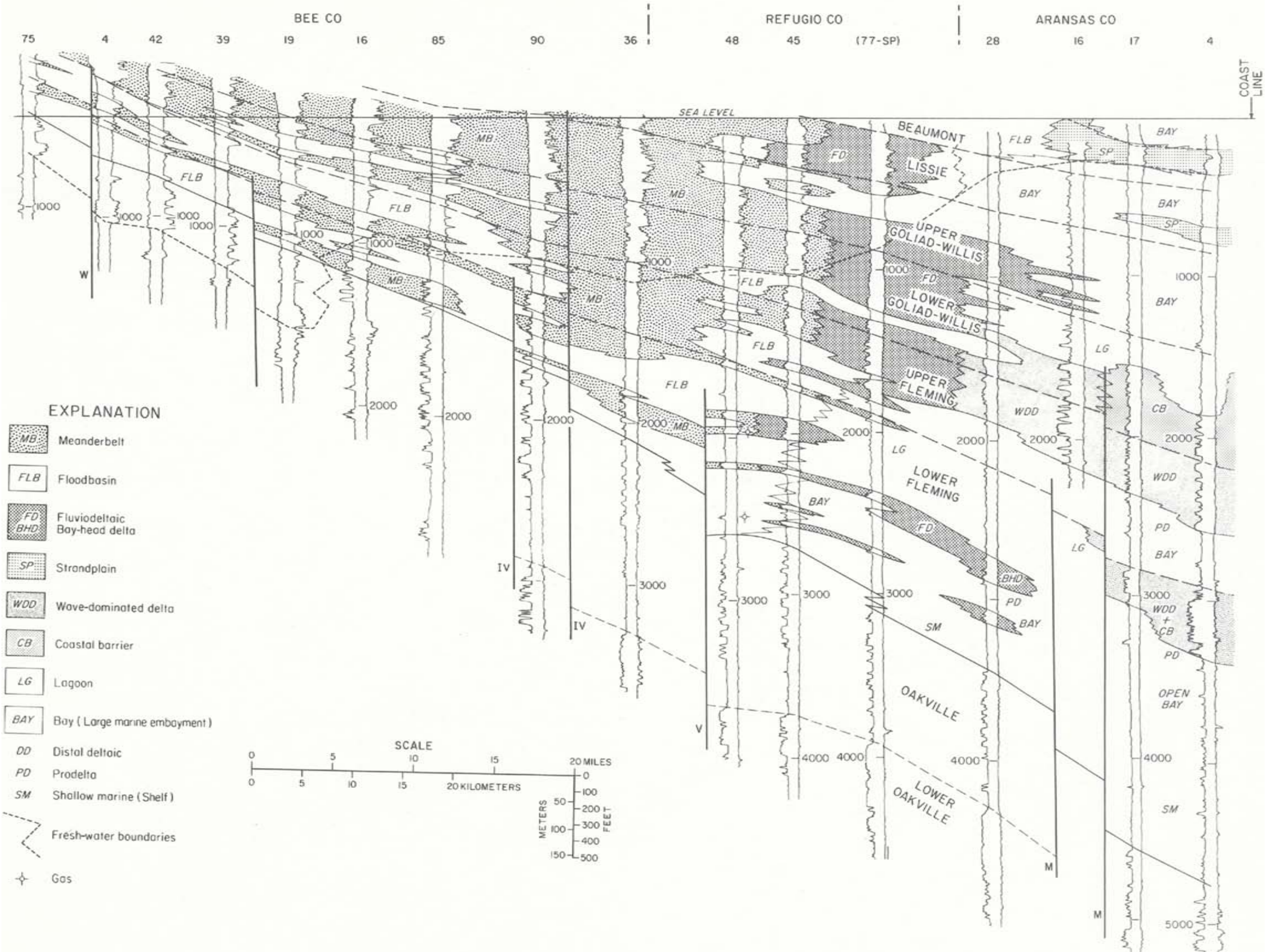


Figure 7. Dip cross section 7. Fault data courtesy of Geomap. See Appendix D for well names.

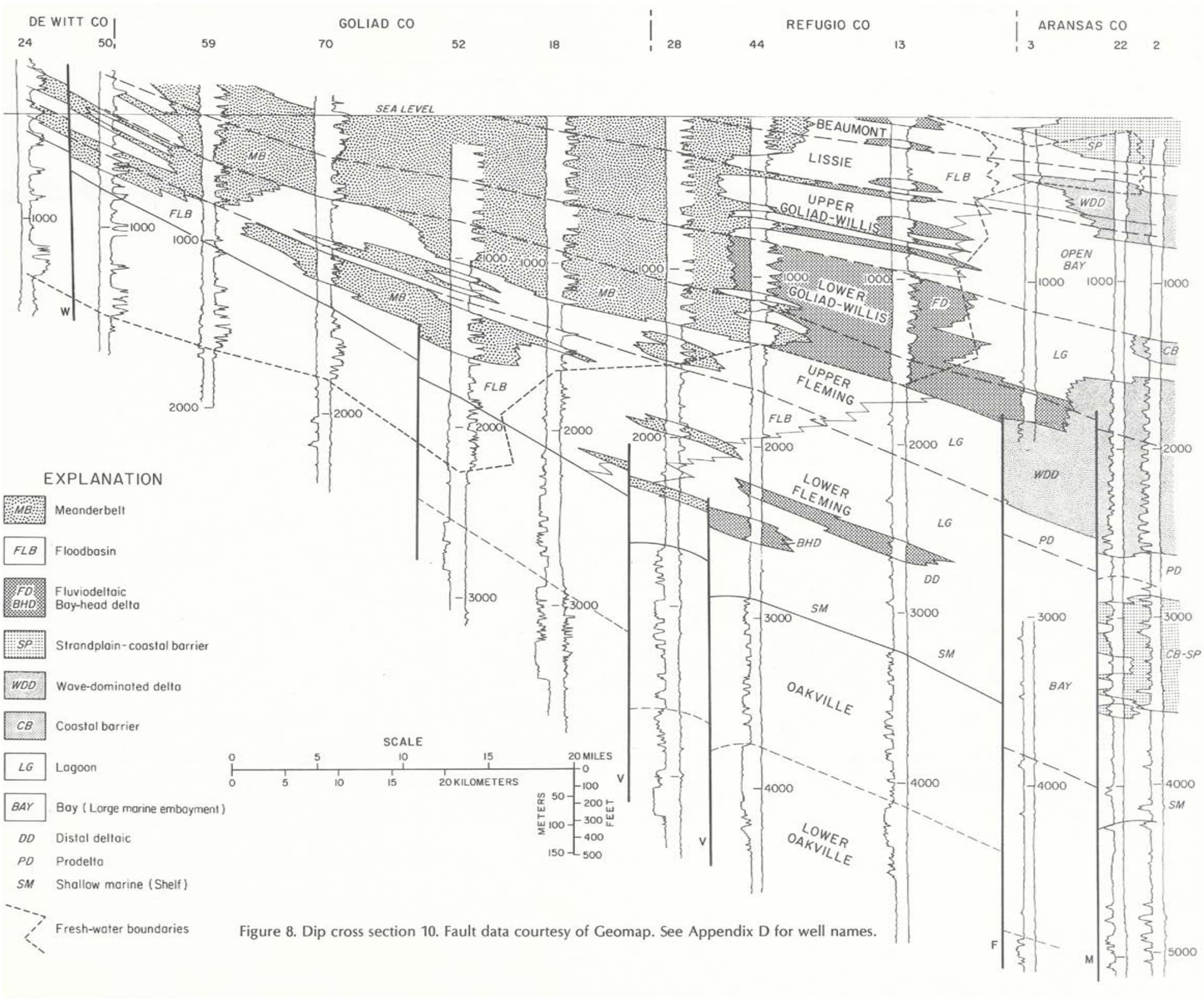


Figure 8. Dip cross section 10. Fault data courtesy of Geomap. See Appendix D for well names.

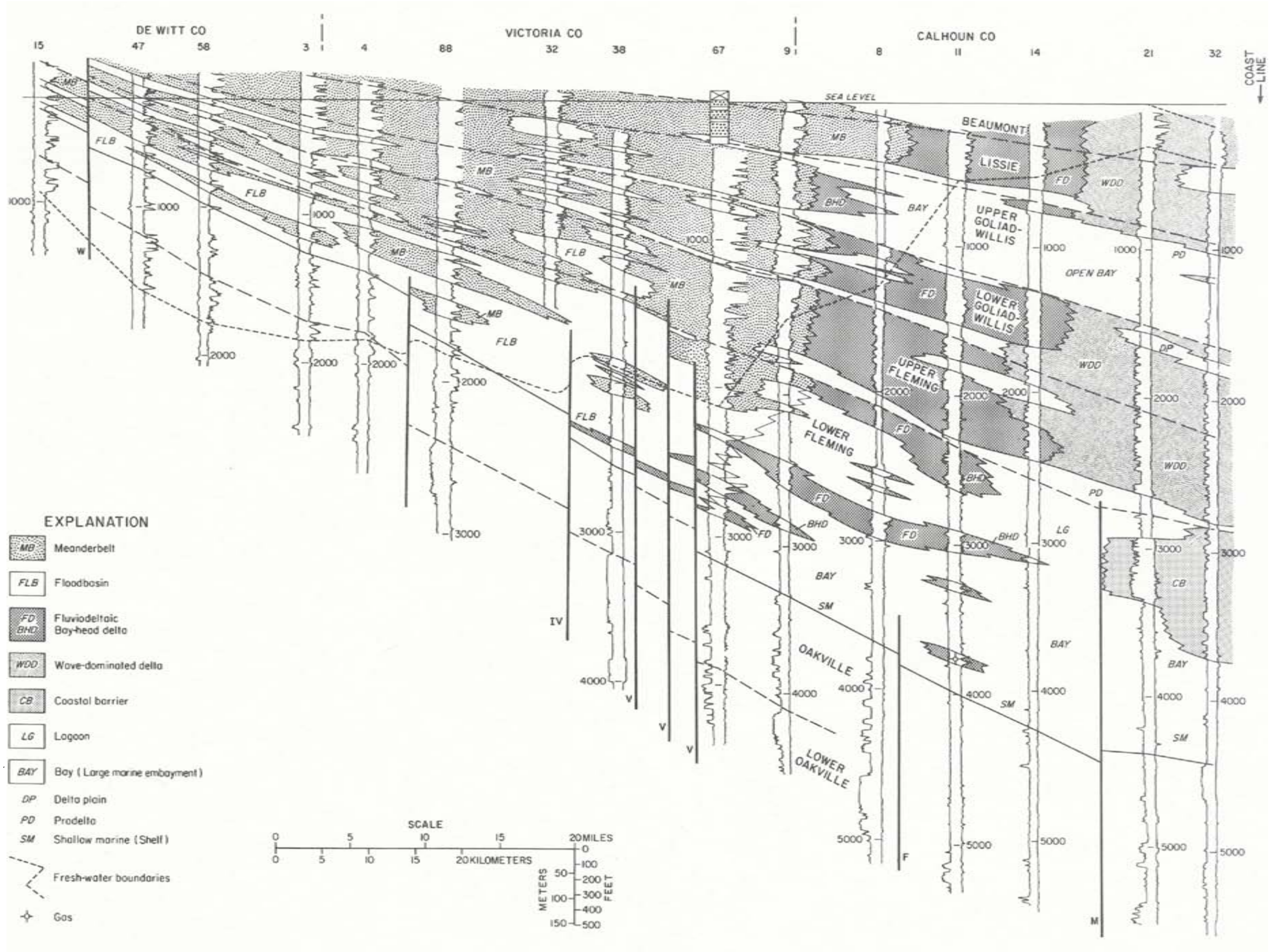


Figure 9. Dip cross section 13. Fault data courtesy of Geomap. See Appendix D for well names.

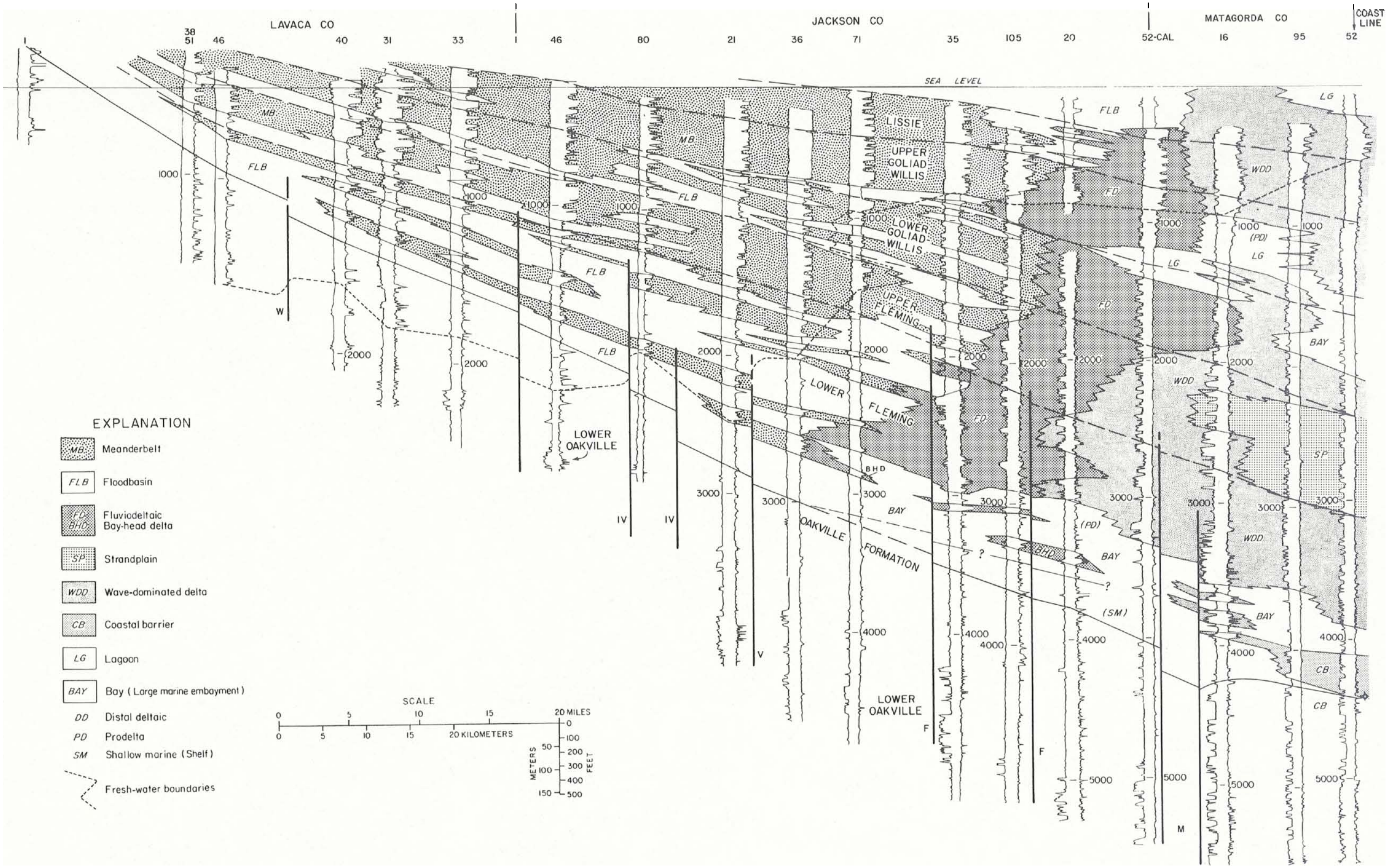


Figure 10. Dip cross section 17. Fault data courtesy of Geomap. See Appendix D for well names.

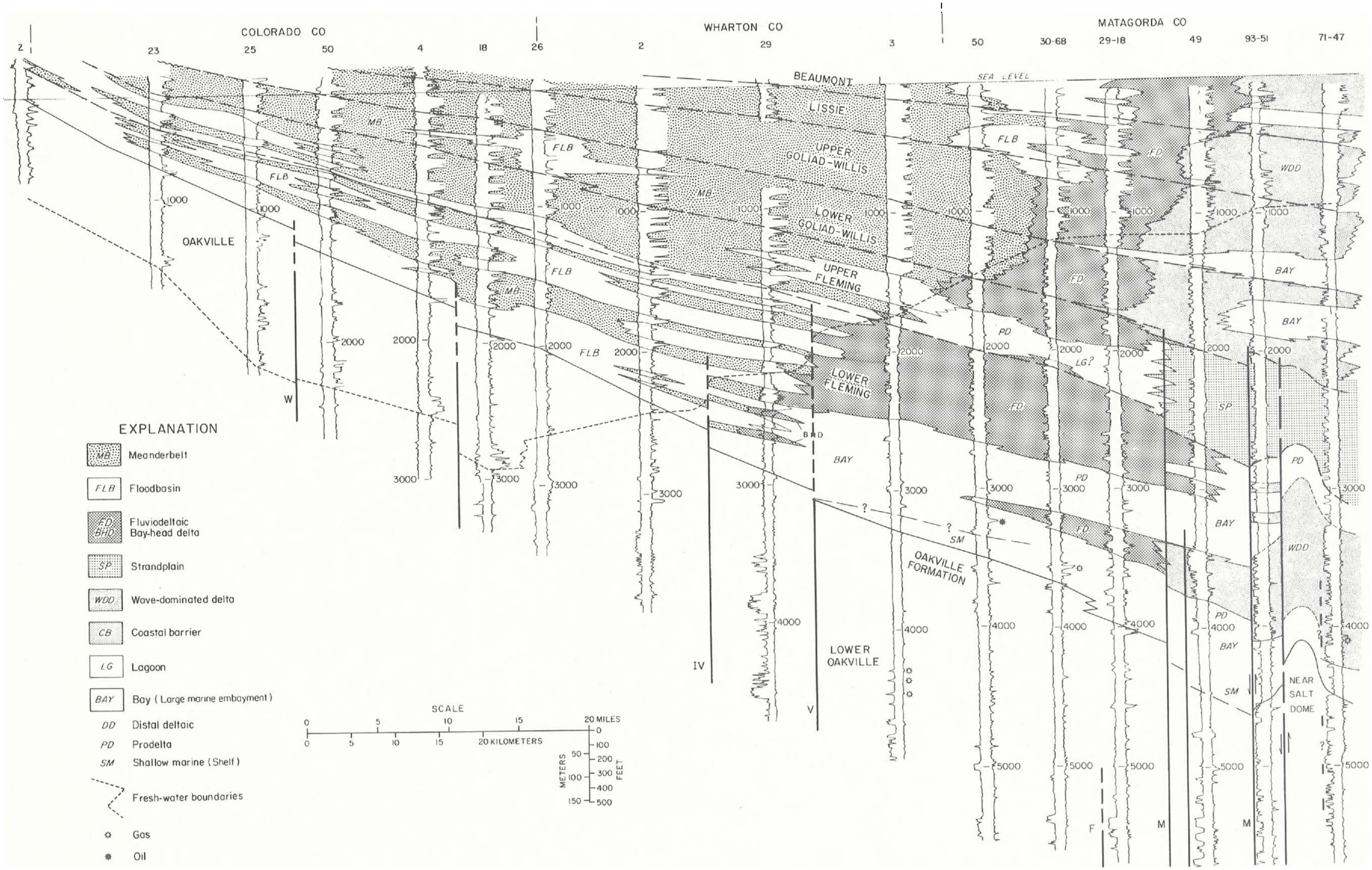


Figure 11. Dip cross section 20. Fault data courtesy of Geomap. See Appendix D for well names.

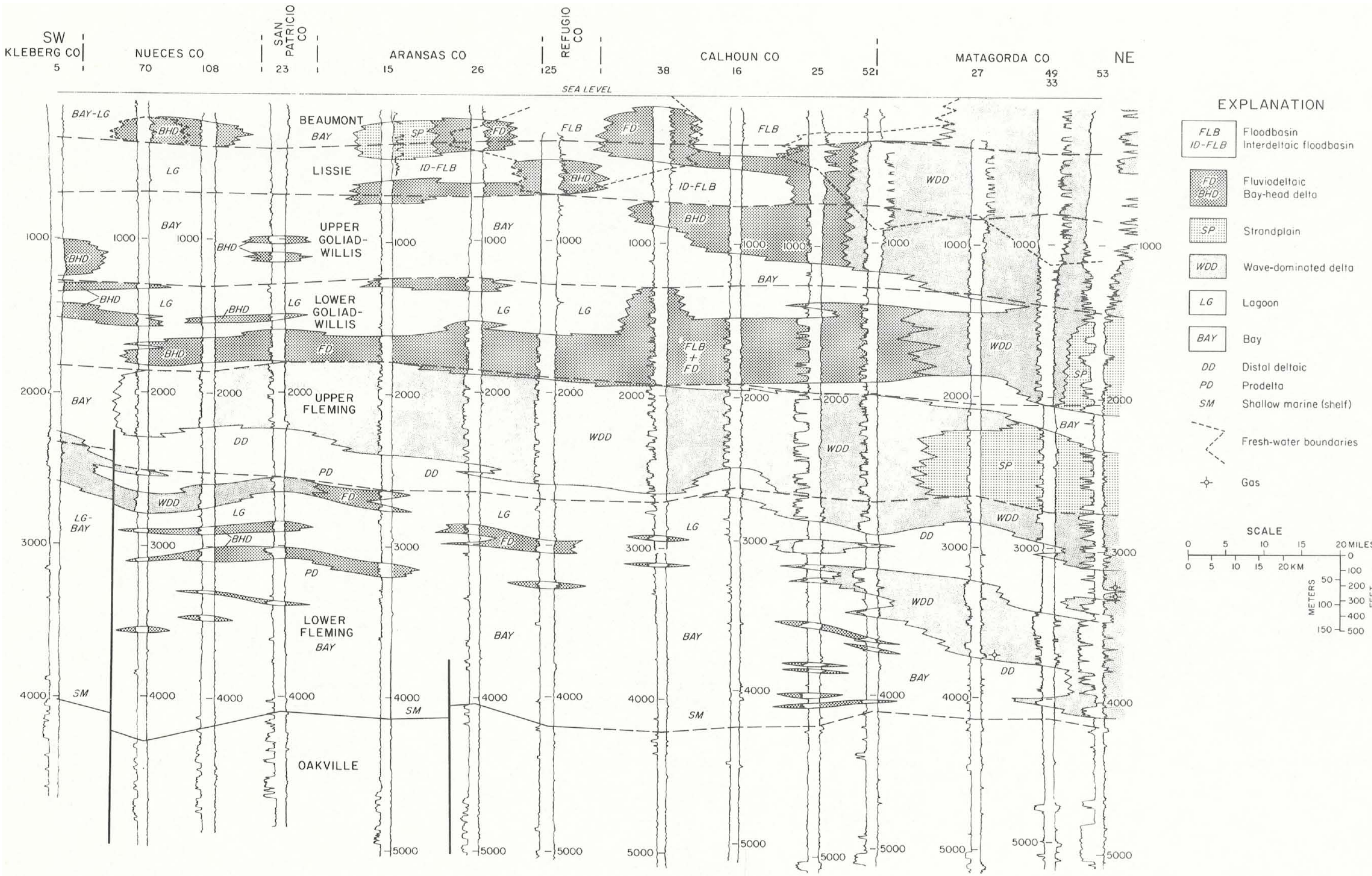


Figure 12. Strike cross section II. Fault data courtesy of Geomap. See Appendix D for well names.

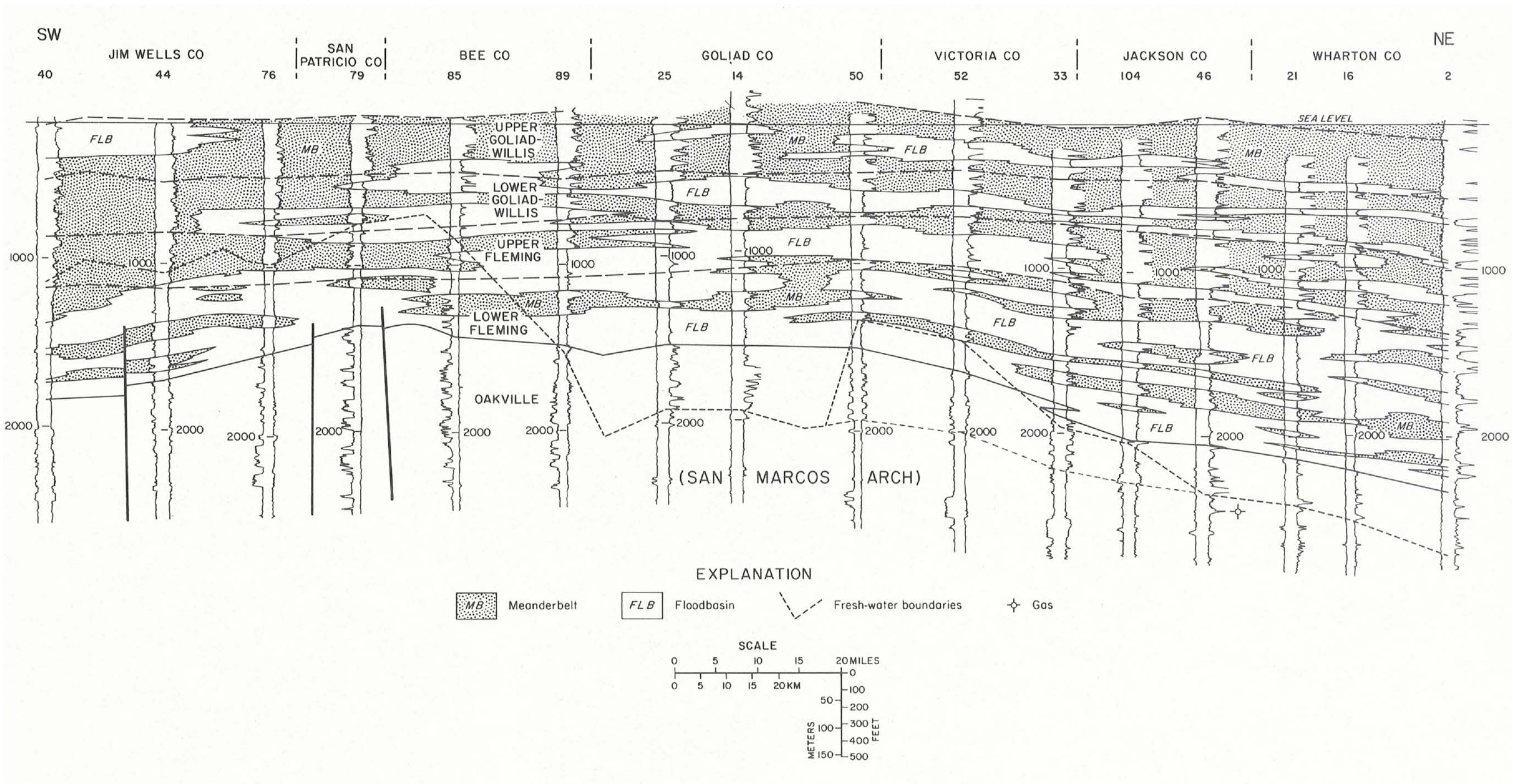


Figure 13. Strike cross section IV. Fault data courtesy of Geomap. See Appendix D for well names.

SALT DOMES

Three salt domes, Palangana, Markham, and Big Hill (Gulf), intruded the upper Miocene-Pliocene sequence in the area (fig. 4). Palangana salt dome, a salt intrusion with a caprock 450 ft (137 m) below the surface, was discovered in the early 1920's in Duval County. The top of the salt is between 850 and 1,000 ft (259 and 305 m), and the caprock consists (from base to top) of gypsum-anhydrite, sulfur, and limestone; total thickness is 440 to 550 ft (134 to 168 m) (Weeks and Eargle, 1960). Lower Fleming and older sediments dip steeply away from the dome. At shallow depths, Goliad sands dip coastward at 20 to 40 ft per mi (6 to 12 m per km) and unconformably overlap Fleming sediments (Hofrichter, 1968). Uranium mineralization occurs in the Lower Goliad-Upper Fleming section above the dome. Weeks and Eargle (1960) described the dome and discussed uranium mineralization. Besides describing the dome, Hofrichter (1968) studied the salt itself. By the end of 1977, the Palangana salt dome had produced 23,088 bbls of crude and 1,201,521 MCF of gas from depths of less than 1,650 ft (503 m) (Appendix C).

Markham salt dome was discovered in 1908 in northwest Matagorda County. The caprock is situated 1,380 ft (421 m) below the surface, and the top of the salt is at 1,417 ft (432 m). Shallow Miocene (below 1,730 ft, 528 m) and Oligocene strata dip steeply away from the fractured dome. Some oil and gas were produced from the caprock and overlying Pliocene sediments (1,240 to 1,500 ft, 378 to 457 m) until deeper traps were discovered in 1931 (Gardner, 1948). Miocene production is reported between 1,730 and 2,300 ft (528 and 701 m), Miocene-Oligocene production from 2,300 to 3,600 ft (701 to 1,098 m), and Frio production from depths deeper than 3,730 ft (1,138 m). Accumulated Markham production from depths shallower than 3,995 ft (1,218 m) is 17,437,230 bbls of crude oil and 1,460 MCF of gas (Appendix C).

Big Hill (Gulf) salt dome, which exhibits a mounded topographic expression, was discovered before 1900. Its caprock is between 825 and 1,300 ft (252 and 396 m) below the surface and consists of an upper thin limestone cap that grades downward into a thick anhydrite section. The flattened top of the salt is about 1,300 ft (396 m) deep (Wolf, 1925). Overlying the caprock are Beaumont clays and slightly sandier Lissie deposits. In sediments above the dome, Wolf (1925) identified ostracods, chara fruit cases, oysters, barnacles, pelecypods, gastropods, and the foraminifers *Rotalia, Polystomella,* and *Anomalina*. Big Hill produced 211,000 bbls of oil between 1904 and 1908 from depths shallower than 1,300 ft (396 m) (Appendix C). Interest in the dome revived in 1919 because of its reserves of sulfur. Big Hill later was one of the nation's largest sulfur-producing deposits until it was depleted in 1936.

SEDIMENT DISTRIBUTION AND DEPOSITIONAL SYSTEMS

Fisher and McGowen (1967) introduced the concept of depositional systems and defined them as three-dimensional, genetically defined stratigraphic units that consist of process-related sedimentary facies. Depositional systems are process-response systems that constitute the principal building blocks of a sedimentary basin fill (Galloway, 1979b). Terrigenous depositional systems in this study were defined by the following criteria:

1) Position of the systems within the sedimentary fill: laterally, vertically, and within the complete facies tract.
2) Lithologic composition: stratal variations based on log-response patterns.
3) Sediment distribution: net-sand values and sand-shale ratios or percentages and their differential geographic distribution.
4) Three-dimensional geometry and orientation of the system.

Sediment distribution within each operational unit is illustrated by a net-sand map and a sand-percentage map. The maps are complementary and provide the basis for corresponding interpretive or depositional systems maps.

The following is an analysis of sediment distribution and depositional patterns for each lithostratigraphic operational unit from late Miocene to Pleistocene age in the region.

LOWER FLEMING OPERATIONAL UNIT

The Lower Fleming is the thickest unit (up to 2,000 ft, 610 m, beneath the coastline area) investigated in this study. It consists predominantly of shales that include relatively thin updip fluvial sands and relatively thick downdip coastal sands in the upper part of the unit (figs. 5 to 13). Dip rates at the base of this unit, calculated from all constructed dip sections, range between 50 and 56 ft per mi (9.5 and 10.6 m per km). Beneath the present lagoon and barrier islands of the central Coastal Zone of Texas, the top of the Lower Fleming unit is at depths that range from 2,600 ft (793 m) in the southwestern area to 3,100 ft (945 m) in the eastern area (fig. 40). Its base in the same areas is from 4,400 to about 5,000 ft (1,340 to 1,525 m) deep (fig. 14).

The recognition of depositional systems within this unit is based on criteria stated in the section "Sediment Distribution and Depositional Systems" of this report. Determination of sediment distribution, represented by a net-sand map and a sand-percent map (figs. 15, 16), provides the basis for the interpretation of depositional systems (fig. 17). Three principal

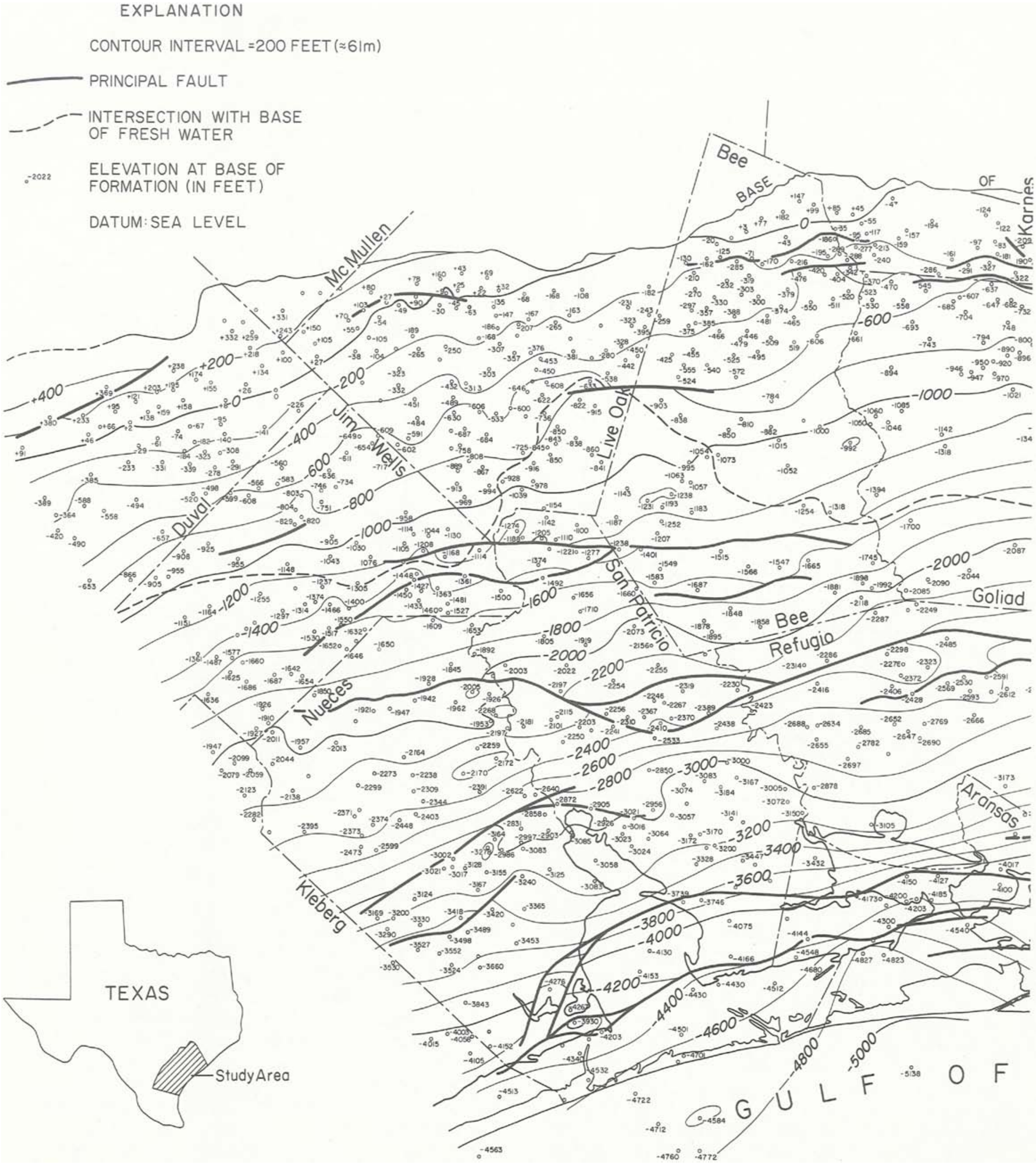
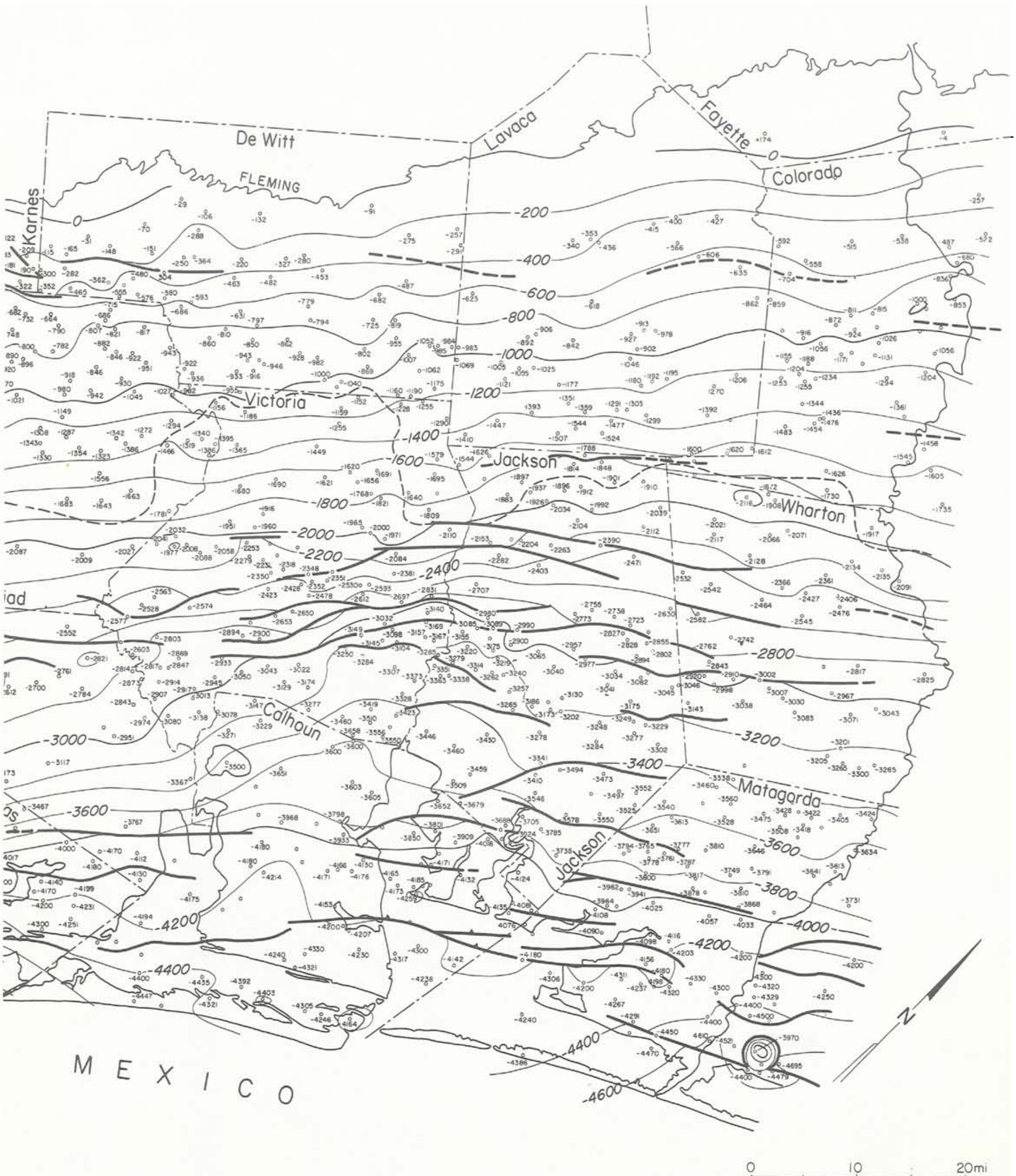


Figure 14. Structural map, base of Fleming



Formation. Fault data courtesy of Geomap.

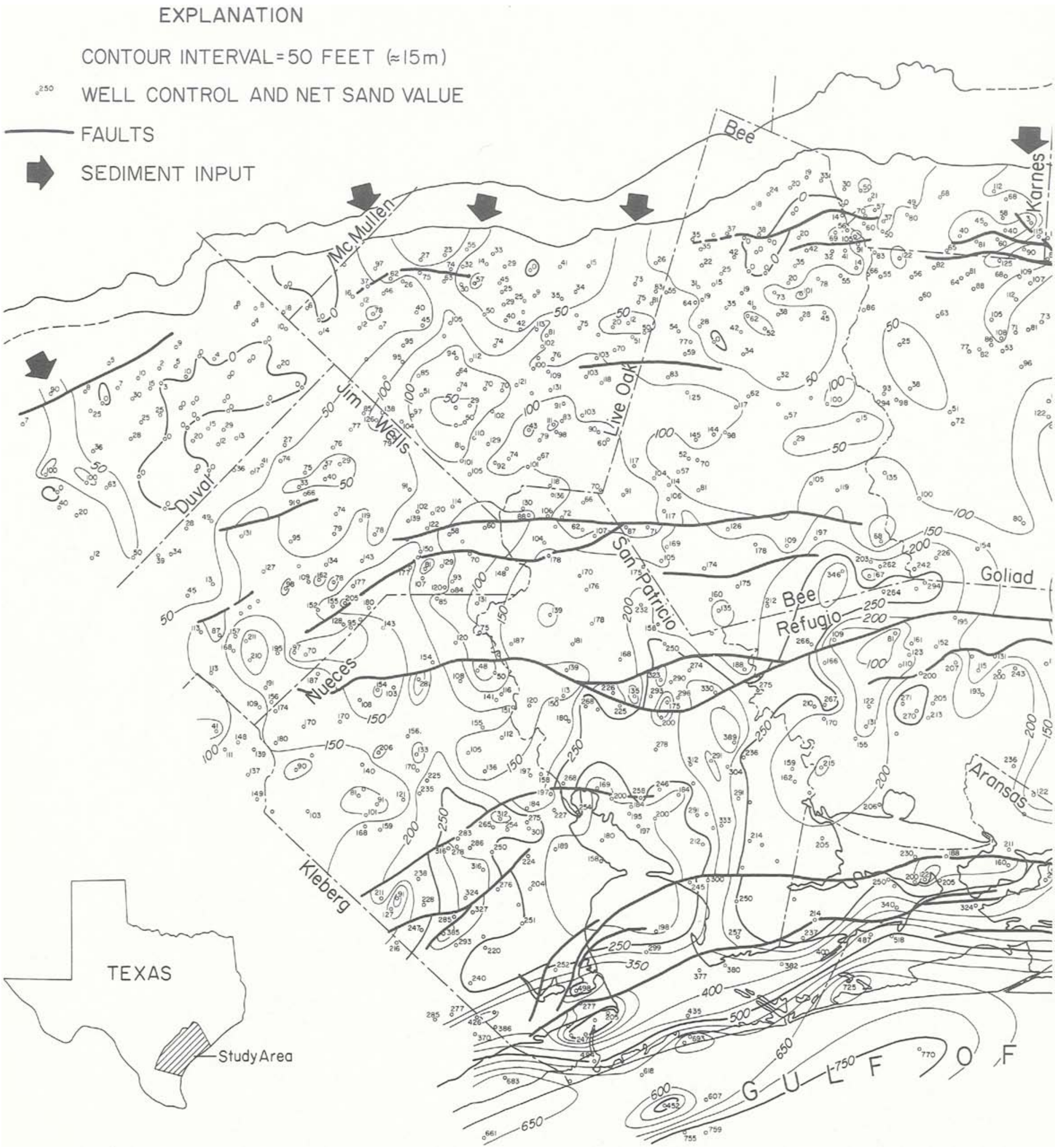
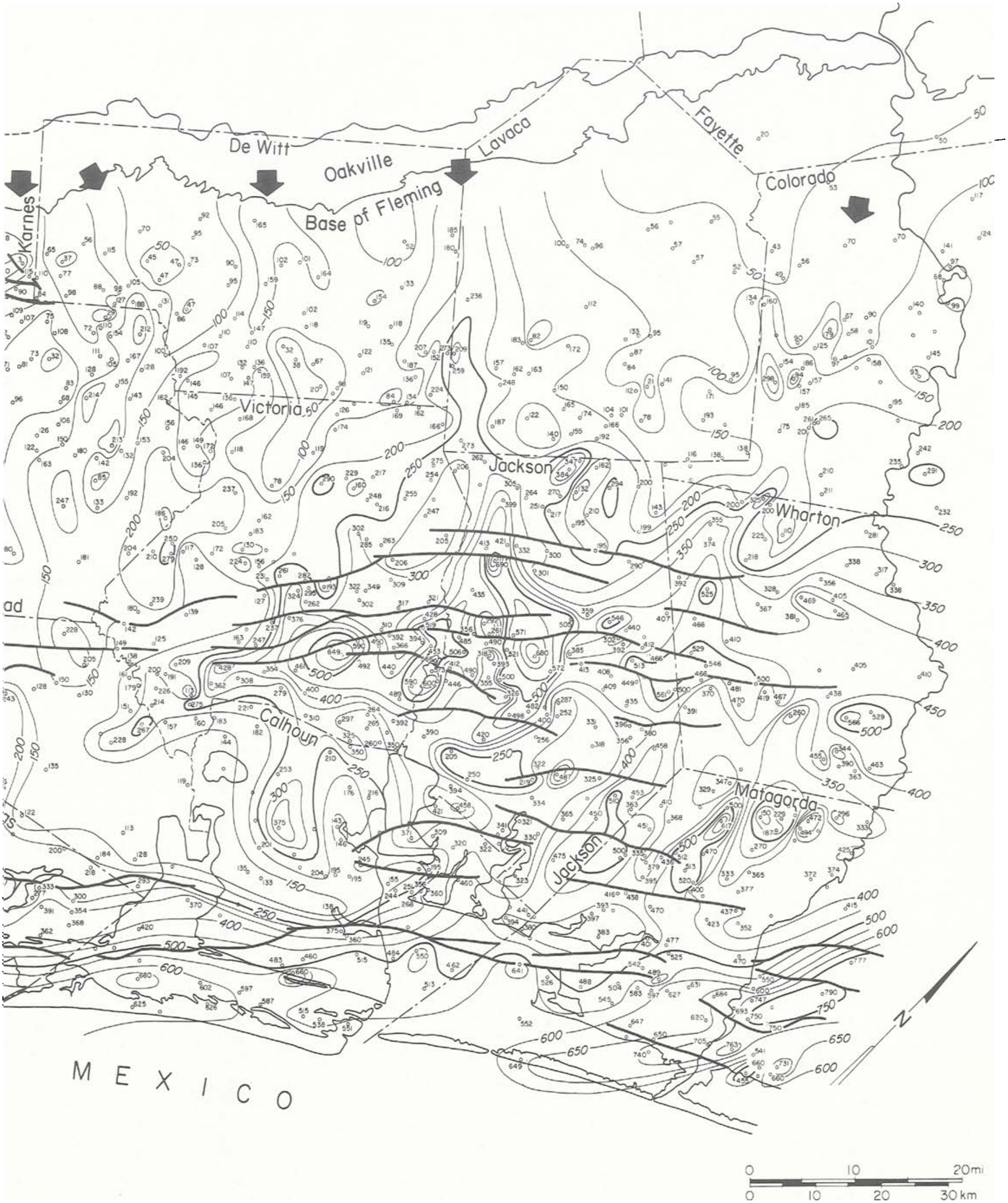


Figure 15. Net-sand map, Lower Fleming



operational unit. Fault data courtesy of Geomap.

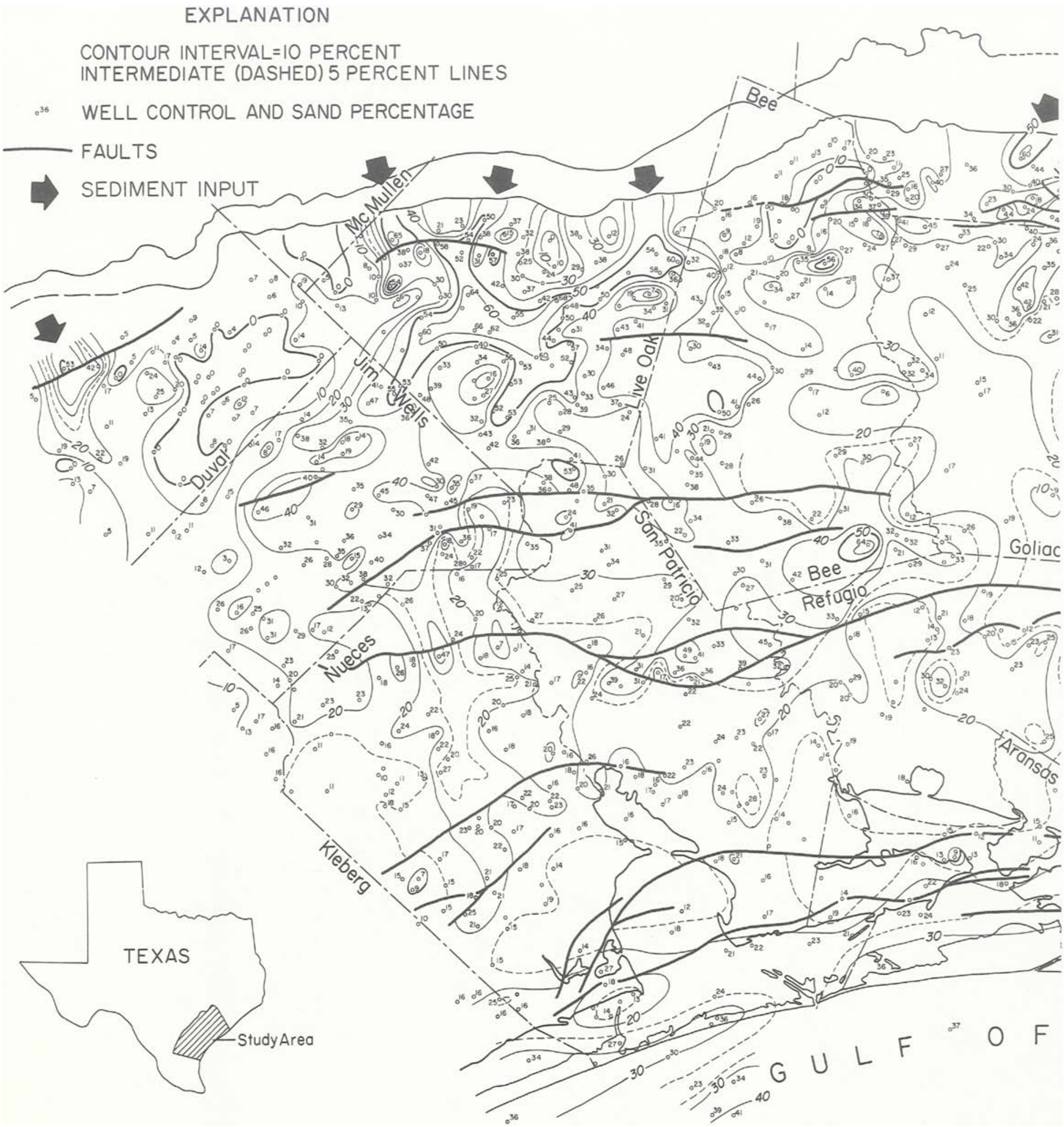


Figure 16. Sand-percentage map, Lower Fleming

operational unit. Fault data courtesy of Geomap.

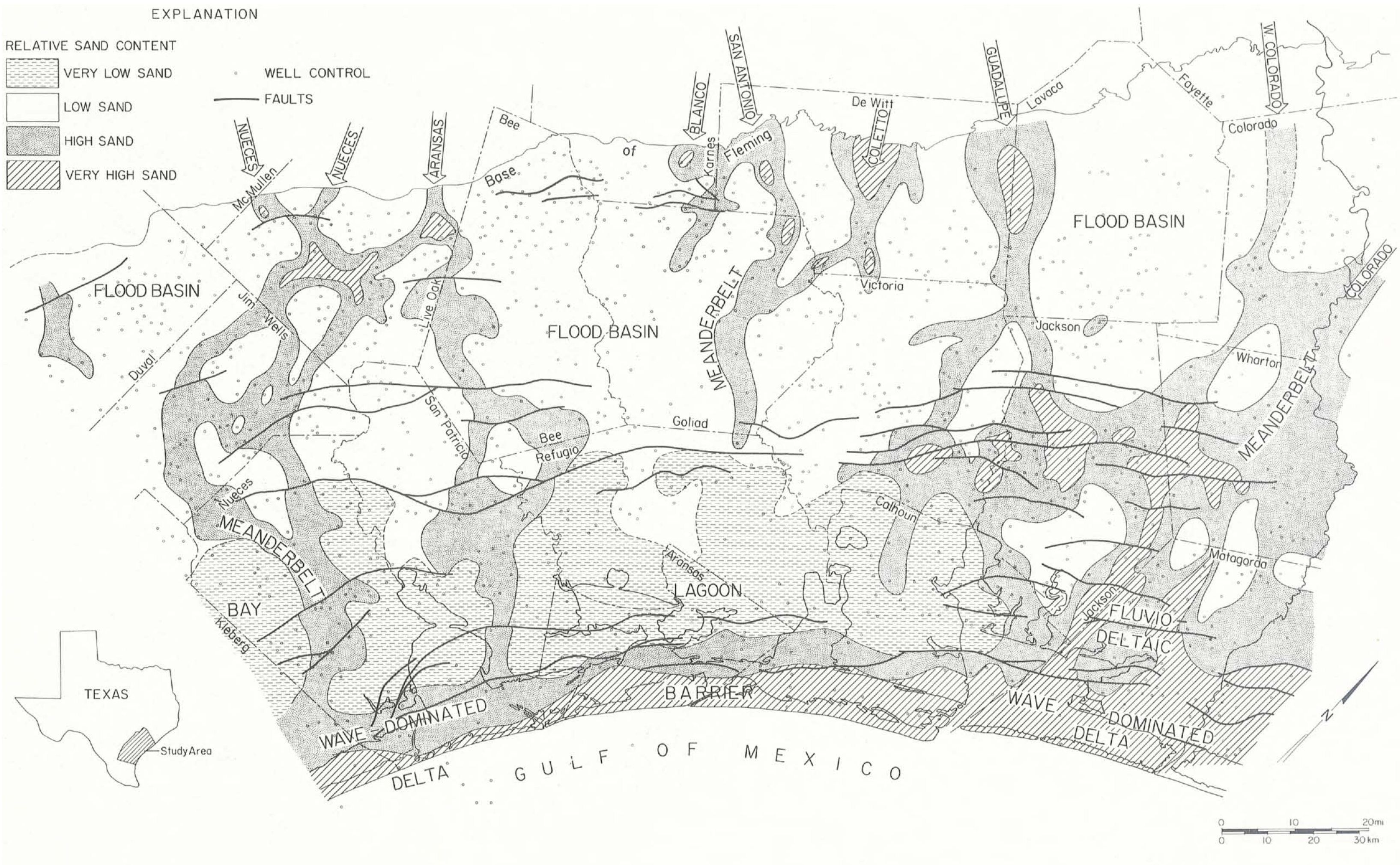


Figure 17. Depositional systems, Lower Fleming operational unit. Fault data courtesy of Geomap.

depositional systems were identified within this unit: (1) fluvial meanderbelt and interfluvial-interdeltaic floodbasin, (2) wave-dominated deltaic to coastal barrier, and (3) lagoonal.

Fluvial System

The fluvial system is composed of two component facies: meanderbelt and interfluvial-interdeltaic floodbasin facies.

Fluvial braided to meanderbelt facies.— Recognition of these sand axes is based primarily on lithology, geometry, orientation, vertical sequence of sands, floodplain-mud setting, sinuosity, and anastomosing of sand trends. The updip parts of these trends probably consist of braided-stream sands, as indicated by their dip orientation and outcrop descriptions (Plummer, 1932; Barnes, 1974, 1975). It should be noted that sediments underlying (Oakville) and overlying (Goliad) this formation are known to contain in outcrop coarse sands and gravels typical of braided streams (Galloway, 1979a; Plummer, 1932; Barnes, 1974).

Five main meanderbelts, or sand axes, were recognized within the Lower Fleming unit. From southwest to northeast they are the relict Nueces, Aransas, Blanco-San Antonio-Coletto, Guadalupe, and West Colorado-Colorado river systems. The Lower Fleming Guadalupe and Colorado Rivers were the most active in the area during deposition of the Lower Fleming. They transported large volumes of sand coastward to supply a large wave-dominated deltaic and coastal barrier complex (fig. 17). The less active western rivers, the Nueces and Aransas, prograded across a coastal lagoon and constructed minor wave-dominated deltas, which were subsequently reworked and incorporated into an extensive coastal barrier complex by marine processes (fig. 17).

The western meanderbelts (Nueces and Aransas) are separated from the eastern ones by a relatively large area of floodbasin facies in Bee, Goliad, and Refugio Counties (fig. 17). The absence of important meanderbelts in this area, together with slight differences in dips southwest and northeast of this area and the gentle arching of Lower Fleming and Oakville sediments (fig. 13), indicates clearly the structural influence of the San Marcos Arch on sediment distribution.

The Guadalupe and Colorado meanderbelts coalesce in southeast Victoria, central Jackson, and Wharton Counties to develop important fault-influenced, strike-oriented sand thicks on the downthrown sides of shallow extensions of the Vicksburg fault system (figs. 10, 15, 17). Similar depocenters were deposited along the Aransas fluvial axis in Bee and San Patricio Counties (figs. 7, 15, 17).

High net- and percentage-sand values for the Lower Fleming meanderbelts are presented in table 3.

Table 3. High net-sand and sand-percentage values for the Lower Fleming meanderbelts.

System	Facies	Net sand (ft)	Sand %	Location (county)
Nueces	UD.MB. DD.MB.	75-125 125-200	45-65 20-30	Live Oak Nueces
Aransas	UD.MB. DD.MB.	100-145 225-325	40-50 20-40	S.E. Live Oak-W. Bee San Patricio
Blanco-San Antonio-Coletto	UD.MB. DD.MB.	100-165 150-250	40-60 25-45	Karnes-De Witt S.E. Goliad
Guadalupe	UD.MB. DD.MB.	100-250 350-600	40-60 20-40	De Witt-Lavaca S.E. Victoria-Jackson
W. Colorado-Colorado	UD.MB. DD.MB.	150-250 350-500	30-40 30-40	S. Colorado Wharton-E. Jackson

Note: UD.MB. = Updip meanderbelt; DD.MB. = Downdip meanderbelt.

These meanderbelts consist of thick superposed point-bar sequences interrupted laterally and vertically by thin overbank, floodbasin, or channel-fill muds. Most of the sands of these systems lie within the fresh-water zone; hence, SP curves are flat and resistivities are high on well logs. These facies are well illustrated on the updip parts of cross sections (figs. 8, 10, 11, 13).

Interfluvial-interdeltaic floodbasin facies.—This facies of the fluvial system, together with a similar one in the Upper Fleming unit, makes up most of the updip and outcropping Fleming Formation (p. 6 to 8). In the subsurface, the interfluvial-interdeltaic floodbasin facies consists predominantly of clay-shale deposits containing thin intercalated sands, which were deposited in minor abandoned channels and crevasse splays. Downdip in the upper part of the Lower Fleming unit, this facies grades gulfward into coastal lagoon facies (fig. 17). Floodbasin muds are well developed in the western half of the area of study and are illustrated in cross sections (figs. 5, 6, 7, 13). Thin sands within this facies lie within the fresh-water zone but do not constitute significant fresh-water reservoirs.

Wave-Dominated Delta - Coastal Barrier Complex

The relict Guadalupe, West Colorado, and Colorado Rivers contributed sediment to a large and thick (up to about 650 ft, 198 m, of net sands) wave-dominated deltaic system in Matagorda County (fig. 17). This system, which constitutes the upper part of the Lower Fleming section, is composed of thick, massive delta-front sands and relatively thin delta-plain muds. In some areas, deltaic sands are composed of two main cycles of sand. These sandy sediments are underlain by distal-deltaic, prodeltaic, and open-bay or shallow-marine shales. This system is illustrated on cross sections (figs. 10, 11, 12). In the western part of the study area, the Nueces and Aransas Rivers prograded deltas across the coastal lagoon system and constructed minor wave-dominated delta systems along the open Gulf shoreline. Subsequently, these deltaic sands were reworked and incorporated into an extensive coastal barrier system, which is outlined by a strike-oriented geometry of sands in coastal Nueces and Aransas Counties (fig. 17).

Southwest of the Guadalupe-Colorado deltaic system of the Lower Fleming is a thick, wide strike-oriented coastal complex that extends along coastal Calhoun, Aransas, and Nueces Counties (fig. 17). This system is composed of superposed, laterally coalesced barrier sand bodies exhibiting up to 600 ft (183 m) of net sand (fig. 15). Barrier sands are intercalated with relatively thin shales, probably tidal flat, lagoon, or shallow-bay mud facies. This coastal barrier sequence is underlain by undifferentiated open-embayment and shallow-marine shales. High net- and percentage-sand values for the coastal sand complex are given in table 4.

Table 4. High net-sand and sand-percentage values for the Lower Fleming coastal sand complex.

System	Net sand (ft)	Sand %	Location (county)
Western W.D.D.-C.B.	300-650	20-40	Coastal and offshore Nueces
Central C.B.	350-575	20-40	Coastal Aransas and Calhoun
Eastern W.D.D.	400-700	27-50	Matagorda and eastern Calhoun

Note: C.B. = Coastal barrier; W.D.D. = Wave-dominated delta.

The landward part of the coastal barrier system is composed of interbedded sands and shales, indicating alternating deposition of lagoon, barrier bar, and/or washover fan (figs. 6, 7, 8). Marine processes reworked and distributed sands along the entire coastal delta-barrier complex. Besides the fluvial sources of sand in the study area, some of the sand within the coastal complex was probably derived from more eastern sources, such as the ancient Brazos or Trinity deltaic systems. Miocene faults exerted structural influence on sediment distribution and orientation of the delta-barrier complex. Miocene faults are located landward and parallel to the coastal sand deposits, marking the boundary between the coastal barrier and the landward lagoonal facies or between the thick deltaic sands and the thinner updip deltaic sands (figs. 15, 17).

These salt-water-bearing sands exhibit on well logs high negative SP deflections and low resistivities that indicate good porosities. Additional well control offshore is needed to determine the gulfward configuration of this coastal sand complex. Nevertheless, data from offshore Nueces County indicate that the middle to late Miocene coastline was situated at least 12 mi (19 km) offshore from the present shoreline (figs. 15, 17).

Lagoon System

A wide and extensive lagoonal system occurs landward of the coastal barrier in the Lower Fleming unit (fig. 17). Lagoonal facies consist predominantly of shales and thin interbedded sands. The low sand content of these facies represents bayhead deltas and washover fans periodically introduced into the lagoon environment. These facies grade landward into fluvial floodbasin facies; the transition is not clear and is determined only by a relative difference in net-sand content.

Lagoonal facies are underlain by prodelta muds, open-embayment muds, or shallow-marine shales that constitute the lower part of the Lower Fleming unit. Shallow-marine foraminifers such as *Amphistegina, Eponides,* and *Cibides opima* are reported in this part of the Fleming (fig. 5). The lagoonal facies occur west of Calhoun County (figs. 5 to 9, 12).

UPPER FLEMING OPERATIONAL UNIT

The Upper Fleming operational unit is composed in outcrop of shales and clays that contain thin sand beds. Minor amounts of feldspar, chert, reworked fossils of Cretaceous invertebrates and Miocene vertebrates are also reported in the outcrop. This unit conformably overlies Lower Fleming sediments and uncomformably underlies Goliad and Willis sands (Doering, 1935). The Upper Fleming unit dips basinward at 38 to 44 ft per mi (7.2 to 8.3 m per km) (calculated from all 20 dip sections).

Beneath the present lagoons and barrier islands of the study area, the top of the Upper Fleming is at depths that range between 2,000 ft (610 m) in the southwestern area and 2,400 ft (732 m) in coastal Matagorda County. The base of this unit for the same areas ranges from 2,600 to 3,100 ft (793 to 945 m), respectively (see fig. 40, p. 72).

Sediment distribution is presented on net-sand and sand-percent maps (figs. 18, 19), which provided the basis for construction of an interpretive Upper Fleming depositional systems map (fig. 20).

The Upper Fleming unit consists of three principal depositional systems: (1) fluvial braided to meanderbelt and interfluvial-interdeltaic floodbasin system, (2) wave-dominated delta system, and (3) lagoon system.

Fluvial System

Fluvial braided to meanderbelt facies.—Nine principal fluvial braided belts to meanderbelts were identified within the Upper Fleming unit. For the same reasons explained in the section entitled "Fluvial braided to meanderbelt facies" of the Lower Fleming unit, it is believed that the updip parts of these sand axes consist of braided-stream deposits. These deposits grade downdip into wider belts composed of point-bar sequences of meanderbelt sands that interconnect and develop sand thicks in association with faulting. From southwest to northeast these belts are the relict West Nueces, Nueces, Aransas, Blanco, San Antonio, Coletto, West Guadalupe, Guadalupe, and West Colorado Rivers (fig. 20). Those east of the San Antonio River were the most active in the area since they carried most of the sand deposited within this operational unit. An examination of the updip net-sand distribution in these meanderbelts indicates that shallow extensions of the Wilcox fault trend exerted only a minor influence on sediment distribution in Live Oak, Bee, and Karnes Counties (figs. 18, 20). Downdip, shallow extensions of Vicksburg faults strongly influenced sediment distribution and orientation of the fluvial systems in southeast Jim Wells, northwest Nueces, and northern Refugio Counties. More importantly, massive strike-oriented sand depocenters developed in Jackson and southeast Victoria Counties on the downthrown sides of extrapolated Vicksburg faults (figs. 18, 20).

High net-sand and sand-percentage values for the Upper Fleming meanderbelts are given in table 5.

Table 5. High net-sand and sand-percentage values for the Upper Fleming meanderbelts.

System	Facies	Net sand (ft)	Sand %	Location (county)
W. Nueces	UD.MB. DD.MB.	100-175 200-300	40-52 40-65	Jim Wells N.W. Nueces
Nueces	UD.MB.	80-130	50-70	Live Oak
Aransas	UD.MB.	80-130	50-70	Live Oak
Blanco	UD.MB. DD.MB.	100-150 130-200	40-60 40-50	N.E. Bee-N.W. Goliad Bee-Refugio county line area
San Antonio-Coletto	DD.MB.	100-225	30-53	S.E. Goliad
W. Guadalupe	DD.MB.	225-375	60-75	S. Victoria
Guadalupe	UD.MB. DD.MB.	150-325 200-325	60-76 60-70	S. Lavaca-N.W. Jackson Jackson
W. Colorado	DD.MB.	225-300	50-65	Wharton

Note: UD.MB. = Updip meanderbelt; DD.MB. = Downdip meanderbelt.

Most fluvial sands occur in the fresh-water zone and exhibit flat or poor SP deflections and high resistivities on well logs. This facies is present in most dip sections and updip strike sections (fig. 13).

Interfluvial-interdeltaic floodbasin facies.—Floodbasin overbank and channel-fill muds were deposited over large updip parts of the study area. The relatively low amount of sand in this facies was deposited in minor tributary or abandoned channels and crevasse splays. This facies grades downdip into a lagoon and lagoon-marsh system in southern Nueces and southeast San Patricio Counties (fig. 20). Most Miocene vertebrates in the outcrop, including several species of horse, are found in floodbasin calcareous clays and shales. This facies is well represented in the updip zone of the study area (figs. 5, 7, 13). Thin sands within this system exhibit flat SP curves and relatively high resistivities on well logs.

Wave-Dominated Delta System

Most of the late Fleming rivers contributed sediment to the wave-dominated deltaic complex where thick sands were deposited in Aransas and Calhoun Counties (figs. 18, 20). Principal sand contributors were the relict San Antonio, Coletto, West Guadalupe, and Guadalupe Rivers.

This delta system consists of thick superposed delta-front sands and intercalated delta-plain shales underlain by distal deltaic and prodelta shales (figs. 5 to 9, 12). Sand depocenters in this system in Aransas and Calhoun Counties display net-sand values between 350 and 450 ft (107 and 137 m) and sand-percent values between 45 to 65 percent (figs. 18, 19). These saline-water sands exhibit on well logs high negative SP deflections and low resistivities, indicating good porosities.

Miocene faulting influenced sediment distribution in this system. Thicker sands with strong strike-oriented geometry were deposited on the downthrown side of faults (figs. 8, 18, 20). The most landward Miocene faults in Aransas and southeast San Patricio Counties separate the deltaic system from the lagoonal facies (fig. 20). The eastern part of this system in Matagorda County is a delta-margin strandplain facies. Sand beds less than 100 ft (30.5 m) thick are regularly interbedded with relatively thick (tidal flat?) shales (figs. 10, 11, 12).

The interpretation of well logs offshore from Nueces and Aransas Counties and the areal geometry of this wave-dominated deltaic system indicate that the late Miocene coastline was situated at least about 10 mi (16 km) offshore from the present coastline (fig. 20).

Lagoon System

A relict lagoon-marsh system is inferred to exist along parts of the landward side of the wave-dominated delta system (fig. 20). These facies consist of thick shales that include a few relatively thin sands that grade updip into floodbasin and meanderbelt facies (figs. 5, 6, 8, 12).

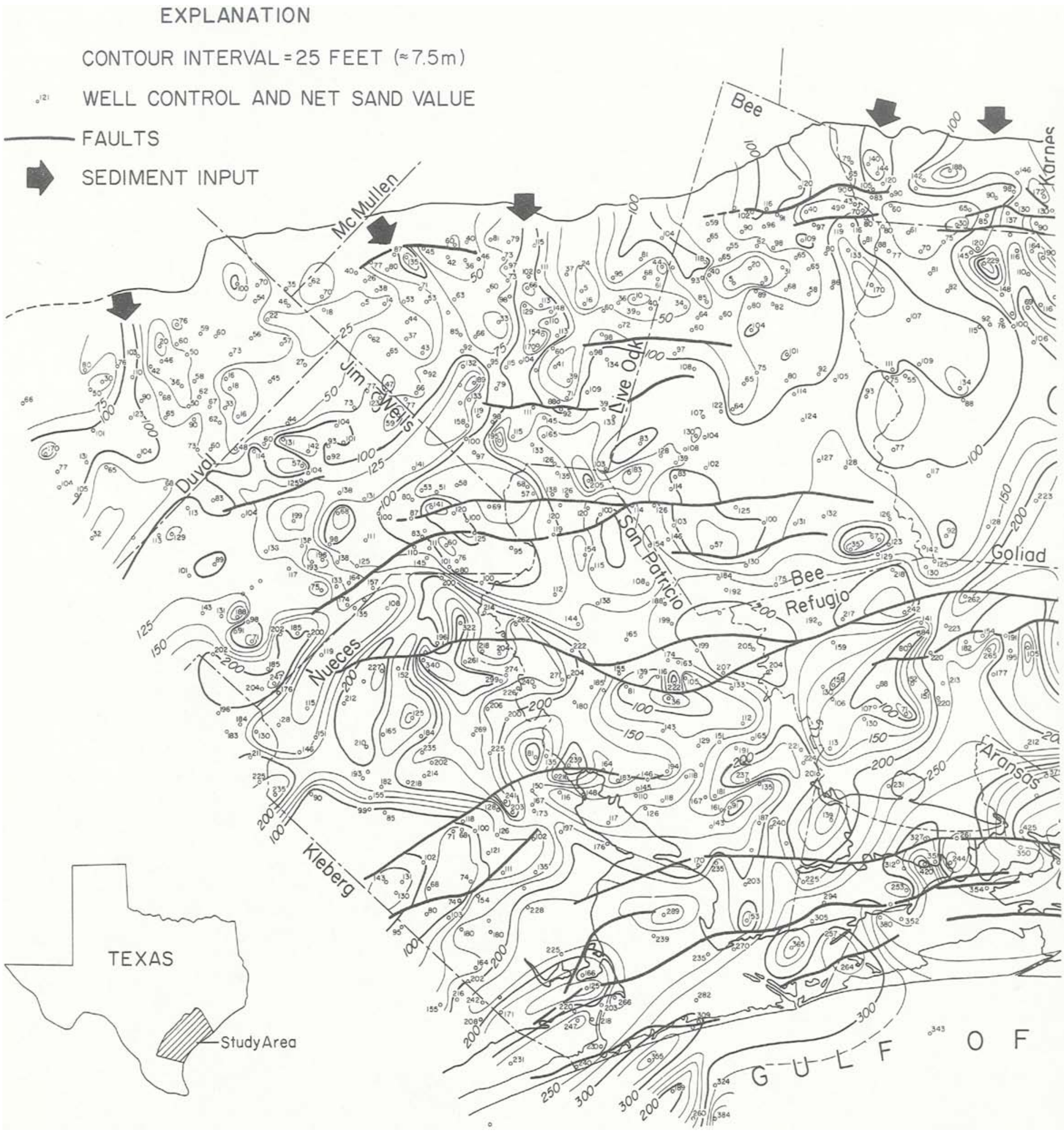


Figure 18. Net-sand map, Upper Fleming

operational unit. Fault data courtesy of Geomap.

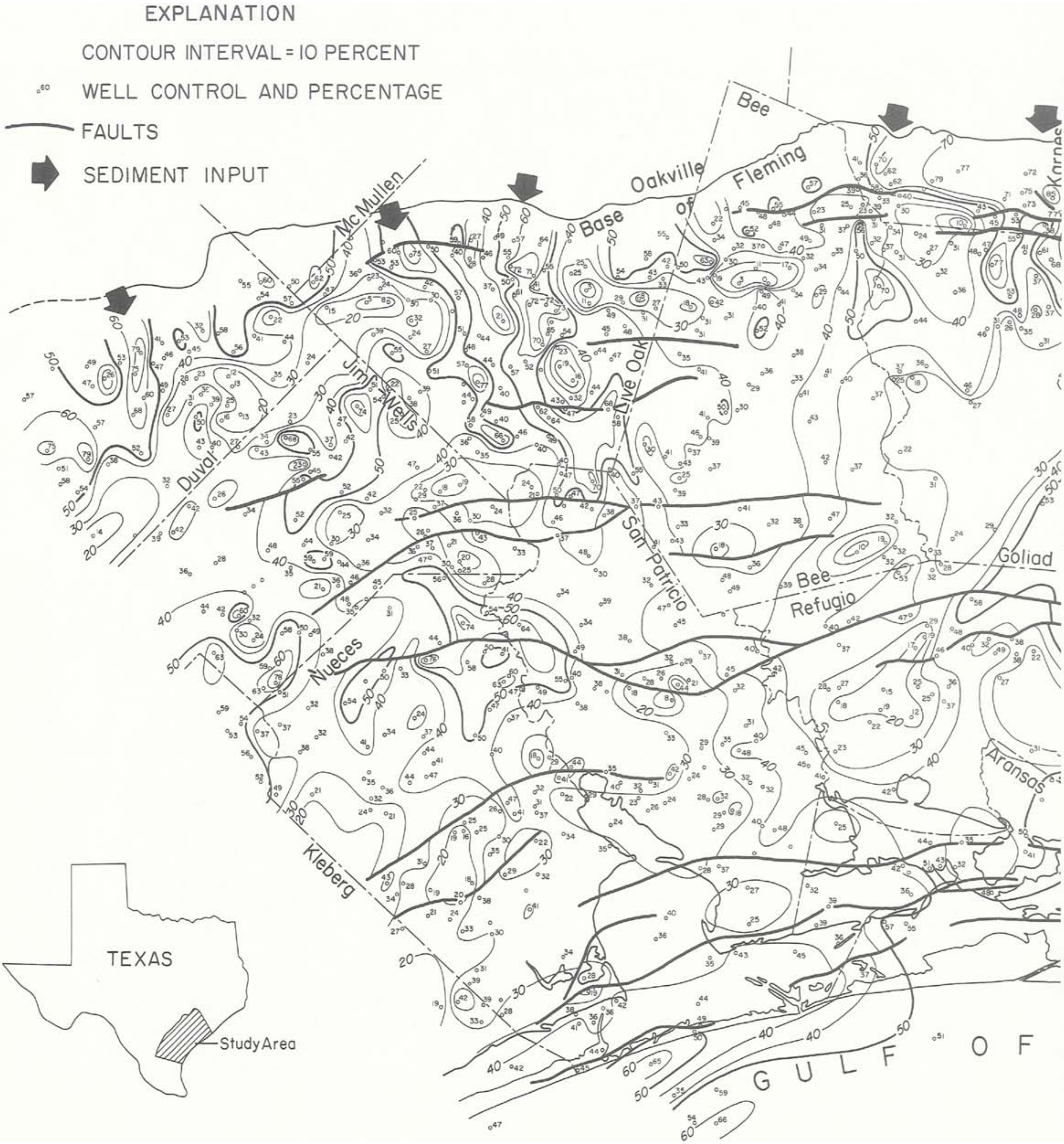


Figure 19. Sand-percentage map, Upper Fleming

operational unit. Fault data courtesy of Geomap

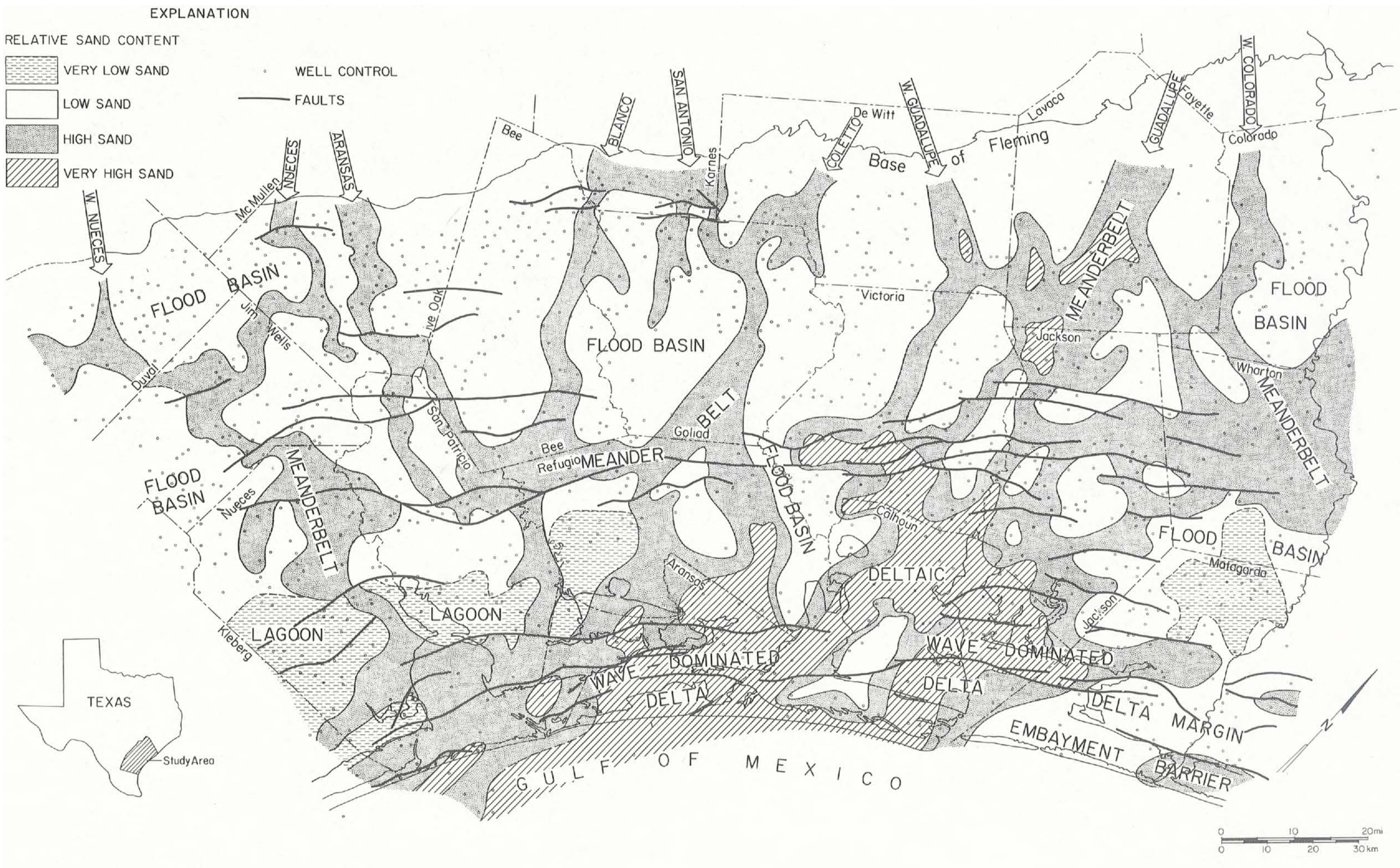


Figure 20. Depositional systems, Upper Fleming operational unit. Fault data courtesy of Geomap.

LOWER GOLIAD-WILLIS OPERATIONAL UNIT

Numerous fluvial meandering courses crossed the area during early Pliocene time. Sediment distribution within this unit is depicted by a net-sand and sand-percent map. Much of the deposited sand was concentrated in the central and coastal regions of the study area (figs. 21, 22, 23), where contemporaneous faulting greatly influenced sediment distribution and orientation of sand trends. The base of this unit dips coastward at 33 to 36 ft per mi (6.2 to 6.8 m per km).

Four principal depositional systems were identified within the Lower Goliad-Willis operational unit: (1) a fluvial braided-meanderbelt and interfluvial-interdeltaic floodbasin system, (2) a central fluviodeltaic system, (3) a coastal barrier - wave-dominated deltaic system, and (4) a lagoonal system.

Table 6. High net-sand and sand-percentage values for the Lower Goliad-Willis meanderbelts.

System	Facies	Net sand (ft)	Sand %	Location (county)
W. Nueces	UD.MB. DD.MB.	150-200 175-250	60-80 60-75	Duval N.W. Kleberg, S.E. of Alice, Jim Wells
Nueces	UD.MB. DD.BHD.	200-230 250-330	60-75 55-75	N.W. Nueces S.E. Nueces
Aransas	UD.MB. DD.MB.	200-250 250-350	65-85 65-85	S.E. Live Oak N.W. San Patricio
Blanco	UD.MB.	175-250	60-75	S.E. Bee, S.W. Goliad
San Antonio	UD.MB. FLD.	175-250 275-390	70-85 60-80	S.E. Goliad Refugio
Coletto-Guadalupe, Guadalupe	UD.MB. FLD.	150-225 200-375	50-75 60-80	N. Victoria-N.W. Jackson S.E. Victoria
W. Colorado	UD.MB. DD.MB.	125-200 275-375	50-70 65-80	W. Colorado-S.E. Lavaca Wharton

Note: UD.MB. = Updip meanderbelt; DD.MB. = Downdip meanderbelt; DD.BHD. = Downdip bayhead delta; FLD. = Fluviodeltaic.

Fluvial System

Fluvial braided to meanderbelt facies.—Seven main sand axes were identified within the Lower Goliad-Willis unit. The updip parts of these trends are composed of braided bed-load sands and gravels (Plummer, 1932; Doering, 1935; Barnes, 1974, 1975). These sediments grade downdip into wider and coalescing sand axes interpreted to be meanderbelt facies. From southwest to northeast they are the relict West Nueces, Nueces, Aransas, Blanco, San Antonio, Coletto-Guadalupe, Guadalupe, and West Colorado meanderbelts (fig. 23). Of these, the three westernmost systems carried lesser amounts of sediment and deposited thinner point-bar sequences than those in the eastern part of the study area. Most of the meanderbelts coalesce and interconnect laterally. Anastomosing channels, sediment loading, and contemporaneous faulting resulted in development of sand thicks with approximate strike orientations. This is evident in southern Bee, Refugio, and southeast Victoria Counties, where up to about 400 ft (122 m) of net sand was deposited (figs. 21, 23). Electric log patterns of these facies indicate thick, superposed point-bar deposits interbedded with floodbasin or channel-fill muds (fig. 13).

Most of the meanderbelt sands of this unit constitute important parts of the fresh-water aquifer, especially in Bee, Goliad, Victoria, and Jackson Counties. SP deflections are poor or flat, and resistivities are high on well logs. Table 6 lists high net-sand and sand-percentage values for the different meanderbelts, including the central fluviodeltaic system.

Interfluvial-interdeltaic floodbasin facies.—These facies are composed principally of floodbasin shales and clays with relatively low sand content. These sands represent deposition in abandoned or minor channels and crevasse splays. Fossils of vertebrates, notably *Camelidae*, *Rhinoceros*, and *Equidae*, have been reported from these facies (Quinn, 1952, 1955; Plummer, 1932; Wilson, 1960, 1962). This system is best represented in updip areas (figs. 9, 13).

Central Fluviodeltaic System

The relict Blanco, San Antonio, Coletto-West Guadalupe, and Guadalupe Rivers of early Goliad-Willis time constituted the source for thick sands deposited on the downthrown side of shallow extensions of the Vicksburg fault system (figs. 7, 8, 9, 21, 22, 23). These sands attain net thicknesses of 275 to 390 ft (84 to 119 m) (60 to 80 percent sand) in Refugio County and 200 to 375 ft (61 to 114 m) (60 to 80 percent sand) in southeastern Victoria County (see table 6). These observations indicate the influence of contemporaneous growth faults on sediment dispersal and orientation of fluvial meanderbelts (north San Patricio, south Bee Counties, fig. 23) and on fluviodeltaic sands (Refugio, Calhoun, southeast Victoria, and western Jackson Counties, figs. 21, 23).

This system is composed of thick fluviodeltaic sands and relatively thin delta-plain and floodbasin muds (figs. 7, 8, 9, and strike section III). Most of the sands lie within the fresh-water zone and exhibit flat or low SP negative deflections and high resistivities on well logs.

Wave-Dominated Delta - Coastal Barrier Complex

A strike-oriented, wave-dominated deltaic system was deposited in coastal Calhoun and Matagorda

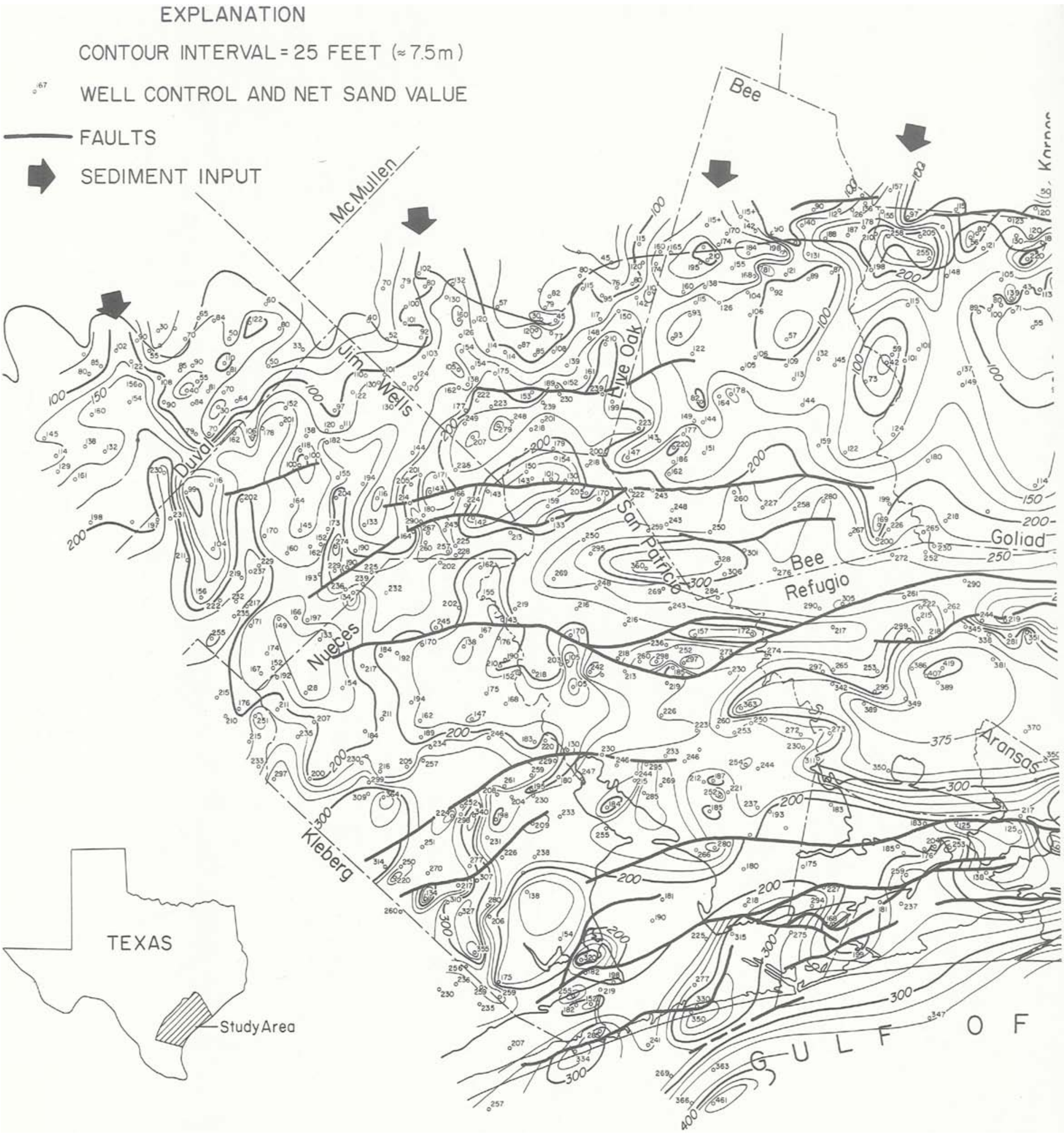
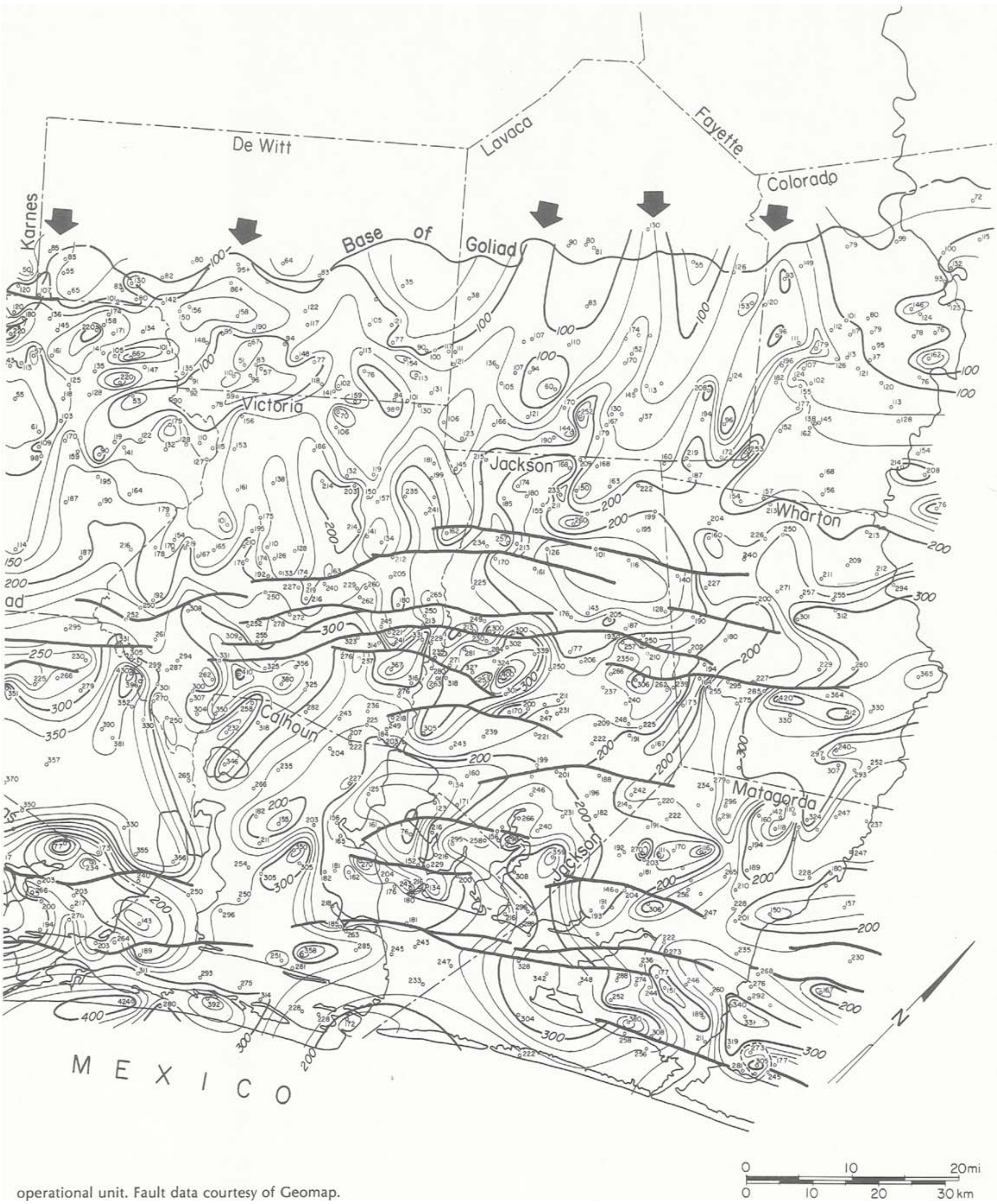


Figure 21. Net-sand map, Lower Goliad-Willis



operational unit. Fault data courtesy of Geomap.

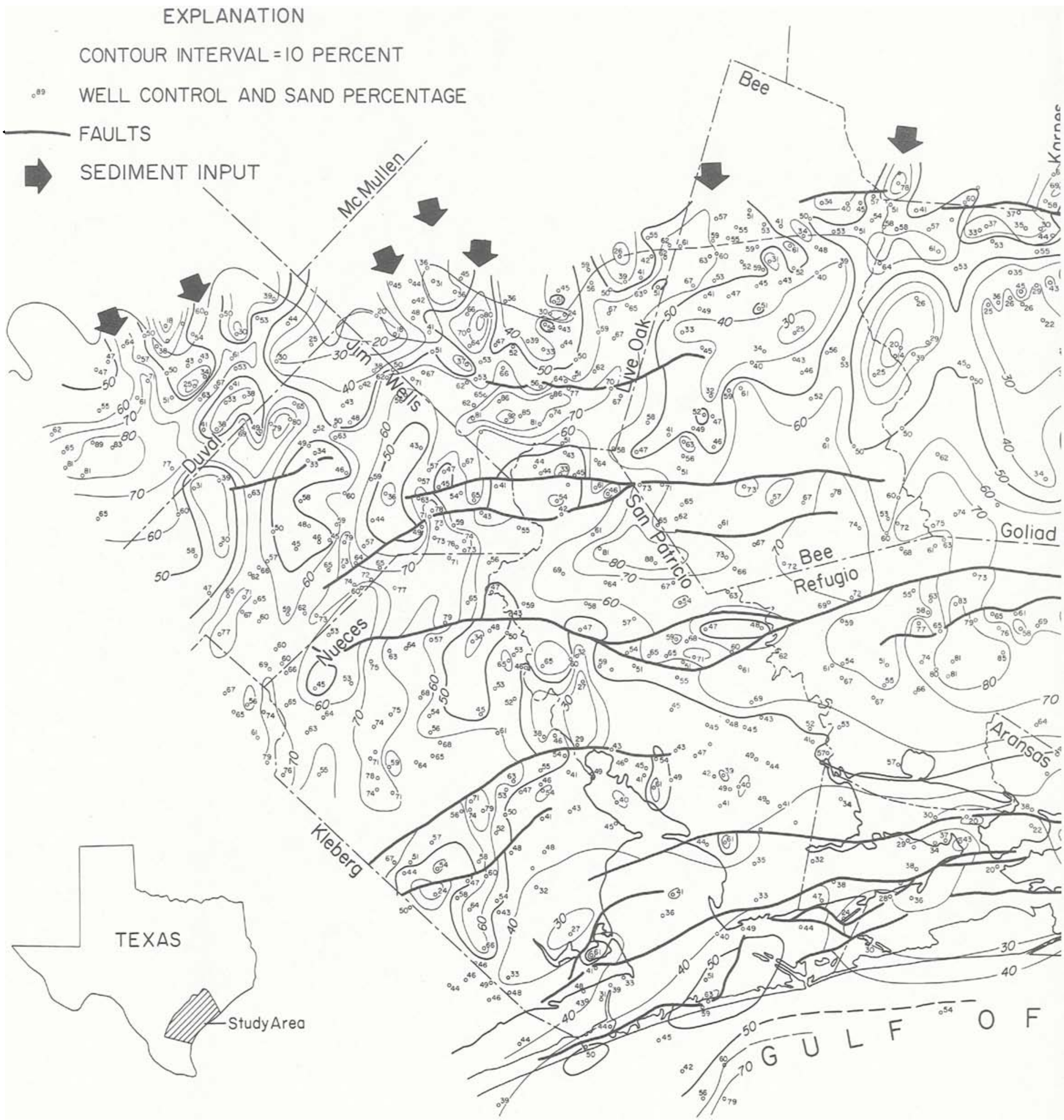
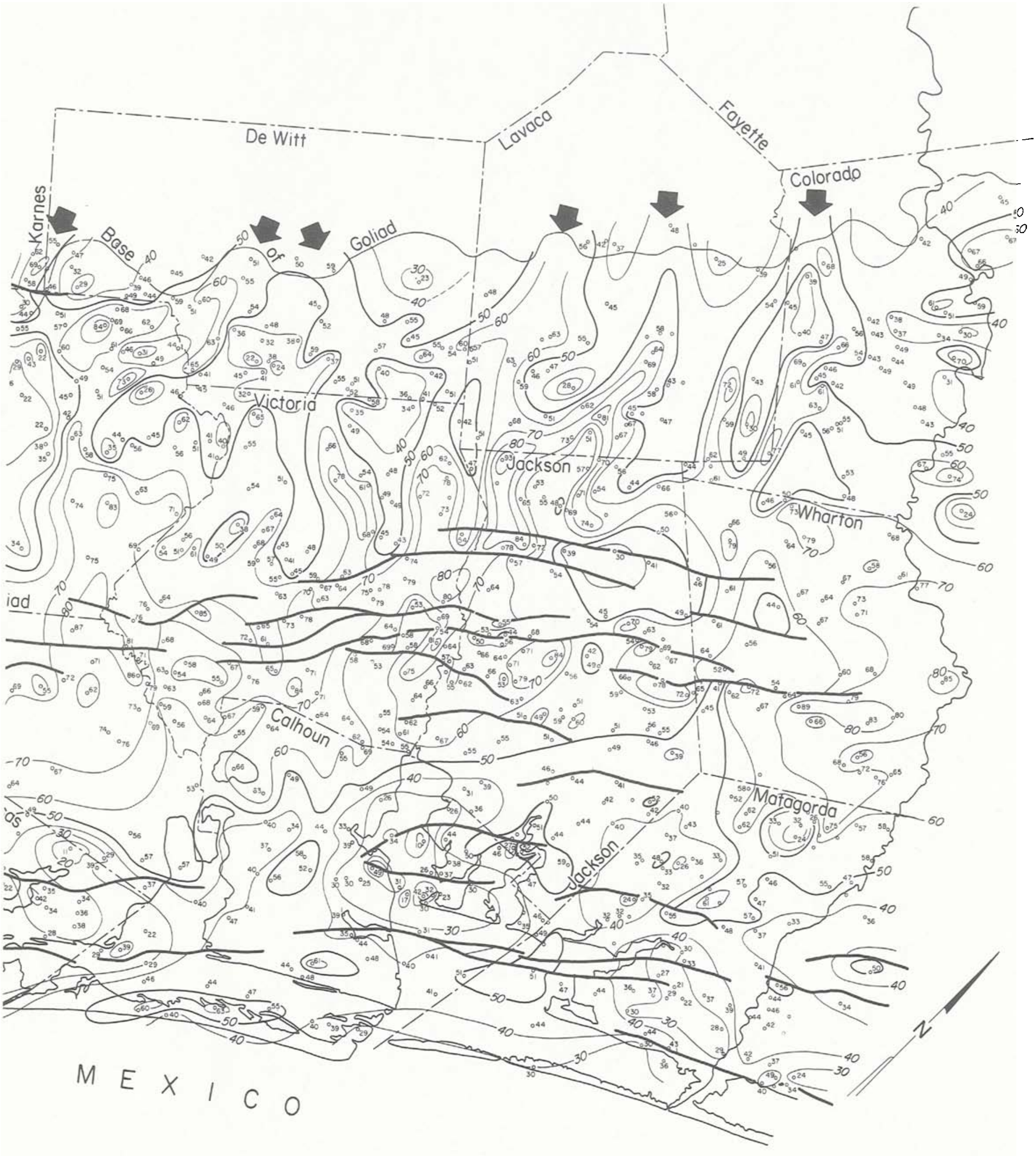


Figure 22. Sand-percentage map, Lower Goliad-



Willis operational unit. Fault data courtesy of Geomap.

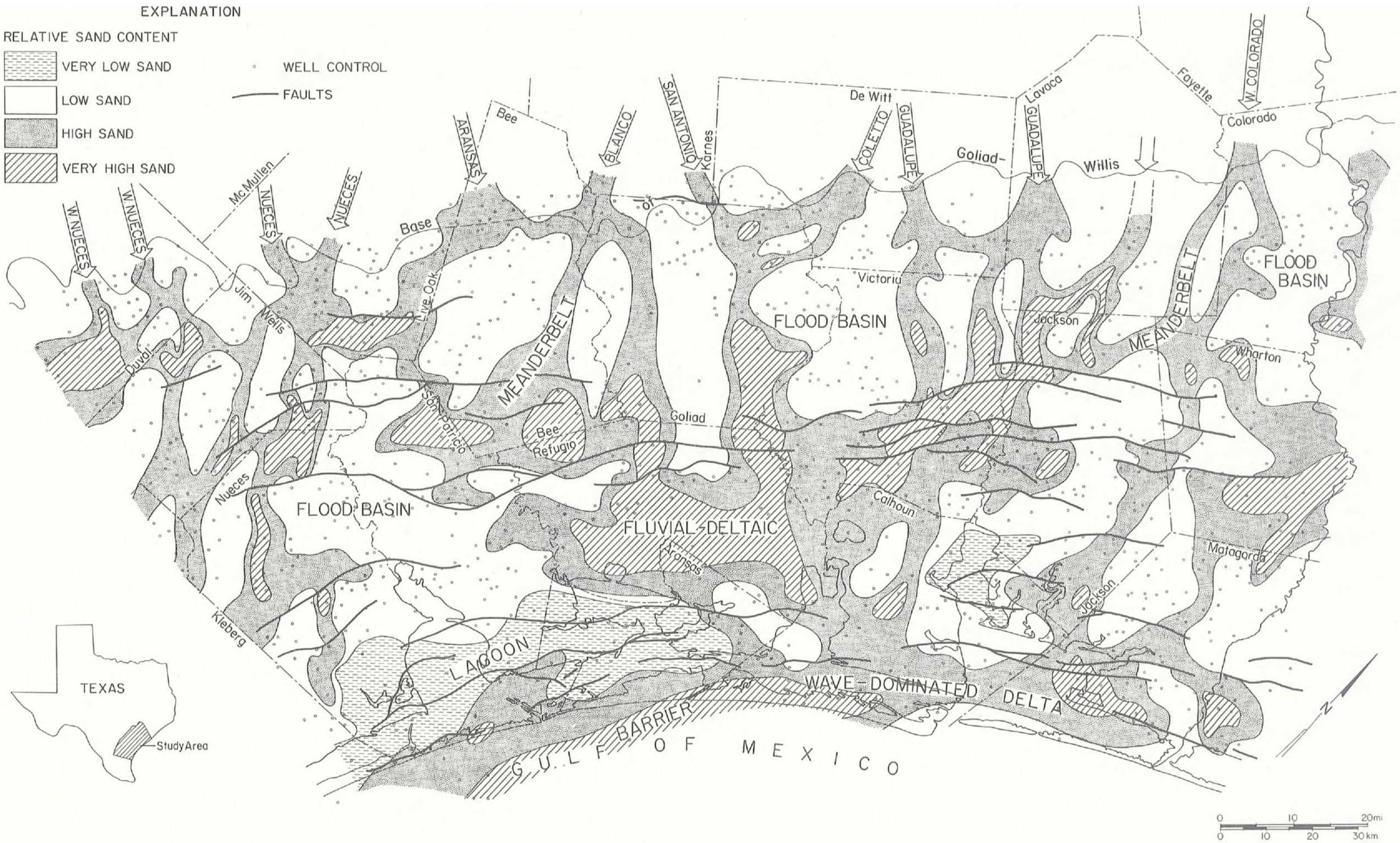


Figure 23. Depositional systems, Lower Goliad-Willis operational unit. Fault data courtesy of Geomap.

Counties during the early Pliocene (fig. 23). In Calhoun County this system consists of thick delta-front sands interbedded with a few relatively thick delta-plain, lagoonal, or bay muds (figs. 8, 9, and strike section I). In Matagorda County west of the Colorado River, the system consists of regularly interbedded sands and shales of similar thicknesses (figs. 10, 11). High net-sand values exhibited by the system range between 250 and 350 ft (76 and 107 m) and sand percentages between 40 and 50 (figs. 21, 22). These facies are underlain in both counties by distal-deltaic and prodelta shales deposited in bays and large open-marine embayments.

Strong wave action and longshore currents carried considerable volumes of sand southwest alongshore from the wave-dominated delta system and deposited a long (about 40 mi, 64 km, in the study area) and wide (about 5 to 8 mi, 8 to 13 km) coastal barrier system located beneath the present Mustang and St. Joseph Islands and extending about 8 mi (13 km) offshore (fig. 23). This thick sand body consists of superposed and laterally coalescing barrier sands. High net-sand values vary between 300 and 400 ft (91 and 122 m) and 40 to 55 percent sand (figs. 21, 22). These sands are illustrated on dip sections (figs. 6, 7, 8). Lagoonal facies were deposited contemporaneously on the landward side of the barrier system. Apparently, shallow extensions of the Miocene fault system influenced the orientation and distribution of the thick sandy coastal barrier and wave-dominated delta systems. Most of the sands were deposited on the downthrown side of the growth faults (figs. 21, 22, 23). Sands of this complex are generally just below 1,500 ft (457 m) deep and are situated beneath the thin, fresh to slightly saline aquifer. High negative SP deflections and very low resistivities on well logs indicate porous saline-water sands.

Lagoon System

A mud-dominated lagoonal system occurs beneath Corpus Christi Bay and southwest Aransas County. Clays and shales of this system were deposited landward of the contemporaneous barrier system (fig. 23). Effects of the Miocene faults on this system are not appreciable because they coincide with predominantly mud facies (figs. 6, 7, 12).

UPPER GOLIAD-WILLIS OPERATIONAL UNIT

Sediment distribution within this unit is shown in net-sand and sand-percentage maps (figs. 24, 25). This information provided the basis for an interpretive map that depicts sediment dispersal patterns within the Upper Goliad-Willis unit (fig. 26). The base of this unit dips gulfward at 24 to 25 ft per mi (4.7 m per km) (about 28 ft per mi, 5.3 m per km, near the outcrop in the southwestern area).

Three principal depositional systems occur within the Upper Goliad-Willis operational unit: (1) fluvial meanderbelt and interfluvial-interdeltaic floodbasin system, (2) eastern fluvial and wave-dominated delta system, and (3) open embayment system.

Fluvial System

Fluvial braided to meanderbelt facies.—The volume of fluvial sands deposited within this unit is less than that of the Lower Goliad-Willis unit, but is greater than that deposited within the Lissie unit. The updip parts of the sand axes of this unit contain coarse sands and gravels (outcrop descriptions of the Goliad and Willis Formations: Plummer, 1932; Doering, 1935; Barnes, 1974), which were deposited by braided streams that grade downdip into meanderbelt deposits, as indicated by their greater width, sinuosity, and anastomosing patterns. The Upper Goliad-Willis fluvial sand axes can be separated into two groups. A western group consists of the deposits of the relict Nueces, East Nueces-Aransas, and Aransas-Blanco Rivers, which coalesced in northwest Nueces, northwest San Patricio, and southeast Bee Counties and then prograded as bayhead deltas into a large open-marine embayment system beneath Nueces and Aransas Counties (fig. 26). This western group of meanderbelts is separated from an eastern group by a large area of floodbasin sediments located in Goliad and northern Refugio Counties, where the deeper seated San Marcos Arch is located. The eastern meanderbelts were deposited by the relict San Antonio, Coletto, Guadalupe, Navidad, and West Colorado Rivers (fig. 26). These rivers carried higher sand loads than those of the western area, and they interconnect in Jackson and Wharton Counties, where they attain net-sand thicknesses up to 350 ft (107 m) (80 to 90 percent sand). This system grades downdip into a fluvial to wave-dominated deltaic system.

Shallow extensions of the Vicksburg fault system appear to have influenced deposition and orientation of Upper Goliad-Willis sand trends in Jackson and southeastern Victoria Counties and other areas. Sand thicks accumulated on the downthrown sides of faults (figs. 24, 26). High net-sand and sand-percentage values within these meanderbelts, including the eastern wave-dominated delta system, are presented in table 7.

Fluvial meanderbelt sediments consist of thick superposed channel-fill gravels and point-bar sands and relatively thin floodbasin muds. These facies are displayed in most dip sections (figs. 5 to 11). Since

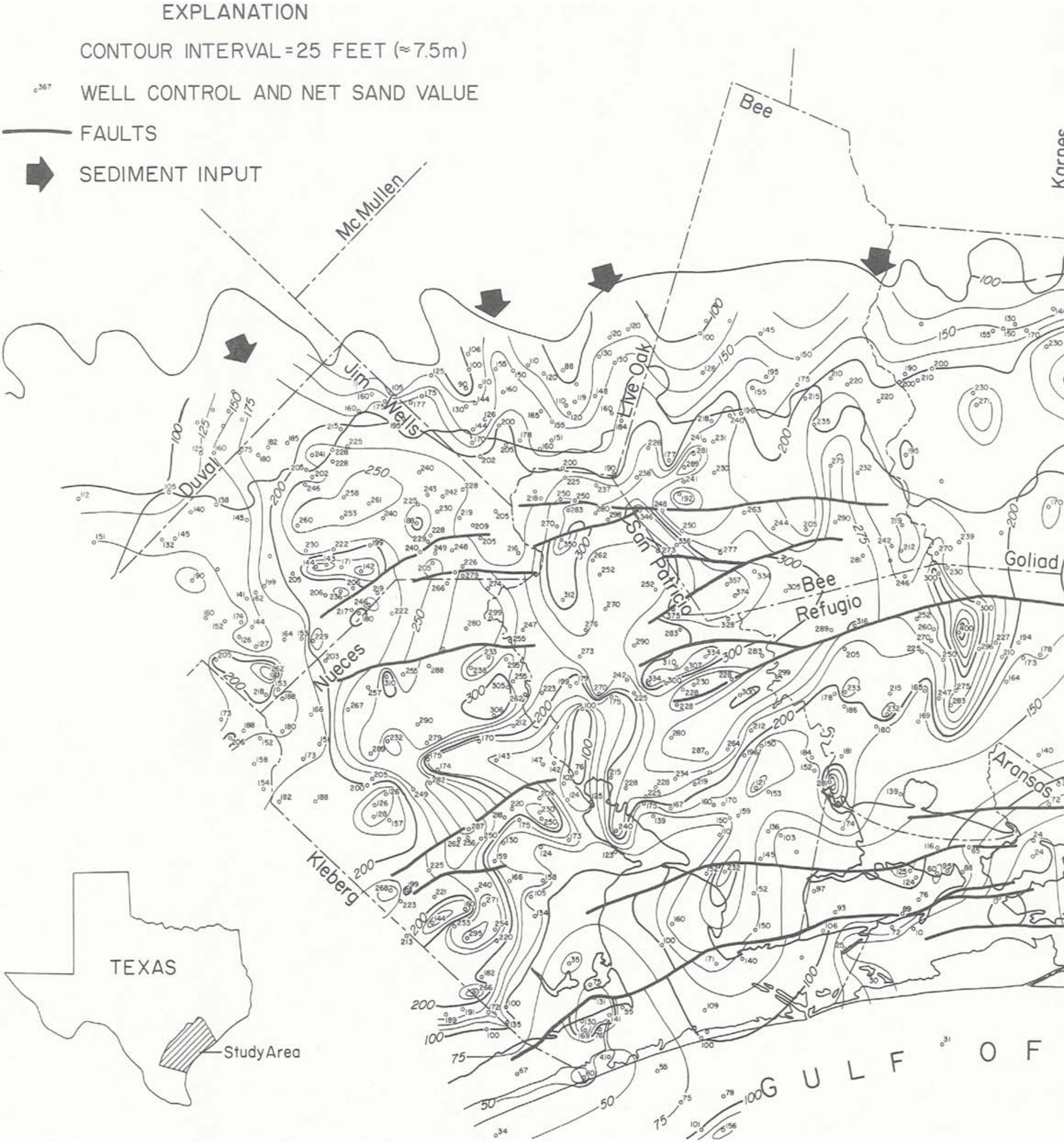


Figure 24. Net-sand map, Upper Goliad-Willis

operational unit. Fault data courtesy of Geomap.

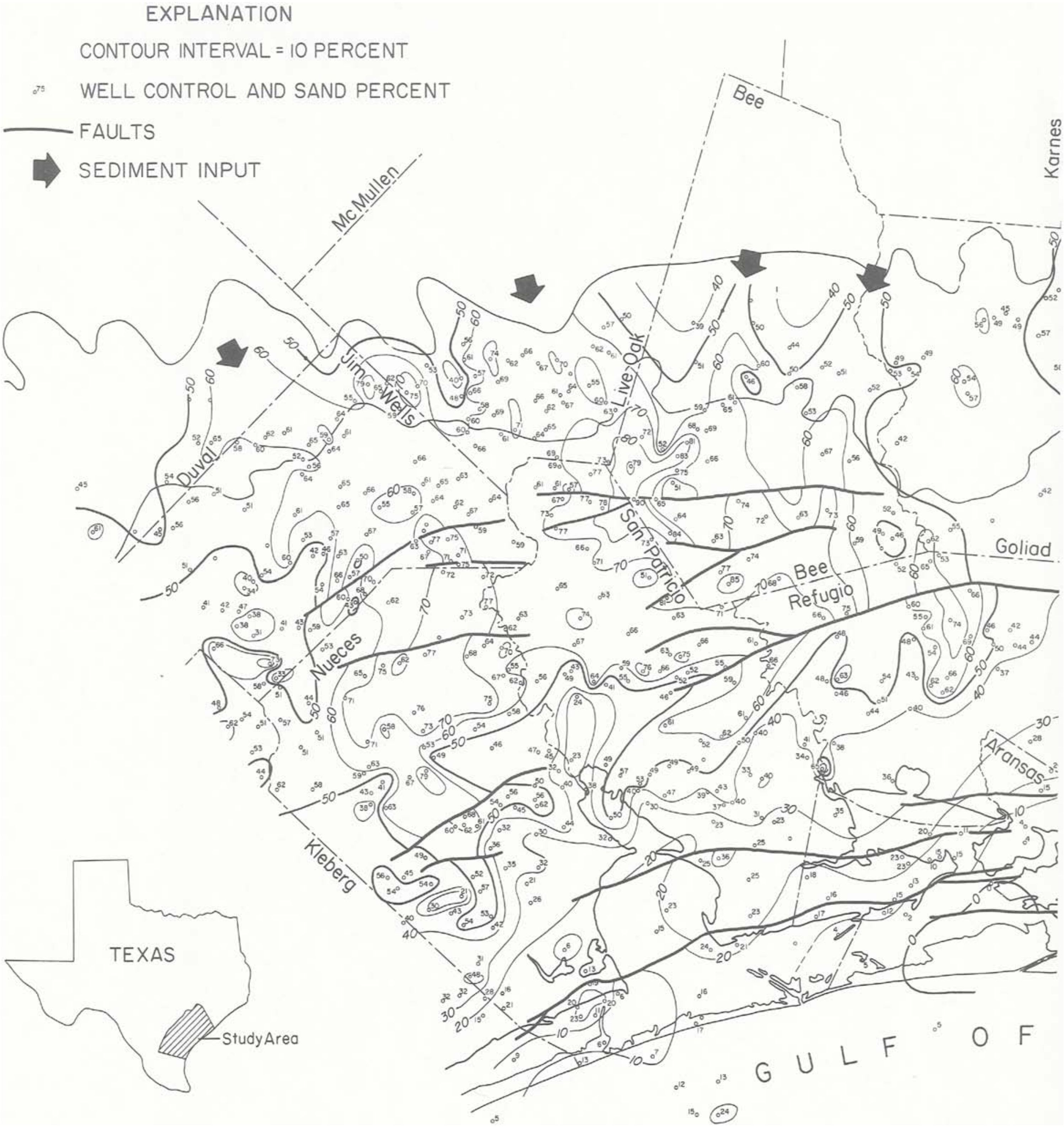
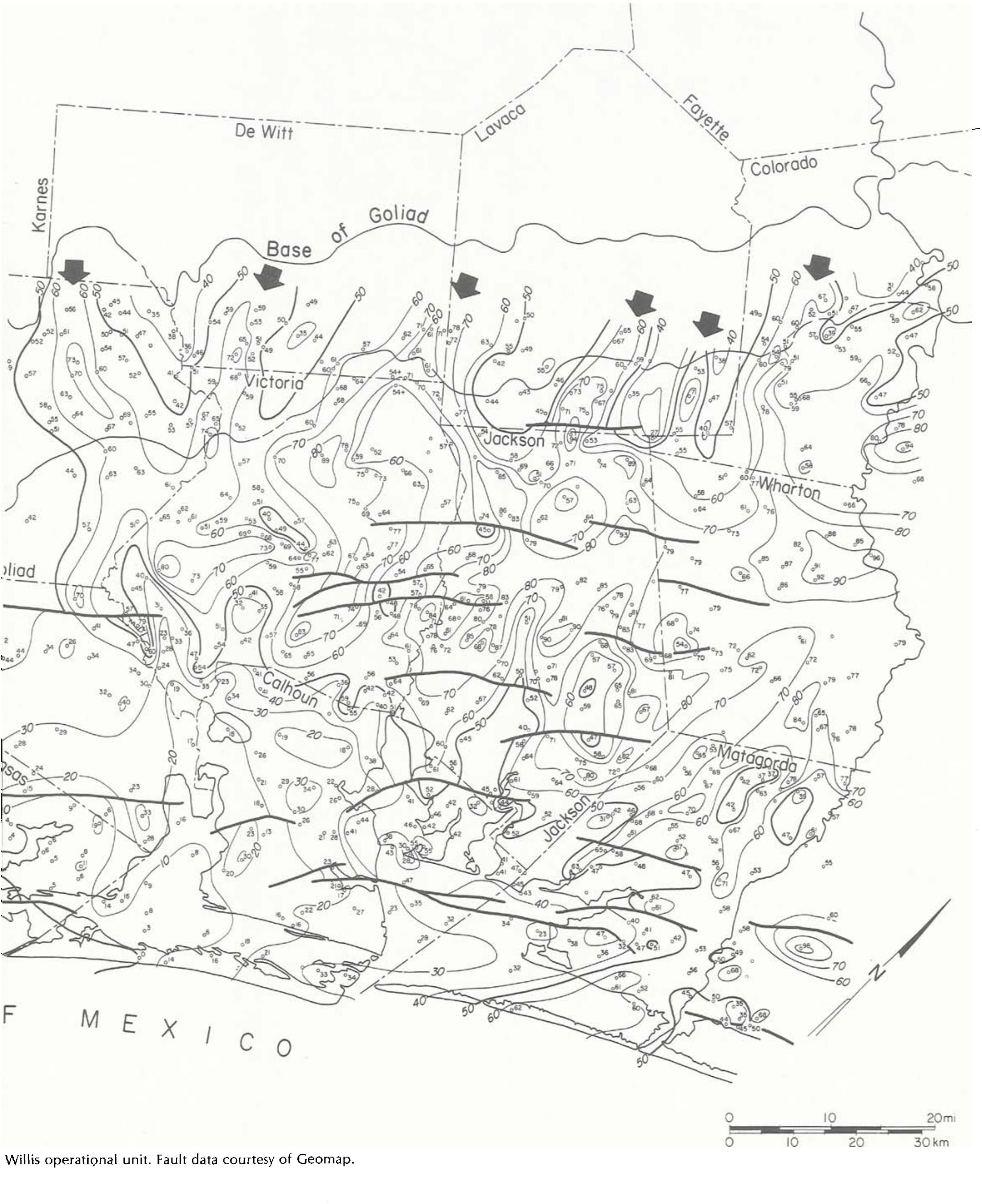


Figure 25. Sand-percentage map, Upper Goliad-



Willis operational unit. Fault data courtesy of Geomap.

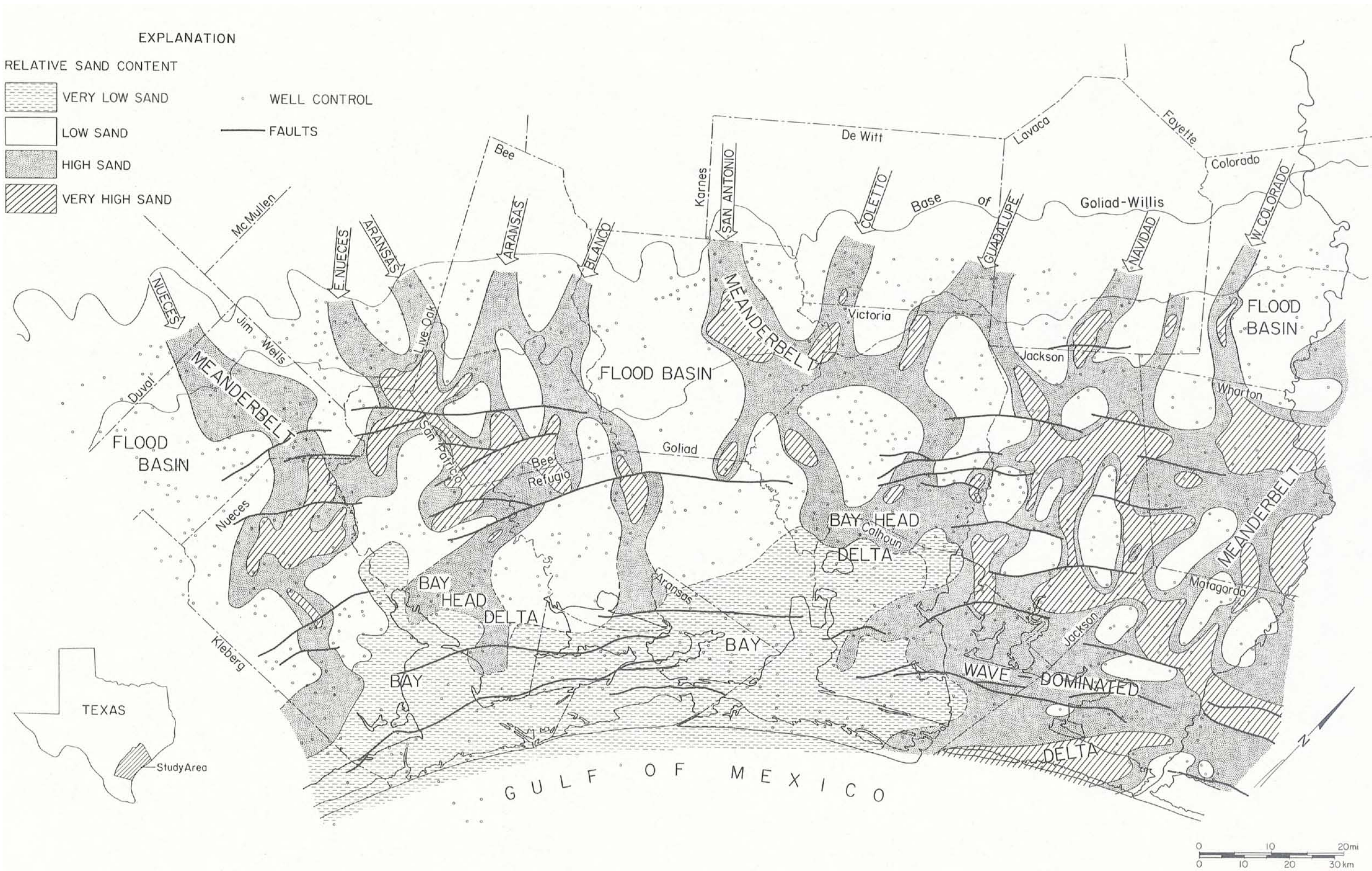


Figure 26. Depositional systems, Upper Goliad-Willis operational unit. Fault data courtesy of Geomap.

Table 7. High net-sand and sand-percentage values for the Upper Goliad-Willis facies.

System	Facies	Net sand (ft)	Sand %	Location (county)
Nueces	UD.MB. DD.BHD.	250-300 150-275	60-76 30-55	N.W. Nueces S.W. Nueces
E. Nueces-Aransas	UD.MB.	200-300	65-80	S.E. Live Oak N.W. San Patricio
Aransas-Blanco	UD.MB. DD.BHD.	275-350 150-275	65-80 50-60	S. Bee S.E. San Patricio
San Antonio	UD.MB.	225-325	55-70	Goliad N.W. Victoria
Coletto	DD.BHD.	125-250	45-75	S.W. Victoria
Guadalupe	UD.MB. DD.BHD.	250-300 200-275	65-75 55-75	N. Victoria S.E. Victoria
Guadalupe-Navidad	UD.MB. DD.WDD.	225-325 175-275	70-85 30-45	Jackson S.E. Jackson N.E. Calhoun
W. Colorado	UD.MB. DD.WDD.	250-350 250-375	70-90 45-70	Wharton Matagorda

Note: UD.MB. = Updip meanderbelt; DD.BHD. = Downdip bayhead delta; DD.WDD. = Downdip wave-dominated delta.

most meanderbelt sands lie within the coastal fresh-water aquifer, SP curves on well logs are generally flat and resistivities are high. Bayhead deltaic sands tend to exhibit modest negative SP deflections and relatively low resistivities, indicating brackish to saline interstitial waters.

Interfluvial-interdeltaic floodbasin facies.—This facies, composed predominantly of overbank clays, shales, and silts, was deposited between the main meanderbelts, and it extends throughout a large part of the study area. Sand within this system was deposited in minor and abandoned channels and crevasse splays. Sand content of this system is relatively low compared with that of meanderbelts. This facies lies within the fresh-water zone, and sands exhibit flat SP deflections and high resistivities on well logs.

Eastern Wave-Dominated Fluviodeltaic System

The relict Guadalupe, Navidad, and West Colorado meanderbelt systems contributed sediment to a large fluviodeltaic complex in Matagorda, northeast Calhoun, and southeastern Jackson Counties (fig. 26). This complex is a strike-oriented, wave-dominated deltaic system consisting of thick, superposed point-bar sands, delta-front sands, and marine-reworked sands interbedded with delta-plain and floodbasin shales. These sediments are underlain by distal deltaic and prodelta shales. High net-sand and sand-percentage values for the fluviodeltaic sediments in southeastern Jackson and northeastern Calhoun Counties range between 175 and 275 ft (53 and 84 m) and 30 and 40 percent. Values for the West Colorado sand trend in Wharton and Matagorda Counties range between 250 and 375 ft (76 and 114 m) and 45 and 70 percent (table 7; figs. 24, 25).

Shallow extensions of the Frio and Miocene fault systems have affected the sediment distribution and orientation of this system in southeastern Jackson and Matagorda Counties (fig. 26), resulting in strike-oriented sand depocenters on the downthrown sides of faults. The lithic composition of this system is well illustrated on cross sections of the eastern downdip region (figs. 10, 11, 12). Electric logs indicate that sands of the system grade transitionally from the fresh-water zone into the saline-water zone. Corresponding SP curves exhibit flat to high negative deflections and high to low resistivities.

Open Embayment

A large open-marine embayment existed in southeast Nueces, Aransas, southeast Refugio, and western Calhoun Counties in late Pliocene time (fig. 26). It is composed of a predominantly shale facies with low sand content. Sand was introduced into the embayment by most of the fluvial systems in the area via bayhead deltas. This system is well developed in the downdip part of the study area (figs. 5 to 9, 12). Since most of this system lies within the saline-water zone, thin sands within it display negative SP deflections and very low resistivities.

LISSIE OPERATIONAL UNIT

Net-sand and sand-percentage maps (figs. 27, 28) provided the basis for interpreting sand trends and principal depositional systems that are depicted in figure 29. The base of the Lissie operational unit dips gulfward at 16 to 18 ft per mi (3.0 to 3.4 m per km). The dip of Lissie beds at the surface has been estimated at 5 to 20 ft per mi (0.9 to 3.8 m per km) (see section entitled "Willis Formation").

The Lissie operational unit is composed of four principal depositional systems: (1) a fluvial meanderbelt and interfluvial-interdeltaic floodbasin system, (2) an eastern wave-dominated delta system, (3) a southern coastal barrier system, and (4) an open-embayment system.

Fluvial System

Fluvial meanderbelt facies.—Two groups of meanderbelts were identified within the Lissie unit. The western group is composed of the relict Nueces and Aransas Rivers that prograded as bayhead deltas into an open embayment (fig. 29). The eastern group is composed of the relict San Antonio, Guadalupe, Navidad, and West Colorado Rivers. These courses carried higher loads and constructed a large wave-dominated deltaic system in Calhoun and Matagorda Counties (fig. 29).

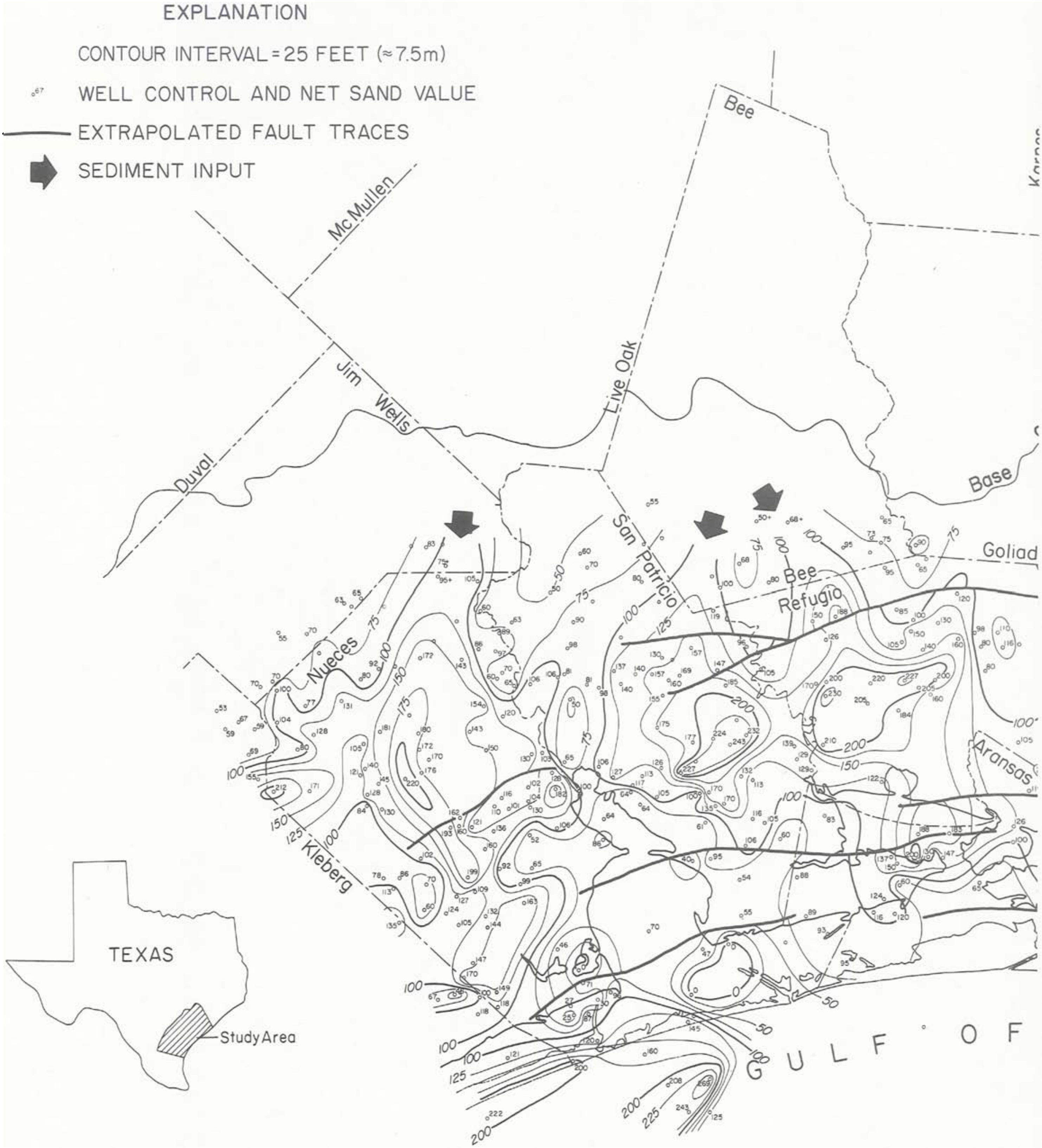
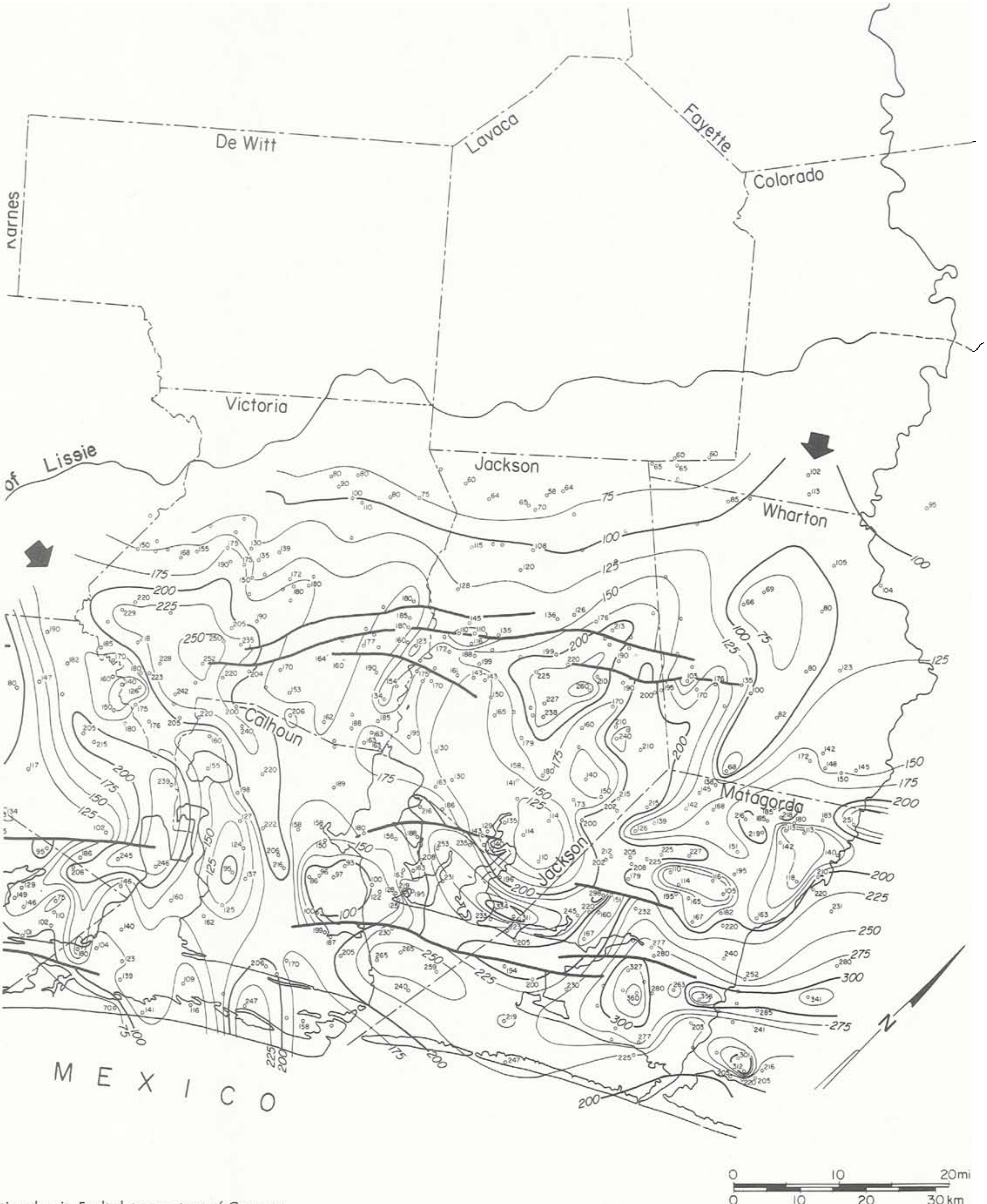


Figure 27. Net-sand map, Lissie opera-



tional unit. Fault data courtesy of Geomap.

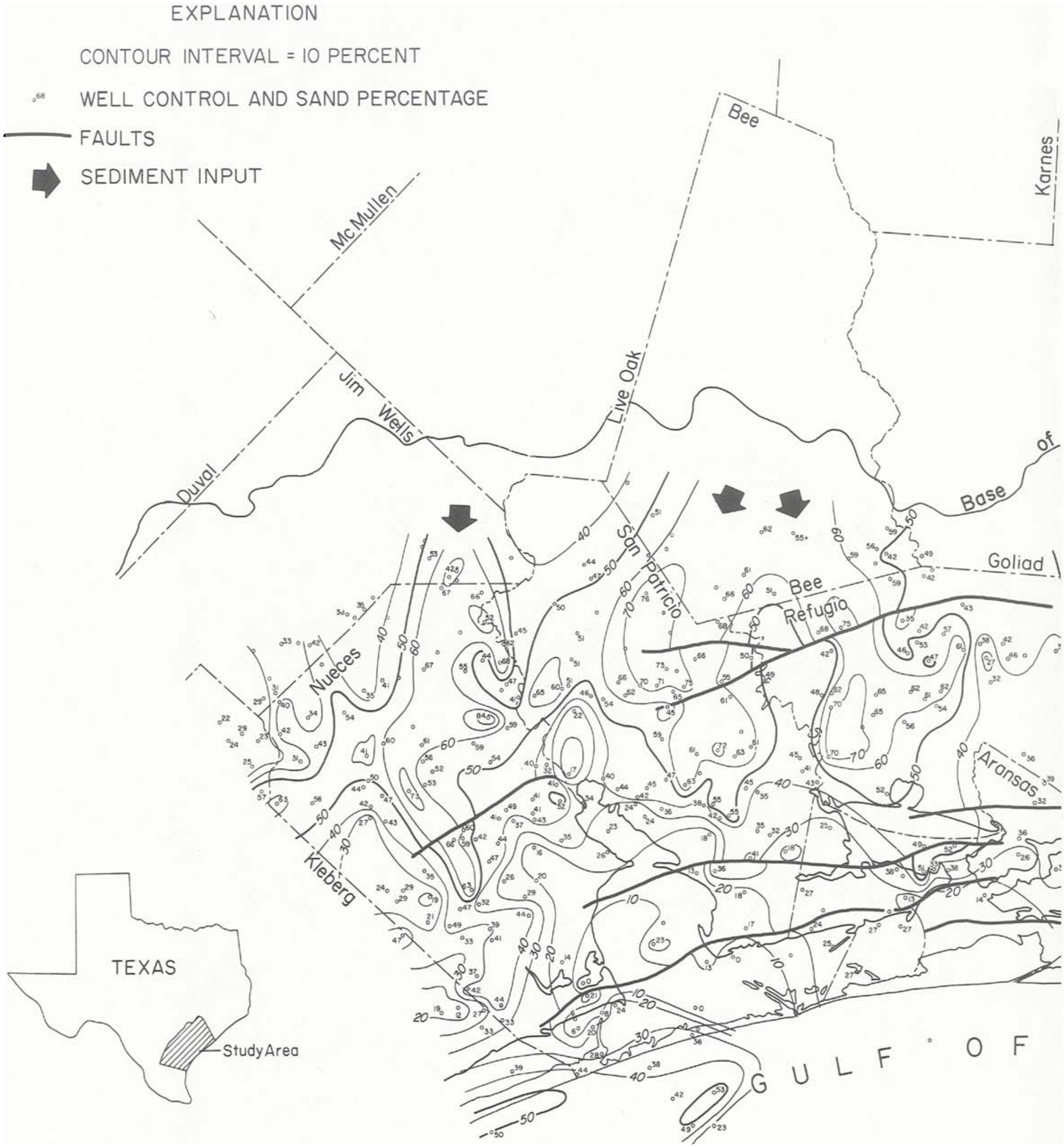


Figure 28. Sand-percentage map, Lissie

operational unit. Fault data courtesy of Geomap.

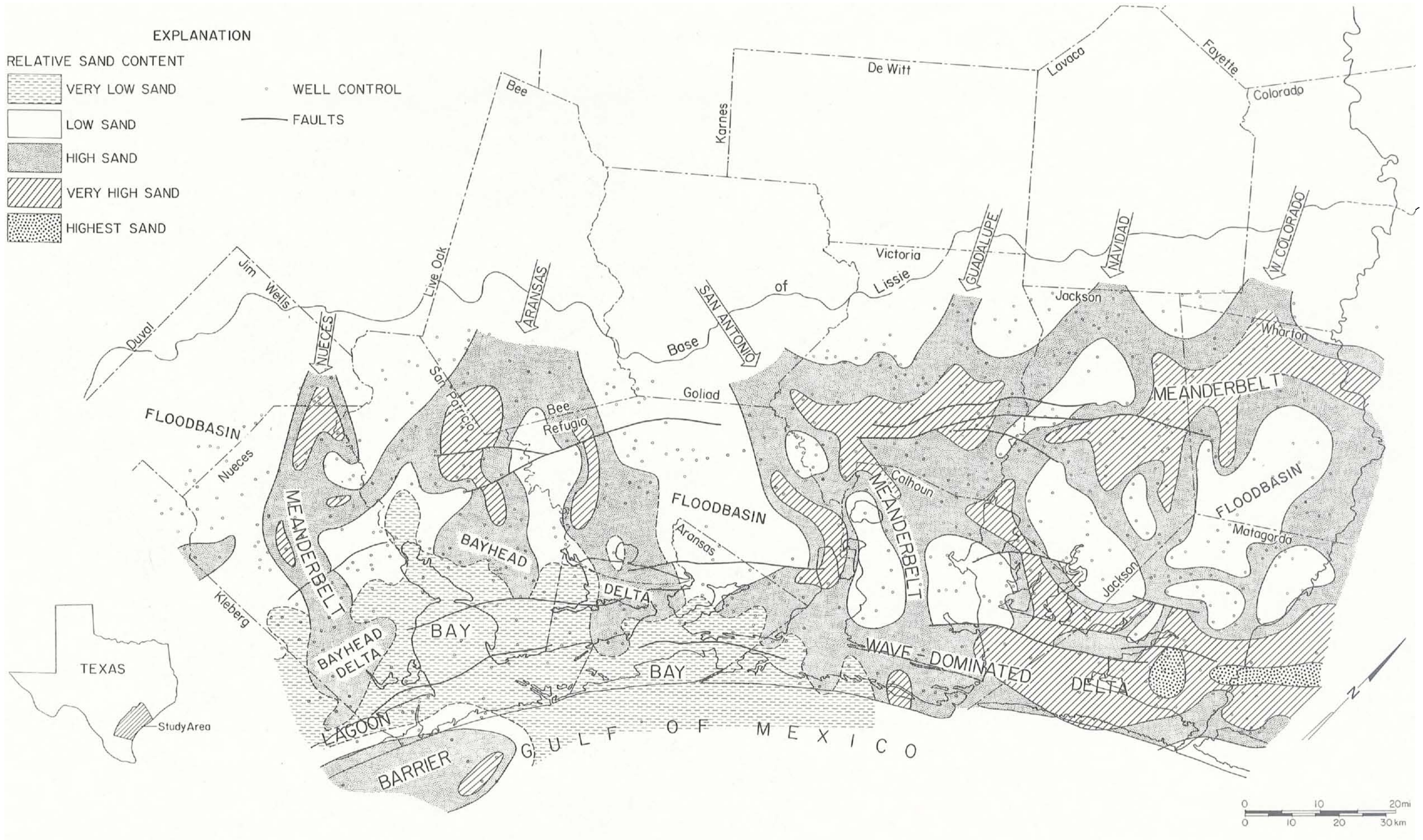


Figure 29. Depositional systems, Lissie operational unit. Fault data courtesy of Geomap.

Apparently, shallow extensions of the Vicksburg, Frio, and Miocene fault systems influenced the distribution and geometry of sediments within the Lissie depositional systems; this is evident in southern Victoria and central Jackson Counties (figs. 27, 29).

High net-sand and sand-percentage values of these fluvial axes are summarized in table 8.

Table 8. High net-sand and sand-percentage values for the Lissie facies.

System	Facies	Net sand (ft)	Sand %	Location (county)
Nueces	UD.MB. DD.BHD.	125-200 125-165	50-68 30-44	N.W. Nueces E., S.E. Nueces
Aransas	UD.MB. DD.BHD.	100-170 130-225	60-75 50-70	S.E. Bee, N.W. San Patricio, N.W. Refugio C., S.E. San Patricio-Refugio
San Antonio-Guadalupe	MB.	150-225	60-75	N.W. Refugio and S. half Victoria
Navidad-W. Colorado	MB.	125-225	60-75	Jackson

Note: UD.MB. = Updip meanderbelt; DD.BHD. = Downdip bayhead delta; MB. = Meanderbelt.

Electric log records indicate that the western meanderbelts consist of thick superposed point-bar and channel sands interbedded with thin overbank and channel-fill muds. The eastern meanderbelts are composed of regularly interbedded point-bar sands and floodbasinal shales. Generally, on well logs, SP deflections for sands are flat or reversed, and resistivities are high. This facies can be observed in most dip sections (figs. 7 to 11).

Interfluvial-interdeltaic floodbasin facies.—This predominantly fine grained facies is composed of floodbasin clays and shales widely distributed throughout the updip part of the Lissie unit. The relatively low sand content is attributed to restricted sand deposition in smaller and abandoned channels and crevasse splays (figs. 5, 6). In the eastern area relatively thick floodbasin sediments are regularly interbedded with fluvial sands of similar thicknesses (figs. 8, 9, 10).

Eastern Wave-Dominated Deltaic Systems

The relict San Antonio, Guadalupe, Navidad, and West Colorado Rivers of the Lissie unit contributed sediment to the strike-oriented wave-dominated deltaic system that was deposited in Calhoun and Matagorda Counties (fig. 29). High net-sand values between 200 and 325 ft (61 and 99 m) and sand percentages of 50 to 65 are typical within this system (figs. 27, 28). Net-sand thicknesses and orientation in this system indicate that shallow extensions of Miocene faults and sediment compaction collectively influenced sediment distribution in the deltaic system (figs. 27, 29). It is probable that eastern sediment sources (relict Colorado-Brazos delta) may have partly contributed sand, which was reworked by wave action and transported by longshore drift to the wave-dominated delta. Electric logs in Calhoun County exhibit reversed or flat SP curves and relatively low resistivities (fig. 9), indicating slightly saline waters. The base of fresh-water sands within the Lissie unit in Matagorda County is situated at greater depths (figs. 12, 33). These sands show flat SP curves and high resistivities (figs. 10, 11).

Coastal Barrier System

Part of a Lissie coastal barrier complex was identified beneath north Padre Island and south Mustang Island; it extends several miles offshore (fig. 29). This barrier complex is actually composed of vertically superposed and laterally coalescing barrier (shoreface) sands interbedded with thin marine shales (figs. 5, 6). High net-sand values in this system range between 125 and 225 ft (38 and 69 m) and sand percentages between 35 and 50. Electric logs of these sands indicate the presence of brackish and saline water (figs. 5, 6).

Embayment System

A Lissie shale-dominated marine embayment system occurs beneath Corpus Christi Bay and Aransas County (fig. 29). The Nueces and Aransas meanderbelts terminate in this shaly embayment system as bayhead deltas composed of delta-front sands up to 80 ft (24.4 m) thick. The southwestern part of this system is composed of lagoonal facies located landward of the Lissie coastal barrier system (fig. 29). Electric logs of sands within the bay system indicate the presence of brackish to saline interstitial water (figs. 5, 6, 7).

BEAUMONT OPERATIONAL UNIT

Distribution of sand and shale within this system is delineated on net-sand and sand-percentage maps (figs. 30, 31). Interpretation of these maps permits the depiction of high- to low-sand depositional systems (fig. 32). Depositional systems within this unit closely resemble the depositional systems in the Texas Coastal Zone as mapped by the Bureau of Economic Geology (Brown and others, 1976; McGowen and others, 1976a, b). The modern Nueces, Aransas, Guadalupe, and Colorado meanderbelts and associated deltaic systems and the late Pleistocene Ingleside strandplain system resemble corresponding systems interpreted in the subsurface Beaumont operational unit. Beaumont sediments dip gulfward from as little

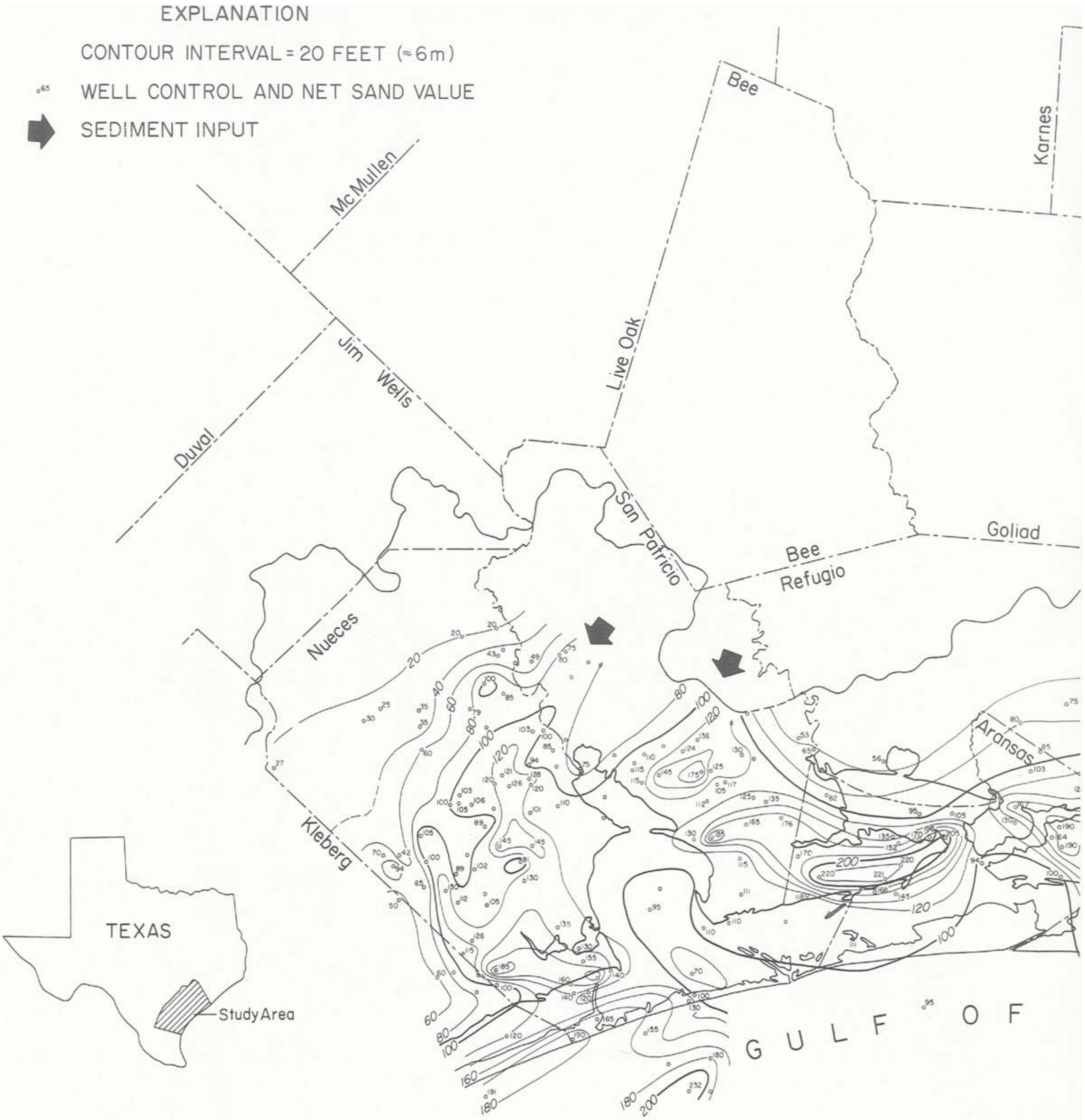
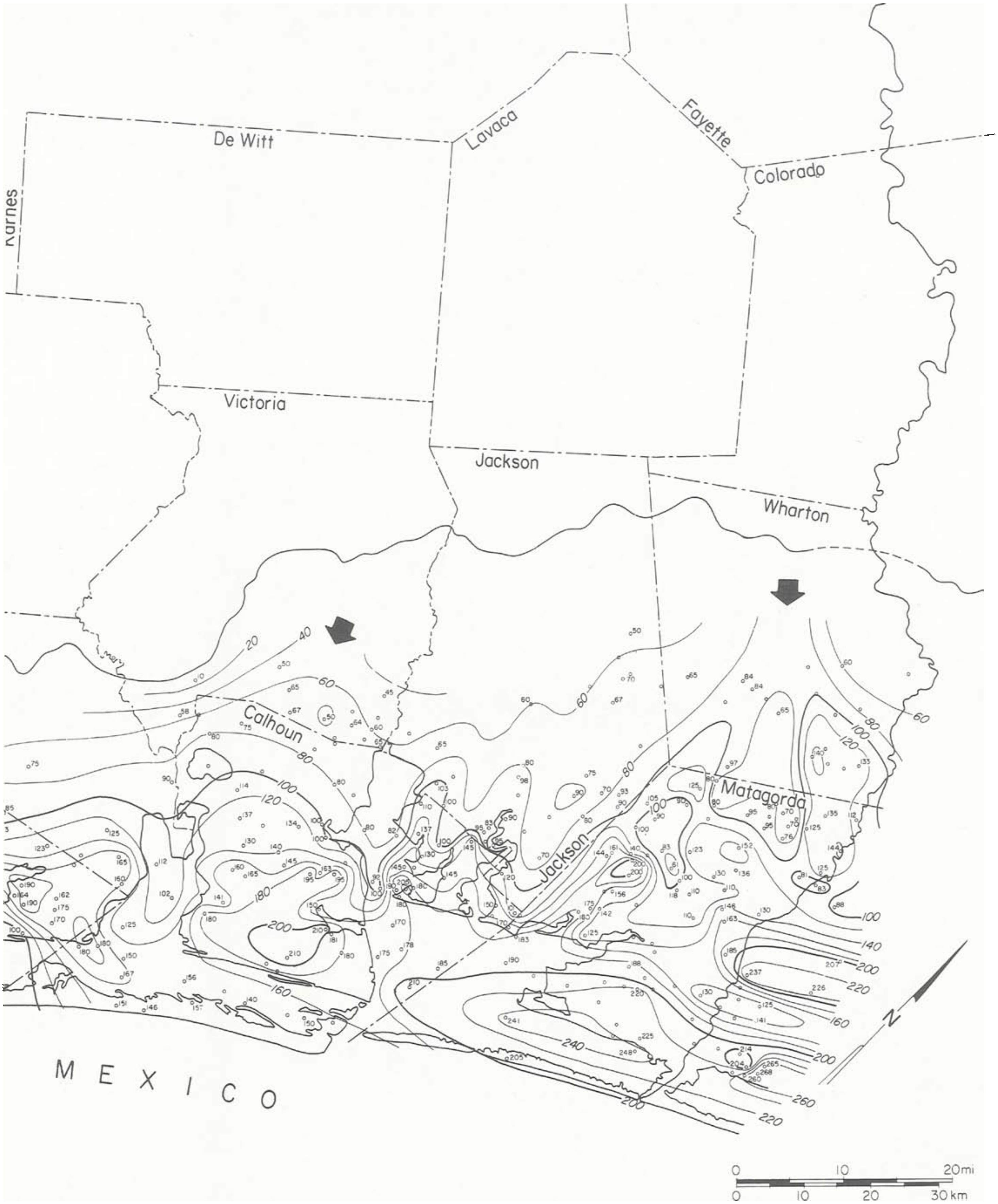


Figure 30. Net-sand map,



Beaumont operational unit.

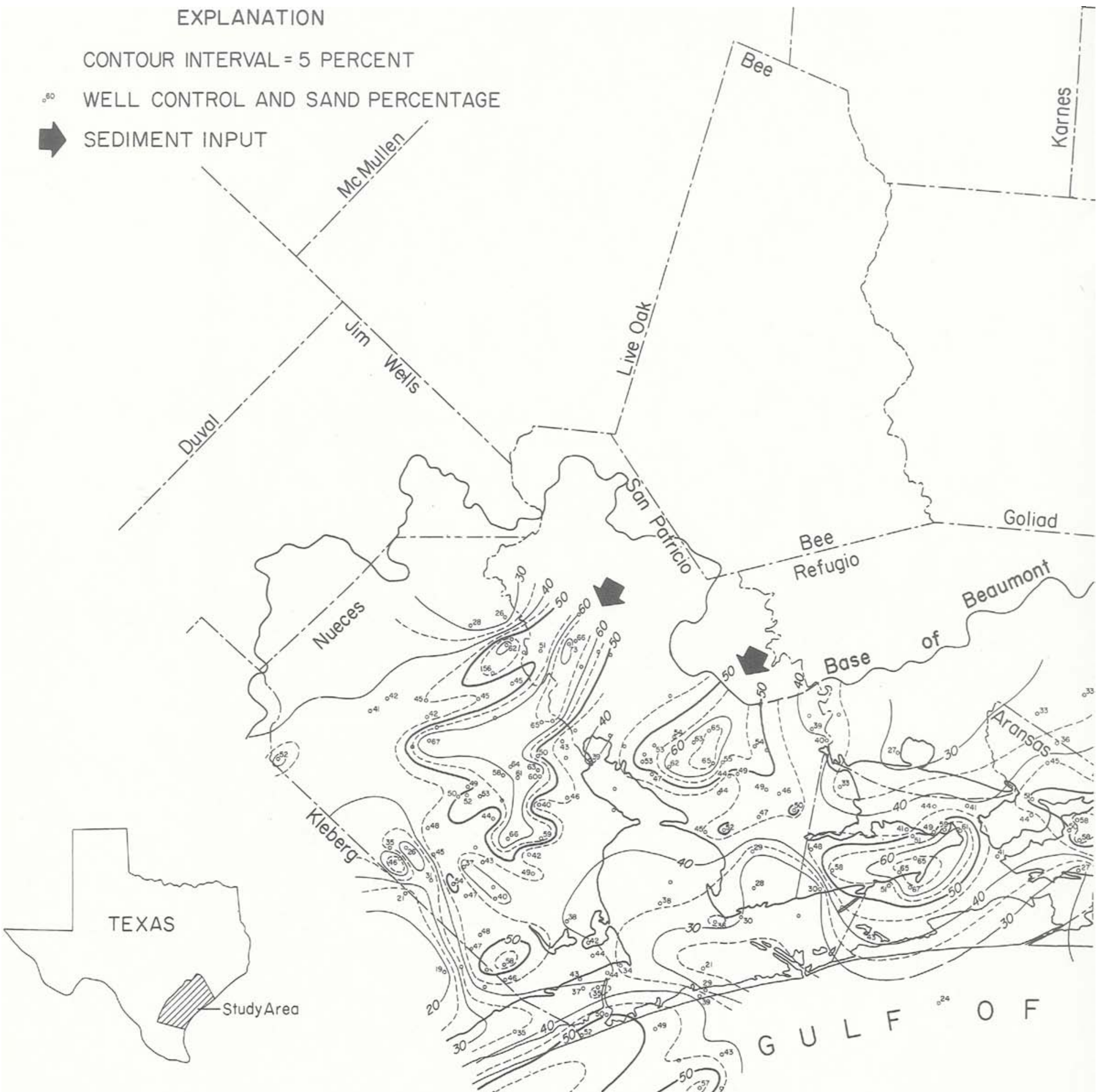
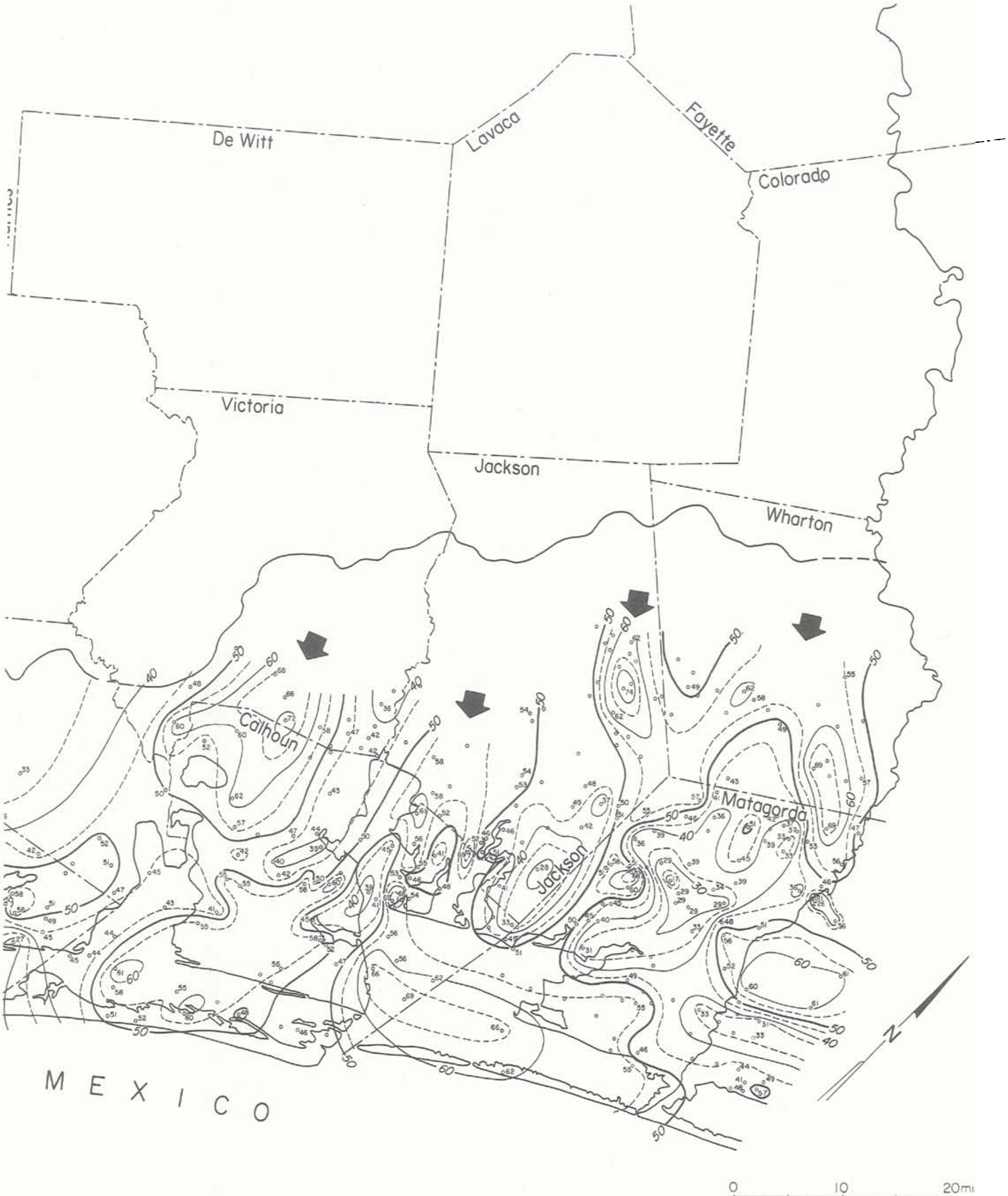


Figure 31. Sand-percentage map,



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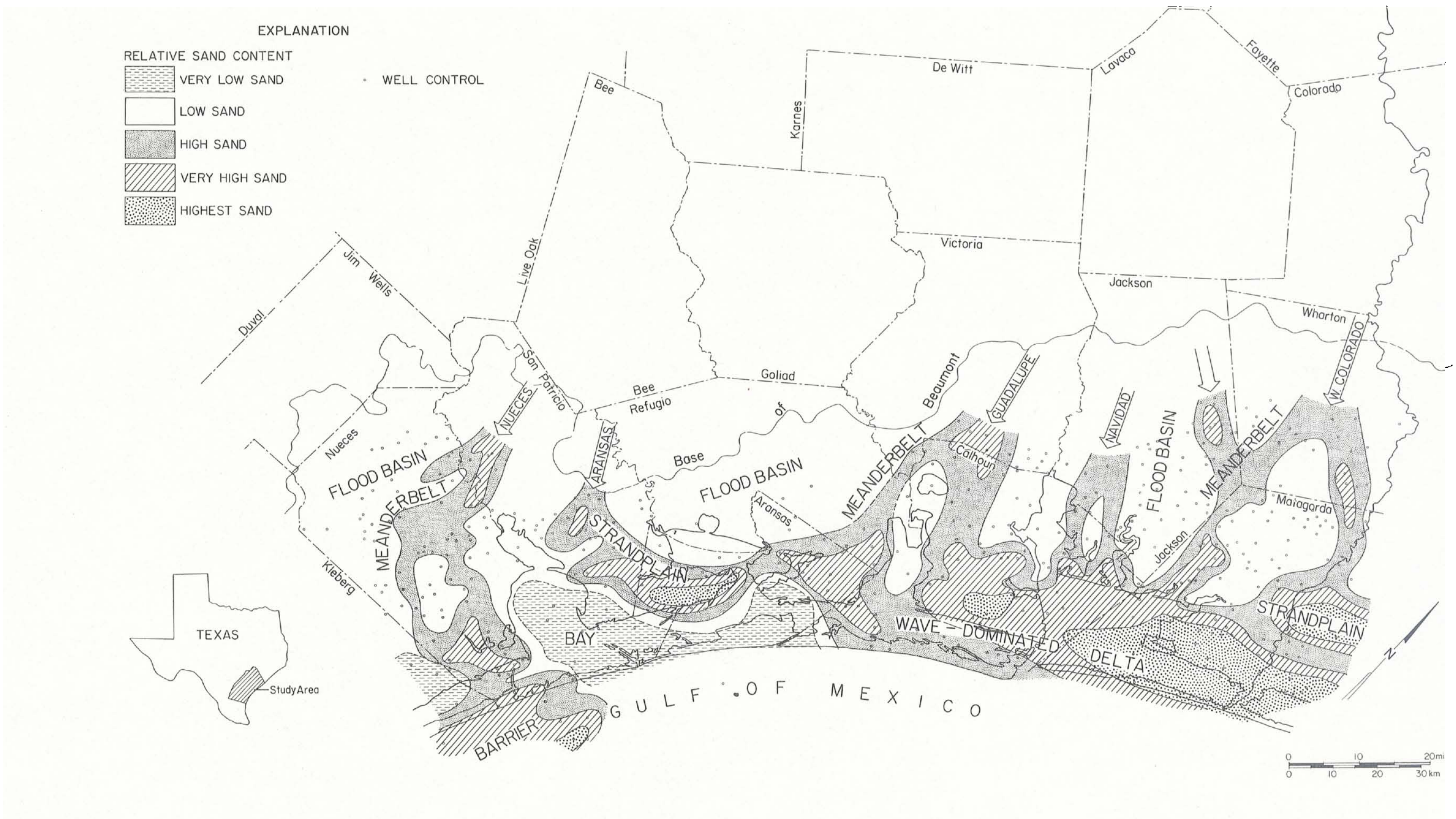


Figure 32. Depositional systems, Beaumont operational unit.

as 1.5 ft per mi (0.3 m per km) (p. 9) to as much as 10 ft per mi (1.9 m per km), according to calculations made using dip sections at the base of the unit.

Four principal depositional systems occur within the Beaumont operational unit (fig. 32): (1) fluvial meanderbelt and interfluvial-interdeltaic floodbasin, (2) wave-dominated deltaic and strandplain, (3) coastal barrier, and (4) bay system.

Fluvial System

Fluvial meanderbelt facies.—Five meanderbelt sand trends were identified within the Beaumont unit and named after modern rivers of corresponding geographical location: Nueces, Aransas, Guadalupe, Navidad, and Carancahua-West Colorado (fig. 32). Although well control for this unit is not dense, owing to shallow casing limitations, these systems are composed of superposed fluvial sands or of intercalations of thicker sands and thinner clays. This facies exhibits flat SP deflections and high resistivities on well logs (figs. 6 to 10). Representative high net-sand and sand-percentage values (figs. 30, 31) are presented in table 9.

Table 9. High net-sand and sand-percentage values for the Beaumont meanderbelts.

Meanderbelt	Net sand (ft)	Sand %	Location (county)
Nueces	120-160	50-65	S.E. Nueces
Aransas	120-150	50-65	S.E. San Patricio
Guadalupe	60-130	50-65	N.W. Calhoun
Navidad	60-140	50-60	N.E. Calhoun S.W. Jackson
W. Colorado	100-160	55-65	S. Wharton N.W. Matagorda

Floodbasin facies.—Interfluvial and interdeltaic Beaumont facies constitute a principal facies within the Beaumont operational unit. This system has been described as Beaumont clays or calcareous montmorillonitic clays and sandy clays. Small and abandoned meanderbelts, bayhead deltas, and crevasse splays deposited limited amounts of sand within this system. Electric log deflections are typical of clays or shales except for thin sands that exhibit flat SP deflections and moderate resistivities (figs. 5, 7, 11).

Wave-Dominated Delta - Strandplain System

This strike-oriented Beaumont system coincides approximately with and underlies the upper Pleistocene Ingleside sand trend in outcrop. Strandplain facies are interpreted beneath Live Oak Ridge and Blackjack Peninsulas in southeastern San Patricio and Aransas Counties. The wave-dominated deltaic system of the Beaumont was deposited in the coastal parts of Calhoun and Matagorda Counties (fig. 32). The offshore extent of this system is unknown because of very limited well control off the coast. In addition to the dip-fed contribution of sand into this system, some sand may have been derived from more eastern sources such as the Pleistocene Colorado or Brazos deltas. High sand content of these systems is presented in table 10.

Table 10. High net-sand and sand-percentage values for the Beaumont deltaic and strandplain systems.

System	Net sand (ft)	Sand %	Location (county)
Live Oak - Blackjack strandplain	140-200	45-60	San Patricio-Aransas
Eastern wave-dominated delta	140-240	45-65	Calhoun-Matagorda

The strandplain system in this unit consists of interbedded strike-oriented sands and shales exhibiting poor or flat SP curves and relatively low resistivities on well logs, indicating the presence of brackish water (figs. 7, 8). The Beaumont wave-dominated deltaic system is composed of thick upward-coarsening delta-front and distributary channel-fill sands and thinner delta-plain muds. Sands display flat or reversed SP deflections and high resistivities on logs, indicating fresh to brackish interstitial waters (figs. 9 to 12).

Coastal Barrier System

Well control on north Padre Island, south Mustang Island, and offshore permitted delineation of part of a coastal barrier system (fig. 32) consisting of superposed and laterally coalescing bar-sand bodies with a few intercalations of shale. High net-sand values are between 140 and 220 ft (43 and 67 m), and sand percentages are between 45 and 55. This system is well defined in the westernmost dip sections (figs. 5, 6). Electric logs of these sands display negative deflections, whereas resistivity curves are essentially flat.

Bay-Lagoon System

A Beaumont bay system underlies the general area of modern Corpus Christi and Aransas Bays (fig. 32). This system is composed mainly of clays and sandy clays containing a few thin sand intercalations. The net-sand content here is less than 110 ft (34 m) and sand percent is less than 35. A Beaumont lagoonal system lies landward of the aforementioned coastal barrier (fig. 32). This system and its typical log patterns are illustrated in dip (figs. 6, 7) and strike (fig. 12) sections.

From the configuration of these coastal systems it is inferred that the Beaumont (high-stand) coastline was situated at least several miles offshore from Calhoun and Matagorda Counties and at least 8 mi (13 km) offshore from north Padre Island and south Mustang Island. Well control offshore is needed to ascertain the distal facies of the Beaumont coastal systems before their complete paleogeographic distribution can be determined.

FAULTING AND SEDIMENT DISTRIBUTION

Analysis of the depositional systems within the different stratigraphic operational units indicates a definite structural influence of contemporaneous faulting on sediment distribution and orientation of middle Miocene to lower Pleistocene sand depocenters.

Shallow extensions of the Wilcox fault system occur in the updip part of the study area in Duval, Live Oak, north Bee, southeast Karnes, and De Witt Counties (figs. 4, 14). Wilcox faults caused considerable displacement of older Catahoula and Oakville sediments (figs. 7, 8, 9) but apparently exerted only minor control on sediment distribution of the updip Fleming meanderbelt systems (figs. 15, 18).

Farther downdip, shallow extensions of the inner Vicksburg fault system, designated as IV on maps and dip sections, trend along strike in northeastern Jim Wells, northwestern San Patricio, southern Bee, and northwestern Jackson Counties. Downdip of this system is the main Vicksburg fault zone (designated V) that extends along strike from northwest Nueces County through central San Patricio, Refugio, southern Victoria, central Jackson, and into southern Wharton Counties (fig. 4). Displacement along these faults (as shown on dip sections) is appreciable for Fleming units but less so for younger operational units. Maximum displacement of the lowermost Fleming and Oakville sediments did not exceed 350 ft (107 m). Thick strike-oriented meanderbelt sand thicks were deposited on the downthrown side of Vicksburg faults. This relationship is clearly shown by net- and percentage-sand maps of the Fleming and Goliad-Willis operational units (figs. 15 to 26).

The Vicksburg fault system produced pronounced rollover structures during the period of its maximum activity (Oligocene Epoch), creating favorable conditions for entrapment of hydrocarbons (Stanley, 1970), such as in the Tom O'Connor, Refugio, and Heard fields in Refugio County. This rollover configuration is readily seen in the area of these fields on structural maps contoured on the top and base of the Lower Fleming (figs. 14, 40). Similarly, gentle rollover or arching of the Oakville and Fleming sediments can be seen on dip sections (figs. 6, 7, 8).

Shallow extensions of the Frio and Miocene faults, designated as F and M on maps and dip sections, were apparently active during the late Miocene and Pliocene. These younger faults extend from southeastern Nueces County through Aransas, Calhoun, and into Matagorda Counties (fig. 4). They influenced sediment distribution and orientation of sand depocenters in the Fleming and Lower Goliad-Willis operational units (p. 28, 29, 41). Sand depocenters developed on the downthrown fault blocks parallel to and/or bounded by the strike-oriented faults (figs. 15 to 23). Maximum displacements of Oakville and lowermost Fleming sediments (Nueces and San Patricio Counties) by the Frio fault system do not exceed 400 ft (122 m). Miocene faults displace the top of the Oakville Sand up to 400 ft (122 m) in Nueces, San Patricio, and Aransas Counties (figs. 6, 7).

Two up-to-the-coast Miocene faults were identified by McCarthy (1970) in Calhoun and Matagorda Counties (figs. 10, 11). These faults exhibit small displacements and cause gentle anticlinal closures (called Miocene ridges by McCarthy) that entrapped oil and gas in the downdip facies of Lower Fleming and older sediments. This is true for the Jay Welder, Powderhorn, Matagorda Bay, Oyster Lake, Steamboat Pass, and Saluria fields.

Since shallow extensions of the Vicksburg faults controlled the distribution and geometry of the fluvial sand facies of the Fleming and Goliad-Willis operational units, the overall geometry of the fresh-water aquifer will tend to conform to the distribution of the updip parts of the fluvial sand axes. This is especially evident in the eastern part of the area of study.

NATURAL RESOURCES

GROUND WATER

General Statement

Fresh ground water forms part of a continuous hydrologic cycle in which water circulates through the ecosystem by means of evaporation, cloud formation, precipitation, and infiltration into the aquifer. In the Gulf Coastal Plain, the fresh-water aquifer is composed of shallow Miocene to Pleistocene porous sands. It is one of the most important fresh-water reservoirs in the United States.

The coastal aquifer is recharged by precipitation in the outcrop area. Precipitation is subject to runoff, interception by vegetation, retention as soil moisture, and, importantly, infiltration into the aquifer. The hydrology of the study area depends largely on its climatic conditions. The area has a moist to dry subhumid climate (Thornwaite, 1952, p. 32) and receives an average annual precipitation that ranges between 26 inches (66 cm) in the western zone and 40 inches (102 cm) in the eastern zone. The average annual temperature is 70°F (21°C). In addition, the hydrologic cycle is also affected by man-made features such as dams, irrigation systems, stream diversion constructions, and the effects of water-well pumpage.

Gulf Coast Fresh-Water Aquifer

Most of the ground water in the study area exists under confined conditions beneath the sand-poor Beaumont aquitard and is contained mostly within sands of the Lissie, Upper Goliad-Willis, and Fleming operational units. Water quality in the aquifer is acceptable for domestic and irrigation purposes. Chloride concentrations generally increase toward the Gulf and with depth; hardness values of more than 120 ppm, found at shallow depths, tend to decrease with depth. Abundant information on water quality has been published in county reports by the Texas Department of Water Resources.

In addition to the sediments considered in this study, sands of the Oakville Formation form a relatively important part of the coastal fresh-water aquifer. Oakville sands containing fresh water extend 25 to 30 mi (40 to 48 km) downdip from their outcrop (shown by a segmented line on fig. 2). The fresh-saline water interface intersects the top of the Oakville Sand at depths that range from 1,200 ft (366 m) below sea level in Jim Wells County to 1,800 ft (549 m) in Colorado County (fig. 14).

County reports published by the Texas Department of Water Resources provide approximate calculations of volumes of fresh to slightly saline water available for pumpage without depleting the aquifer for several decades. Results of these estimates are presented in table 11.

Base and Thickness of Fresh-Water Sands

The coastal aquifer is a three-dimensional sedimentary wedge composed of fresh-water sands and intercalated muds. Its geometry is controlled by the position and configuration of the base of sands containing fresh to slightly saline water. The vertical extent of the fresh-water aquifer in the area of study is shown in figure 33, which is a map prepared on the basis of relative log-response of SP and resistivity curves, depicting the configuration of the base of the aquifer. This map also includes the faults and the extent of a saline- to brackish-water tongue. The tongue consists of a shallow landward-encroaching zone of saline to brackish water within the nearshore Holocene and Pleistocene (Beaumont Formation) strata. This zone overlies a relatively shallow section of fresh to slightly saline water of the Beaumont and Lissie Formations that constitutes the most basinward extension of the aquifer (fig. 33). Information in figure 33 indicates that the base of the aquifer is at maximum depths of 1,500 to 1,600 ft (457 to 488 m) below sea level in Jim Wells County (fig. 5); in Goliad County it reaches depths of 1,600 to 2,000 ft (488 to 610 m) (fig. 8); in the eastern zone, where most usable water is stored, the interface intersects Oakville and Fleming sands at depths between 1,600 and 2,200 ft (488 and 671 m) below sea level (figs. 10, 11, 33). The base of fresh-water sands is indicated on all cross sections.

Another map, figure 34, displays the total net thickness of sands containing fresh to slightly saline

Table 11. Estimates of stored and available fresh water in the coastal aquifer of the study area.

County	Fresh water in storage acre ft x 10^6	Recoverable fresh water acre ft x 10^6	Available fresh water acre ft/yr	Source
Aransas	0.6	0.3	2,000	Shafer, 1970
Bee	48.0	10.0	9,000	Myers and Dale, 1966
Calhoun	20.0	-----	-----	Marvin and others, 1962
De Witt	65.0	12.0	6,500 to 55,000	Follett and Baker, 1965
Duval	-----	-----	26,000	Shafer, 1974
Goliad	100.0	50.0	-----	Dale and others, 1957
Jackson	130.0	-----	300 (acre ft x 10^6)	Baker, 1965
Jim Wells	-----	-----	3,360	Mason, 1963a
Karnes	30.0	-----	10,000	Anders, 1962
Live Oak	20.0	-----	10,000±	Anders and Baker, 1961
Matagorda	88.0	-----	63,000 to 118,000	Hammond, 1969
Nueces and San Patricio	18.0	several	at least 5,400	Shafer and others, 1968
Refugio	10.0 to 20.0	-----	42,000	Mason, 1963b
Victoria	100.0	-----	-----	Marvin and others, 1962

Note: Data for Colorado, Lavaca, and Wharton Counties were not available.

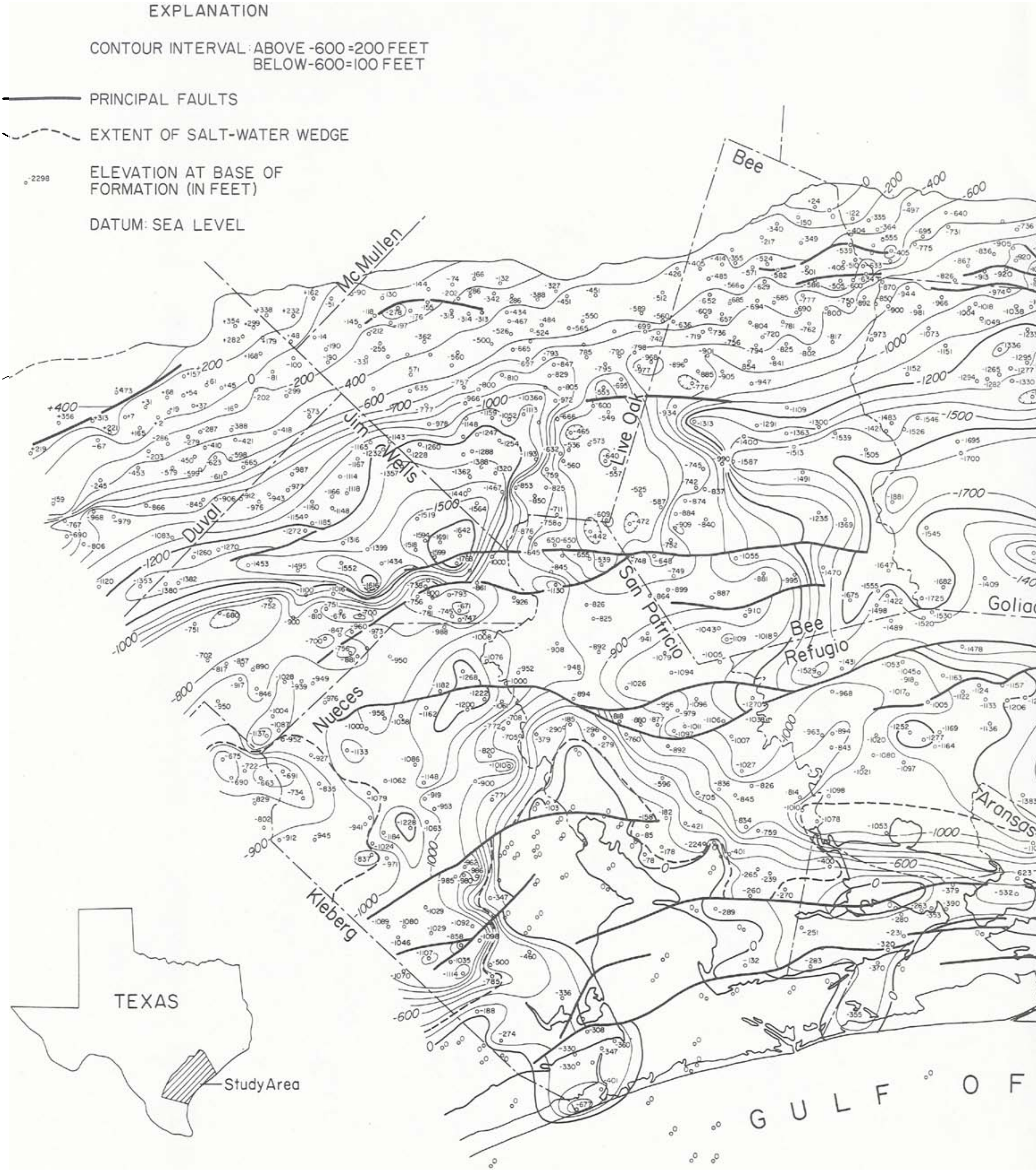


Figure 33. Map showing elevation of base of fresh water,

coastal aquifer system. Fault data courtesy of Geomap.

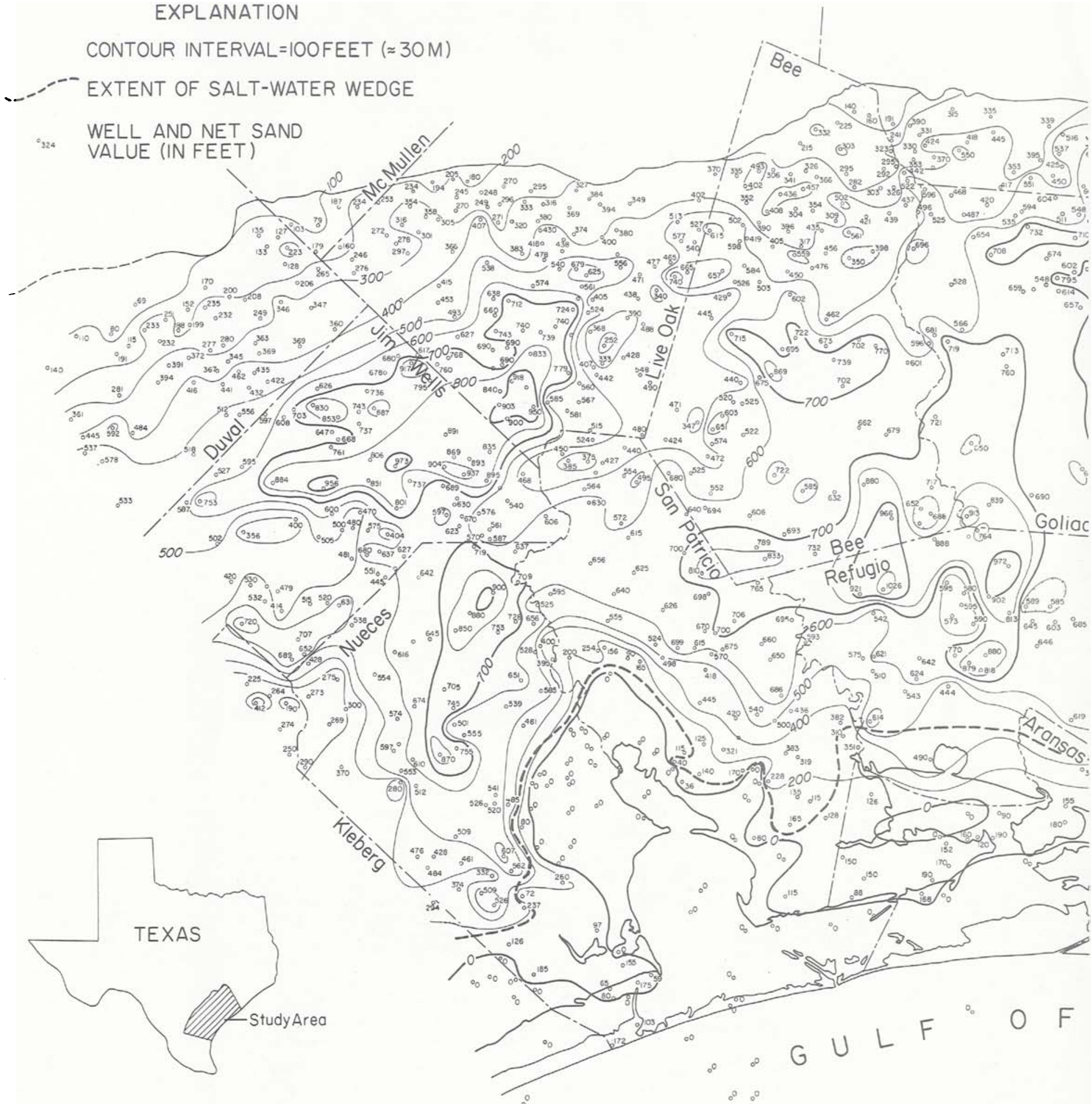
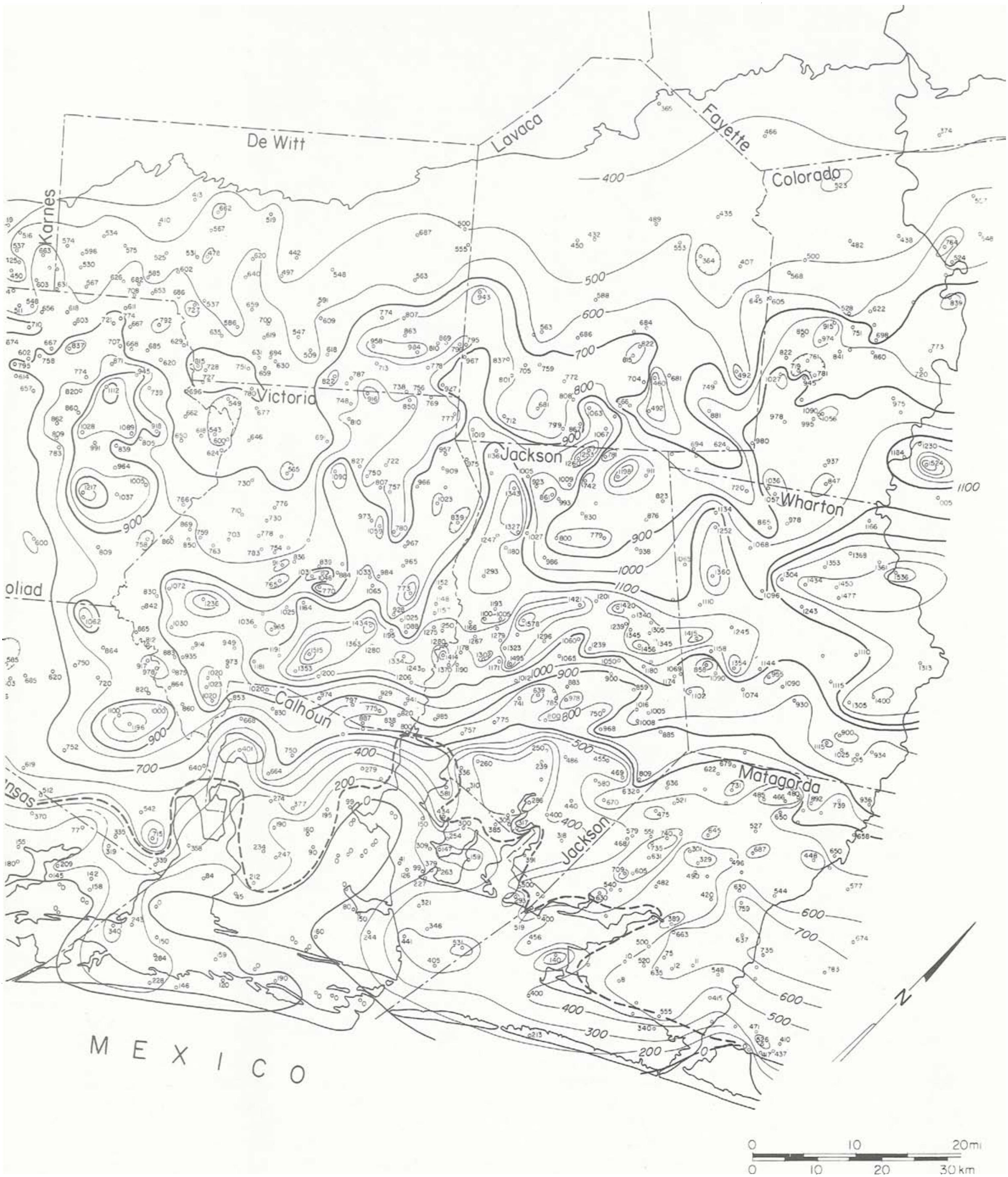


Figure 34. Map of net sand containing



fresh water, coastal aquifer system.

water and areas having greatest potential for drilling and pumpage of usable water.

The base and the net-sand values of the aquifer correspond in general to similar data published in county reports by the Texas Department of Water Resources (Anders, 1962; Baker and others, 1965; Dale and others, 1957; Hammond, 1969; Shafer and others, 1968; Shafer, 1970, 1974). Net-sand values of fresh-water sands in Bee, De Witt, Jim Wells, Live Oak, Refugio, and Victoria Counties are significantly higher than those reported in county reports of the Texas Department of Water Resources (Myers and Dale, 1966; Follett and Baker, 1965; Anders and Baker, 1961; Mason, 1963a, b; Marvin and others, 1962). This difference is attributed to the fact that all sands were counted within the fresh-water column regardless of thickness.

Relationship Between Faulting and the Aquifer

The importance of contemporaneous faulting to the general sediment distribution and orientation of high-sand depositional systems is reflected in the general distribution of sands containing fresh water and in the geometry of the aquifer (figs. 15, 18, 21, 24, compared to figs. 33, 34). Four principal types of variations in the configuration of the base of the fresh-water aquifer are observed in this investigation:

1) The fresh-saline water interface is deeper on the basinward side of some growth faults than on the landward side (for example, the landward fault zone in fig. 35). Similar effects of faults on the base of the aquifer are observed in southeastern Victoria and west-central Jackson Counties (fig. 36) and in other areas (fig. 33).
2) The fresh-saline water interface is shallower on some downthrown fault blocks (for example, the basinward fault zone in fig. 35). This is common in the middle and downdip parts of the area, especially in Jim Wells, Refugio, Aransas, and southern Jackson Counties (fig. 33; and all dip sections).
3) The fresh-saline water interface rises to shallower depths where sand bodies pinch out. This effect is common at the downdip terminations of bayhead deltaic sands within the Upper Goliad-Willis and Lower Fleming units. A variation is the case of combined sedimentary pinch-out and fault-diverted rise of the interface (fig. 37).
4) The fresh-saline water interface rises around salt domes. This may be due to the effect of uplifted strata (see section on salt domes, this work) caused by dome growth or by salt dissolution of the dome, such as in Big Hill (Gulf) and Markham domes in Matagorda County (fig. 33).

Relationship Between Depositional Systems and the Fresh-Water Aquifer

The Gulf Coast fresh-water aquifer has been described as a complex, gulfward-dipping series of sands and shales. Its internal complexity and the absence of regional key beds or reliable paleontological markers make difficult the correlation of fluvial facies that change greatly within short distances in the subsurface. Analysis of sediment distribution in the study area reveals the presence of definite and coherent fluvial sand axes within each operational unit. An attempt is made here to assess the importance of braided to meanderbelt sand trends in providing aquifer volume for the storage of fresh water in the area.

A map of the middle and updip zones of overlapping fluvial sand axes in most operational units (fig. 39) can be compared to and superposed upon a simplified net-sand map of the fresh-water aquifer (fig. 38). Downdip coastal sand systems in the area were not included in figures 38 and 39 (except for a fluvial sand trend in Nueces County) because most of them occur beneath the fresh-water aquifer and contain brackish or saline water. The combined use of both maps (notice trend designations A, B, C, and D) indicates the following:

(A) The Nueces meanderbelt - bayhead delta systems of the Upper Goliad-Willis and Lissie units (figs. 26, 29, 39) conform closely with a dip-oriented fresh-water sand trend (A) in Nueces County (figs. 34, 38).

(B) Relatively thin fresh-water sand trends (B) in Live Oak County (figs. 34, 38) are composed predominantly of the most updip segments of the Nueces and Aransas fluvial sand trends in the Upper and Lower Fleming operational units (figs. 17, 20, 39) and sands of the Lower Goliad-Willis unit.

(C) Fresh-water high-sand areas (C) in the aquifer in southeastern Bee, southwestern Goliad, and northwestern Refugio Counties (figs. 34, 38) are composed mostly of sands of the Blanco, San Antonio, and Coletto meanderbelts of the Upper Fleming and Lower and Upper Goliad-Willis operational units (figs. 20, 23, 26, 39).

(D) The area of thickest fresh-water sands (D) (over 700 ft, 213 m, of net sand) is located in Wharton, Colorado, Jackson, Victoria, and eastern Goliad Counties (fig. 34 or 38), where most of the aquifer is composed of sands of the West Guadalupe, Guadalupe, and Colorado meanderbelt facies, mainly in the Fleming and Lower Goliad-Willis operational units (figs. 17, 20, 23, 39). Oakville and Catahoula sands also form part of the aquifer in this area.

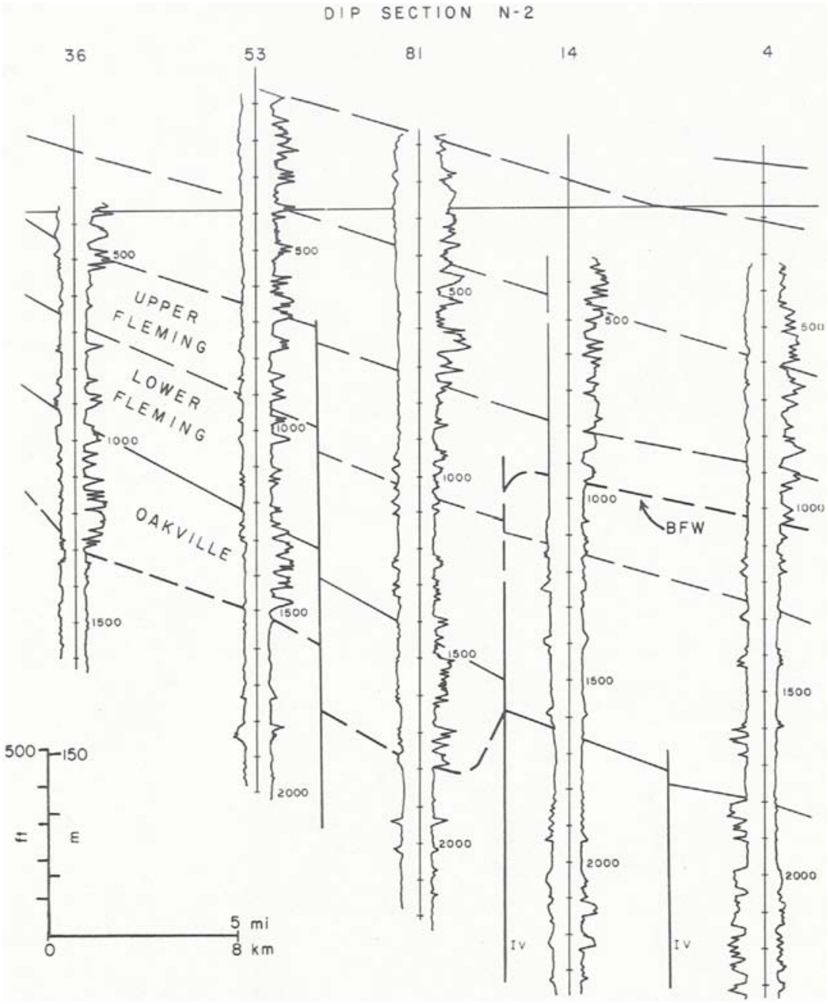


Figure 35. Faults and the base of the fresh-water aquifer, Jim Wells County. Fault data courtesy of Geomap. BFW = Base of fresh water.

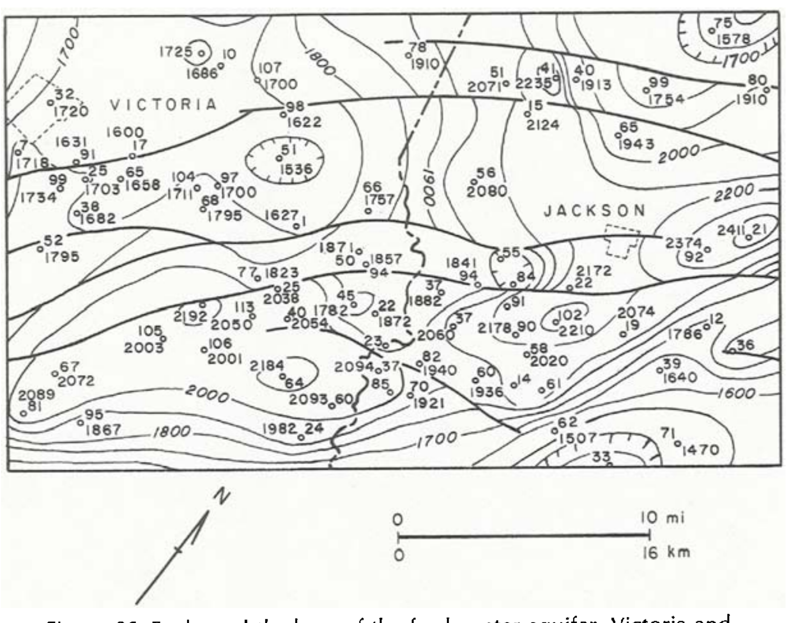


Figure 36. Faults and the base of the fresh-water aquifer, Victoria and Jackson Counties. Fault data courtesy of Geomap.

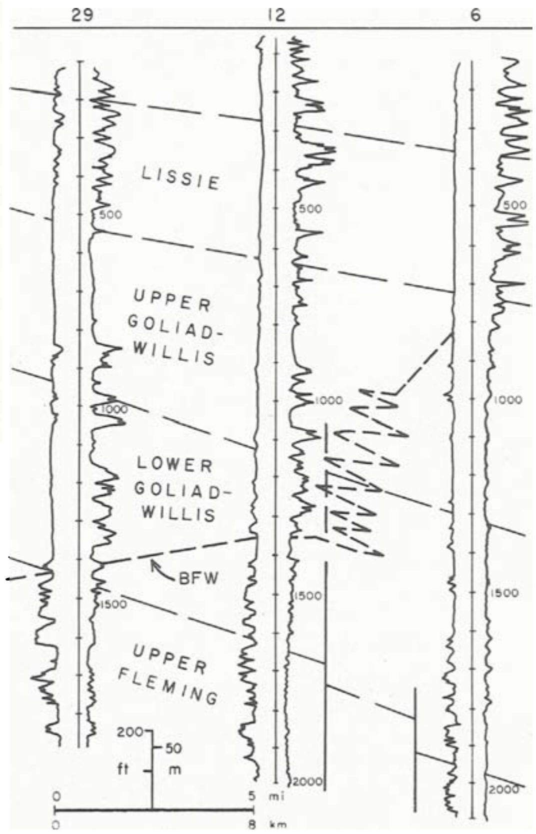


Figure 37. Sedimentary pinch-out, faults, and the base of the fresh-water aquifer, Refugio County. Fault data courtesy of Geomap. BFW = Base of fresh water.

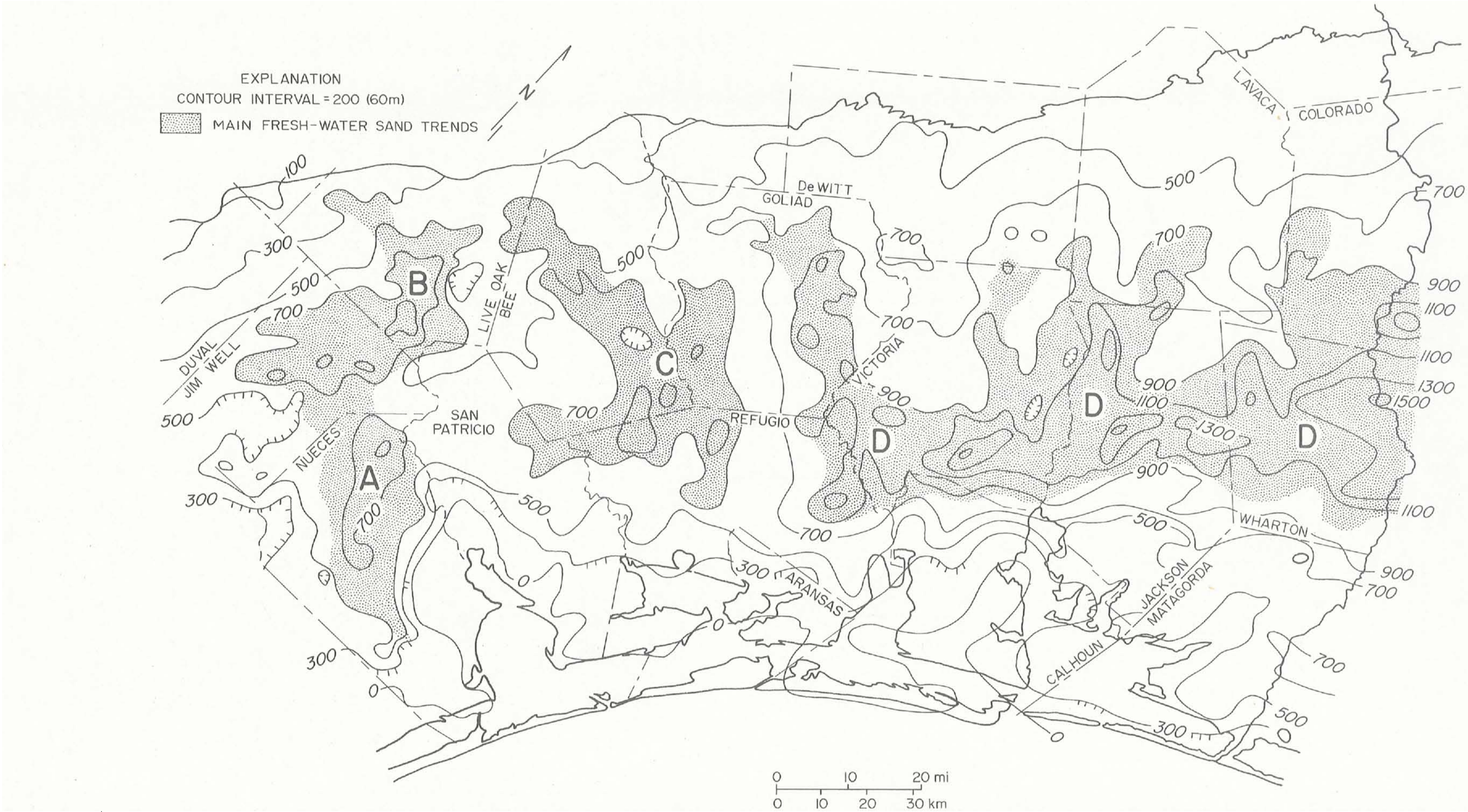


Figure 38. Main fresh-water sand trends of the coastal aquifer. See page 66 for discussion of areas A to D.

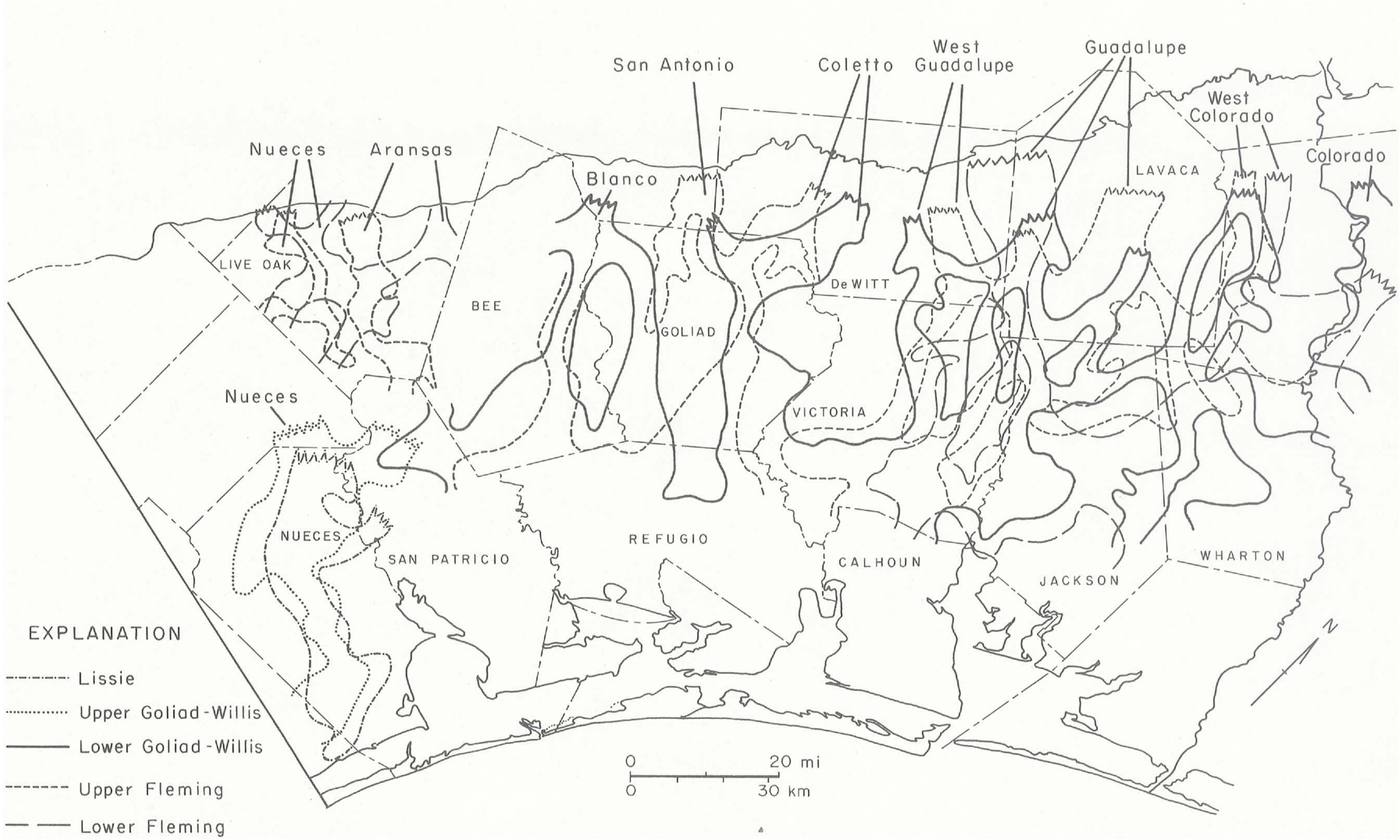


Figure 39. Superposed Fleming to Lissie fluvial sand trends and inferred paleorivers.

It is important to note that most of the fresh water is located in the easily rechargeable, dip-oriented, and coalescing fluvial sands and not in the strike-oriented coastal sands. Most of the strike-oriented coastal sands are isolated from the fresh-water aquifer by their orientation perpendicular to the regional hydraulic gradient, by floodbasin and lagoonal muds, and by growth faults.

Analysis presented in this section emphasizes the significance of interrelationships between sediment distribution, depositional systems, effects of fault zones, and the overall distribution of fresh ground water and its potential in the Gulf Coast aquifer. This approach permits the investigator to identify the main reservoirs, preferential routes of basinward ground-water movement (hydrologic plumbing system), and the sensitive recharge zones of the aquifer.

Ground-Water Use

Considerable volumes of fresh water have been and are currently being pumped from the coastal aquifer for irrigation, municipal, and industrial uses. Information on ground-water use in the area of study from 1969 to 1976 was made available from the computerized records of the Texas Department of Water Resources and is included in Appendix B. Partial data on irrigation for 1969 and 1974 are included in the Department's report number 196 (Texas Water Development Board, 1975). These figures are released every 5 years.

Some significant figures on water use for 1974, 1976, and 1979 are as follows:

Category		**Year(s) Acre ft**
Counties with lowest municipal and industrial use:		**1976**
Aransas		199.0
Calhoun		214.5
Goliad		388.1
Counties with highest municipal and industrial use:		**1976**
Colorado		6,204.4
Victoria		10,503.9
Wharton		9,751.2
Counties with lowest irrigation use:	**1974**	**1979**
Aransas	0.0	0.0
Refugio	0.0	0.0
Nueces	3.0	0.0
Goliad	179.0	0.0
Counties with highest irrigation use:	**1974**	**1979**
Colorado	45,619.0	53,795.0
Jackson	122,568.0	128,578.0
Wharton	175,906.0	93,138.0
Matagorda	20,674.0	102,430.0
Counties with highest total use (municipal, industrial, and irrigation):		**1974**
Colorado		54,152.7
Jackson		127,479.7
Wharton		184,258.5

The grand total use of ground water for the study area in 1974 was 486,724.4 acre feet, of which 87.5 percent was for irrigation. Total consumption of ground water in 1976 for municipal and industrial purposes (irrigation not included) in the same area was 55,344 acre feet.

SUBSURFACE LIQUID-WASTE DISPOSAL

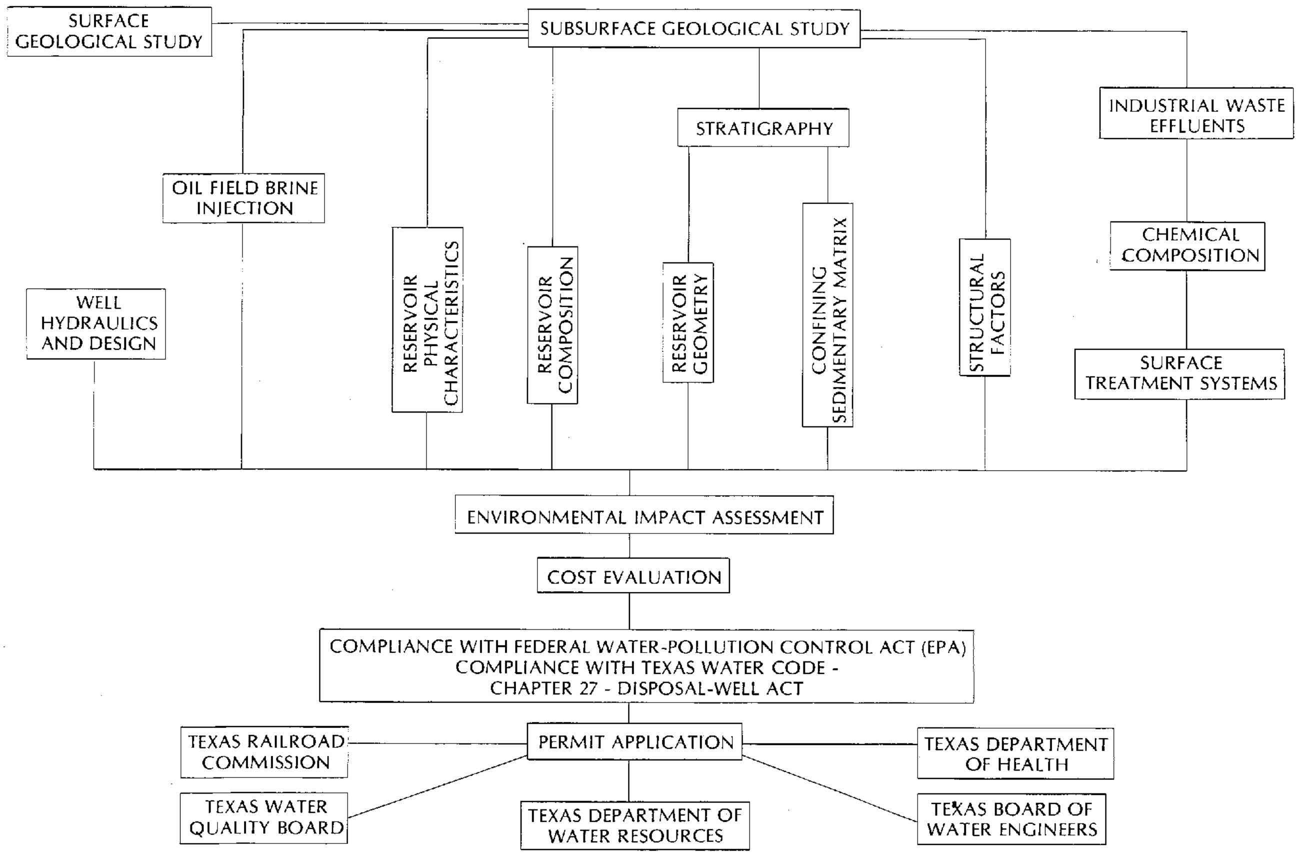
Increased concern in Texas about harmful effects of industrial liquid waste on ground water, surface waters, vegetation and animals as well as human health underlines the need for studies that ensure appropriate and safe disposal of potentially harmful effluents. The following is a review of the feasibility of waste disposal in the subsurface sand systems in the study area. Past experience in subsurface disposal (especially of brines derived from oil well drilling) has proved the effectiveness of injection wells for the disposal of large volumes of liquid waste (Appendix A).

Several factors must be considered for a successful completion of an injection well for the disposal of industrial or municipal effluents. A subsurface study should include (1) stratigraphic analysis that includes age, geometry of repository reservoir, depths to reservoir, confining sedimentary matrix (clay and shale facies), and relationship of the target reservoir to the fresh-water aquifer; (2) reservoir composition including lithology, mineralogy, sorting, anisotropy, diagenesis, and chemistry of connate waters; (3) physical properties of the reservoir including analysis of porosity, permeability, transmissivity, storage coefficient, pressure, temperature, and anisotropy; and (4) structural factors including possible influence of fault zones, folding, dome structures, stratal attitudes, and seismic stability. Table 12 is a flow chart that illustrates these main areas of consideration.

In the area of study, thick coastal sands within the Lower Fleming operational unit appear to constitute an optimum reservoir for the disposal of liquid industrial or municipal wastes. Selection of these sands was based on their adequate thickness, lateral continuity, non-interference of the fresh-water aquifer, good porosity, intermediate depth ranges, and more importantly, effective sealing and confinement.

These sands, designated as the western wave-dominated delta and central coastal barrier system (see "Wave-Dominated Delta - Coastal Barrier Complex" of the Lower Fleming unit; fig. 17) form part of the uppermost section of the Lower Fleming and exhibit net-sand thicknesses of between 350 and 600 ft (107 and 183 m) (fig. 15). Figure 40 illustrates the coastal depositional systems, the general thickness, and the depth to the top of the Lower Fleming unit. Depths to the reservoir beneath the present western and central lagoon and barrier islands range between

Table 12. Waste disposal flow diagram.
Factors involved in the disposal of liquid wastes.



2,700 and 2,900 ft (823 and 884 m) (fig. 40). These sands are illustrated on dip sections and on strike section I. Although the optimum area (fig. 40) in part includes reserved state park areas, it is also near populated and industrial areas, especially Corpus Christi.

The reservoir is effectively confined and isolated by updip and downdip shales, and it is also overlain and underlain by shales. These sealing facies are, respectively, landward-lagoon, basinward-marine, and overlying and underlying open-bay and shallow-marine deposits (figs. 5 to 9, 17). Overlying shales display thicknesses of about 120 ft (36.6 m) in Kleberg County, 20 ft (6 m) in Nueces County, 350 ft (107 m) in southwest Aransas County, and 150 ft (46 m) in Calhoun County (figs. 5 to 9). These bounding shales are in turn overlain by sands and shales of the Upper Fleming fluviodeltaic complex.

Tectonically, the area of the potential disposal reservoir has been affected slightly by late Miocene contemporaneous faulting. Two associated faults display displacement of no more than 100 ft (30 m) (see landward side of Aransas 22 well, fig. 8). These faults are currently inactive, and reactivation from drilling is improbable since there are only a few oil wells and no water wells in the area. In any case, fluid from the reservoir would have to leak through the overlying shales, after which it would reach the overlying brine-bearing sands and shales of the fluviodeltaic complex of the Upper Fleming unit, where it would finally disperse.

Although specific data on porosity and permeability of these sands are not available, good approximations can be made from available information on deeper Tertiary sands (fig. 41). According to Loucks and others (1979), most of the effective porosity and permeability of sands is caused by compaction from the original ± 40 percent porosity to about the 30 percent current porosity. In addition, they are also influenced to a lesser degree by diagenetic factors such as formation of clay coats, feldspar leaching, replacement of feldspar by calcite, feldspar overgrowths, and precipitation of minor amounts of iron-rich carbonates. Figure 41 shows that general values of porosity for Miocene sands at depths between 2,800 and 4,000 ft (854 and 1,220 m) range between 27 and 32 percent; permeability commonly ranges between 0.3 and 5.0 darcys (Loucks and others, 1979).

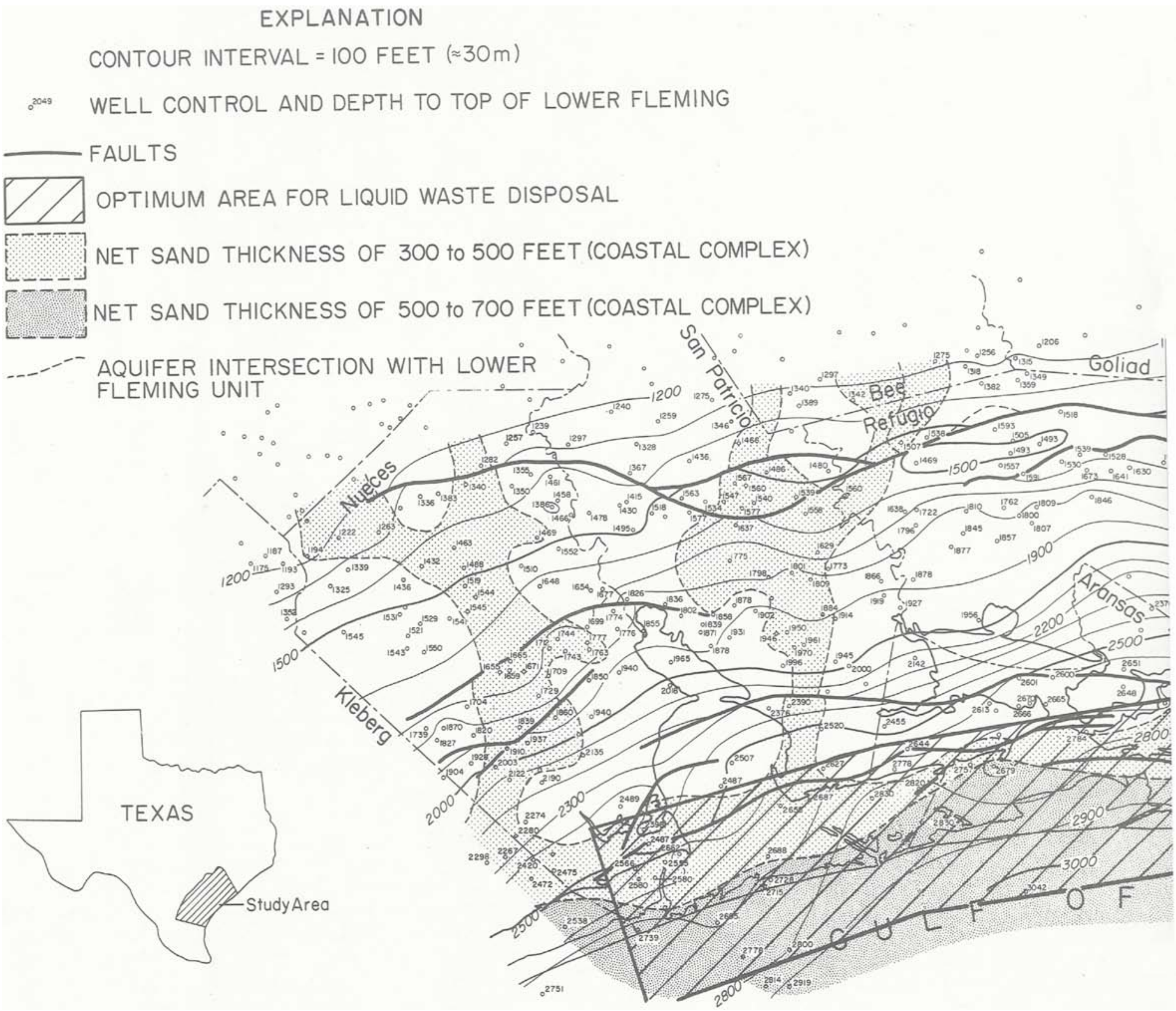
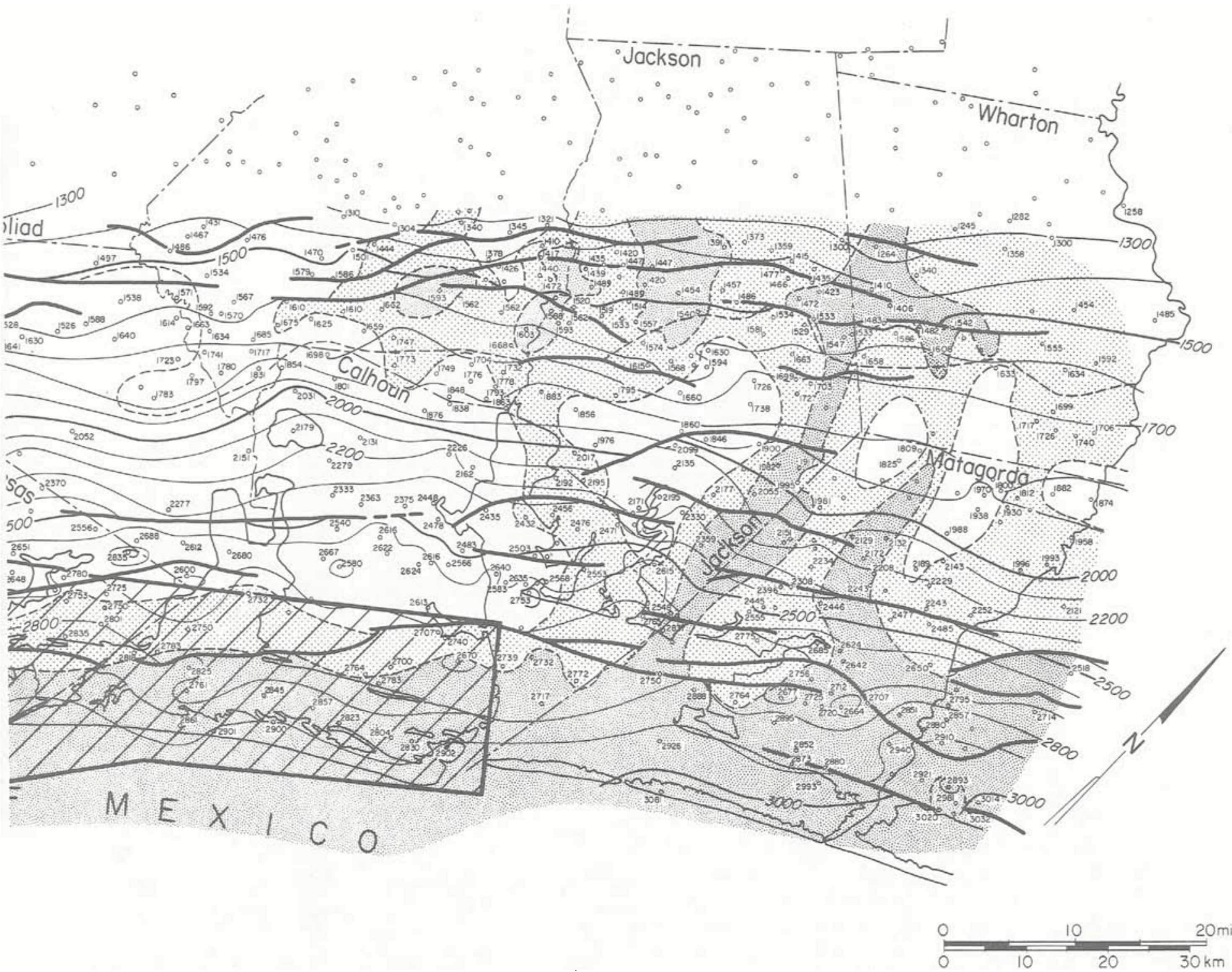


Figure 40. Map of potential reservoirs for liquid-waste disposal, Lower Fleming Formation. Contours are depth to top of optimum



waste disposal reservoir; dashed line shows downdip limit of fresh water in Lower Fleming unit. Fault data courtesy of Geomap.

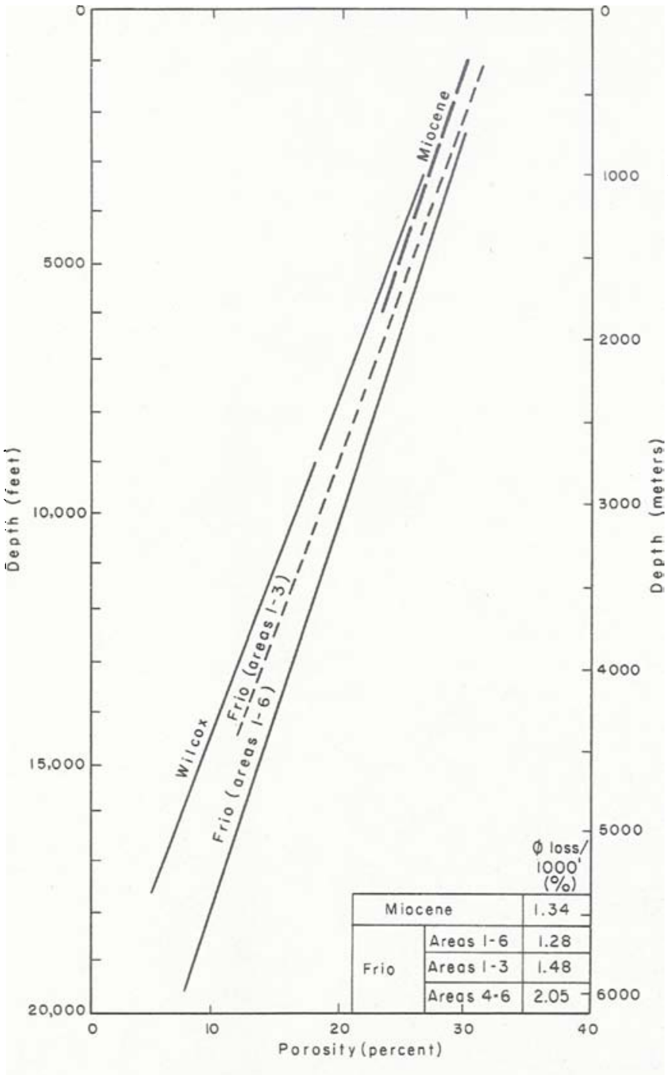


Figure 41. Porosity versus depth for late Tertiary formations. After Loucks and others (1979).

OIL AND GAS PRODUCTION

Most onshore production of oil and gas from the late Miocene to Pleistocene section in the area of study is from Fleming reservoirs, but some production also occurs from sands of the downdip Goliad-Willis section. Gas production has been relatively significant, whereas oil production has been very small. It is believed that hydrocarbons in Fleming and Goliad-Willis sands migrated from deeper levels.

Gas production at the end of 1977 for the most productive counties was as follows:

Victoria: 4,393,258 MCF (1977); 81,396,374 MCF (cumulative)

Wharton: 2,367,884 MCF (1977); 83,502,940 MCF (cumulative)

Oil production in 1977 was low (Appendix C); counties with the highest cumulative production were as follows:

San Patricio: 2,203,983 bbls (mostly from Sinton North field)

Matagorda: 17,701,015 bbls (mostly from Markham field)

The grand total oil production from the studied section in the area was 13,383 bbls in 1977, and cumulative production was 21,351,242 bbls. The grand total gas production was 50,170,548 MCF in 1977, and cumulative production was 428,834,672 MCF. Detailed production of oil and gas by fields and counties is included in Appendix C.

CONCLUSIONS

Interpretation of late Miocene, Pliocene, and Pleistocene sediment distribution in the subsurface of the central Coastal Plain of Texas indicates the presence of distinctive lithofacies and depositional systems: fluvial meanderbelt and floodbasin, fluviodeltaic system, lagoon, bayhead deltas, large marine embayment, thick wave-dominated delta, strandplain, and thick, superposed coastal barrier. The western relict fluvial systems (Aransas, Nueces, and Blanco) were less active than were the eastern rivers (Coletto, Guadalupe, Navidad, and West Colorado), which generally transported greater volumes of sand.

The late Miocene is represented by a transgressive marine event that resulted in the deposition of shelf and shallow-marine shales. Fluviodeltaic progradation occurred during deposition of the upper part of the Lower Fleming unit and continued during the deposition of the Upper Fleming and Lower Goliad-Willis units. A minor late Pliocene transgressive event is represented by shales of a downdip marine embayment system within the Upper Goliad-Willis operational unit. Finally, Lissie and Beaumont progradation deposited lithofacies and systems similar to modern analogs.

The geographic location of the various fluvial systems remained relatively persistent throughout deposition of the interval studied. Principal depocenters were mostly located in the eastern zone (Jackson, Matagorda, Wharton, eastern Victoria Counties). However, during deposition of the Upper Fleming and Lower Goliad-Willis units, depocenters shifted to the central coastal area (Refugio, Calhoun, and Aransas Counties).

The basinward configuration of the coastal systems of the Lower and Upper Fleming and Lower Goliad-Willis operational units indicates that the coastline during latest Miocene and earliest Pliocene was located at least 10 mi (16 km) offshore from the present coastline. Similarly, configuration of the coastal systems of the Lissie and Beaumont units suggests that the Pleistocene high-stand coastline was situated at least 10 mi (16 km) offshore from the present coast of Nueces, Calhoun, and Matagorda Counties.

Shallow extensions of the deeper Vicksburg, Frio, and Miocene fault trends produced small displacements and had a clear and significant influence on sediment distribution of the upper Miocene, Pliocene, and Pleistocene, as evidenced by the development of sand thicks in the downthrown blocks, by abrupt changes in sand-body orientation along faults, and by the formation of gentle rollover structures, some of which were hosts for oil and gas accumulations.

A direct relationship between the high-sand, dip-oriented fluvial trends and the geometry of the coastal aquifer was established by comparing location, geometry, and sand values of the updip braided-meanderbelt sand trends with the net-sand distribution of the fresh-water aquifer. Most of the Oakville and Fleming fresh-water sands are located in the inland part of the study area; Goliad-Willis and Lissie sands containing fresh water extend farther downdip. The area of highest fresh-water potential is located in Victoria, Jackson, Wharton, and Colorado Counties.

Review of the feasibility of using isolated downdip coastal sands for disposal of industrial and municipal wastes indicates that thick coastal barrier sands in the upper part of the Lower Fleming unit offer optimum conditions for such an application.

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APPENDIX A

INJECTION WASTE DISPOSAL WELLS IN THE AREA OF STUDY*

County	No. of wells	Company
Victoria	10	E. I. Du Pont de Nemours
Matagorda	5 (plugged)	Celanese Chemical Co.
Nueces	2	Calallen Ind. School Dist.
	1	International Pollution Control, Inc.
	1	Pax Christi Home
	1 (plugged)	Nolan's Fireside Inn, Inc.
	1 (plugged)	Bishop Consolidated Ind. School Dist.
San Patricio	1	San Patricio Municipal Water Supply
	3	E. I. Du Pont de Nemours
Live Oak	7	U. S. Steel Corp.
	1	Wyoming Miner Corp.
Duval	1	Union Carbide Corp.
	1	Mobil Oil Co.

*Source: Texas Department of Water Resources.

APPENDIX B

GROUND-WATER USE*
Ground-water pumpage totals by source county
(units-acre feet/yr)

Year	Municipal	Industrial	Total	Ground-water irrigation	1969 and 1974 total
			ARANSAS COUNTY		
1969	939.1	301.4	1,240.5	0.0	1,240.5
1970	699.2	381.2	1,080.4		
1971	198.4	269.9	468.3		
1972	167.7	277.3	445.0		
1973	209.3	182.8	392.2		
1974	128.8	200.2	329.0	0.0	329.0
1975	154.5	201.4	355.9		
1976	152.5	46.5	199.0		
			BEE COUNTY		
1969	2,464.6	626.3	3,090.9	2,106.0	5,196.9
1970	2,372.6	631.0	3,003.6		
1971	2,814.1	622.5	3,436.6		
1972	2,604.8	642.3	3,247.1		
1973	2,406.7	623.5	3,030.3		
1974	2,482.2	625.4	3,107.6	1,611.0	4,718.6
1975	2,513.3	405.5	2,918.8		
1976	2,570.3	412.8	2,983.2		
			CALHOUN COUNTY		
1969	1,562.2	37.0	1,599.2	1,544.0	3,143.2
1970	800.1	31.9	832.0		
1971	211.3	61.0	272.2		
1972	180.5	64.7	245.3		
1973	175.6	39.9	215.5		
1974	175.6	33.4	209.0	2,715.0	2,924.0
1975	191.2	27.8	219.0		
1976	189.7	24.8	214.5		
			COLORADO COUNTY		
1969	1,512.7	3,883.8	5,396.5	49,046.0	54,442.5
1970	1,509.2	3,249.5	4,758.7		
1971	1,746.7	5,046.2	6,792.9		
1972	1,701.8	9,032.7	10,734.5		
1973	1,475.9	7,959.4	9,435.4		
1974	1,609.9	6,923.8	8,533.7	45,619.0	54,152.7
1975	1,636.8	19,769.3	21,406.0		
1976	1,685.1	4,519.3	6,204.4		

*Source: Texas Department of Water Resources.

APPENDIX B
(continued)

Year	Municipal	Industrial	Total	Ground-water irrigation	1969 and 1974 total
			DE WITT COUNTY		
1969	2,521.7	176.4	2,698.1	564.0	3,262.1
1970	2,251.8	156.4	2,408.2		
1971	2,412.3	160.8	2,573.0		
1972	2,599.5	172.2	2,771.7		
1973	2,191.5	172.2	2,363.7		
1974	2,362.0	150.7	2,512.7	821.0	3,333.7
1975	2,259.5	141.3	2,400.8		
1976	2,263.7	129.1	2,392.8		
			DUVAL COUNTY		
1969	1,070.2	1,552.8	2,623.0	2,359.0	4,982.0
1970	1,107.8	1,476.5	2,584.2		
1971	1,435.6	3,896.4	5,332.0		
1972	747.1	4,219.0	4,966.1		
1973	822.0	4,264.8	5,086.8		
1974	1,016.0	4,472.4	5,488.4	2,909.0	8,397.4
1975	2,082.2	1,679.2	3,761.4		
1976	1,870.1	1,792.8	3,662.9		
			GOLIAD COUNTY		
1969	314.3	1.8	316.1	200.0	516.1
1970	323.7	1.8	325.6		
1971	358.4	1.8	360.2		
1972	320.6	2.2	322.9		
1973	278.0	2.2	280.2		
1974	322.8	2.1	324.9	179.0	503.9
1975	336.9	2.1	339.1		
1976	386.0	2.1	388.1		
			JACKSON COUNTY		
1969	1,387.7	3,158.4	4,546.1	114,128.0	118,674.1
1970	1,070.5	2,910.0	3,980.5		
1971	1,310.1	3,304.6	4,614.7		
1972	1,280.6	3,067.4	4,348.0		
1973	1,609.2	3,038.2	4,647.4		
1974	1,281.0	3,630.7	4,911.7	122,568.0	127,479.7
1975	1,566.1	2,832.1	4,398.2		
1976	448.3	3,000.3	3,448.6		
			JIM WELLS COUNTY		
1969	1,037.5	1,568.5	2,606.0	2,142.0	4,748.0
1970	1,035.5	762.2	1,797.7		
1971	1,095.8	490.2	1,586.0		
1972	957.2	437.2	1,394.4		
1973	862.3	520.0	1,382.4		
1974	875.2	575.4	1,450.6	2,914.0	4,364.6
1975	866.5	505.5	1,372.0		
1976	930.4	509.7	1,440.0		
			KARNES COUNTY		
1969	1,336.0	650.6	1,986.6	845.0	2,831.6
1970	1,499.9	627.6	2,127.5		
1971	1,771.0	633.9	2,404.9		
1972	1,609.1	971.8	2,580.9		
1973	1,383.0	1,051.6	2,434.6		
1974	1,605.3	797.4	2,402.7	2,677.0	5,079.7
1975	1,879.5	989.8	2,869.3		
1976	1,599.5	905.7	2,505.2		
			LAVACA COUNTY		
1969	1,266.1	189.8	1,455.9	23,512.0	24,967.9
1970	1,236.8	80.6	1,317.4		
1971	1,439.8	286.0	1,725.8		
1972	1,371.2	237.7	1,608.9		

APPENDIX B
(continued)

Year	Municipal	Industrial	Total	Ground-water irrigation	1969 and 1974 total
1973	1,242.3	262.8	1,505.1		
1974	1,285.8	284.5	1,570.3	23,965.0	25,535.3
1975	1,267.0	279.5	1,546.5		
1976	1,475.7	277.4	1,753.1		
			LIVE OAK COUNTY		
1969	219.0	385.7	604.7	1,679.0	2,283.7
1970	203.1	385.9	589.0		
1971	229.6	428.3	658.0		
1972	195.3	346.3	541.7		
1973	202.3	366.0	568.3		
1974	228.9	366.0	594.9	1,724.0	2,318.9
1975	256.4	427.3	683.7		
1976	281.3	394.9	676.2		
			MATAGORDA COUNTY		
1969	2,671.1	4,741.0	7,412.1	18,921.0	26,333.1
1970	2,463.5	5,383.8	7,847.2		
1971	2,954.7	2,190.5	5,145.3		
1972	2,779.2	2,096.1	4,875.3		
1973	2,657.0	1,855.3	4,512.3		
1974	2,815.6	2,298.0	5,113.6	20,674.0	25,787.6
1975	2,845.7	1,732.0	4,577.7		
1976	2,842.2	1,839.3	4,681.4		
			NUECES COUNTY		
1969	667.7	1,526.8	2,194.5	802.0	2,996.5
1970	558.7	2,573.2	3,131.9		
1971	632.5	1,387.4	2,020.0		
1972	557.7	1,325.8	1,883.5		
1973	497.8	1,409.6	1,907.4		
1974	553.8	1,454.1	2,007.9	3.0	2,010.9
1975	538.7	1,400.0	1,938.8		
1976	707.8	1,173.9	1,881.7		
			REFUGIO COUNTY		
1969	790.3	485.6	1,275.9	0.0	1,275.9
1970	716.4	485.5	1,201.9		
1971	859.8	484.8	1,344.6		
1972	736.6	490.7	1,227.3		
1973	596.3	488.7	1,085.0		
1974	851.5	488.5	1,340.0	0.0	1,340.0
1975	938.4	480.5	1,418.9		
1976	918.3	452.3	1,370.6		
			SAN PATRICIO COUNTY		
1969	975.9	169.8	1,145.7	6,097.0	7,242.7
1970	1,028.3	169.9	1,198.2		
1971	1,422.0	174.5	1,596.6		
1972	1,367.7	174.8	1,542.6		
1973	1,190.7	174.6	1,365.2		
1974	1,286.9	175.4	1,462.3	5,926.0	7,388.3
1975	1,116.8	92.3	1,209.1		
1976	1,233.6	53.6	1,287.2		
			VICTORIA COUNTY		
1969	6,448.1	5,916.2	12,364.3	17,338.0	29,702.3
1970	6,625.7	7,890.1	14,515.8		
1971	7,717.2	6,664.0	14,381.2		
1972	7,149.4	4,956.9	12,106.3		
1973	7,036.8	8,634.8	15,671.6		
1974	6,698.9	4,119.7	10,818.6	15,983.0	26,801.6
1975	6,638.8	4,156.5	10,795.3		
1976	6,761.3	3,742.6	10,503.9		

APPENDIX B
(continued)

Year	Municipal	Industrial	Total	Ground-water irrigation	1969 and 1974 total
		WHARTON COUNTY			
1969	2,490.2	6,503.7	8,993.9	190,298.0	199,291.9
1970	2,636.1	6,407.5	9,043.6		
1971	2,980.1	6,511.3	9,491.5		
1972	2,917.4	5,126.3	8,043.7		
1973	2,953.5	5,353.4	8,306.9		
1974	3,008.3	5,344.2	8,352.5	175,906.0	184,258.5
1975	3,283.5	5,561.1	8,844.7		
1976	3,310.9	6,440.3	9,751.2		
Grand totals for 1969 and 1974				857,775.0	979,855.4

APPENDIX C

OIL AND GAS PRODUCTION*

Field	Depth top producing zone (ft)	OIL (BBLS) 1977	OIL (BBLS) Cumulative	GAS (MCF) 1977	GAS (MCF) Cumulative
		ARANSAS COUNTY			
Goose Is.	4,274	0	640	0	258,292
Half Moon	3,900-4,300	97	2,190	77,577	1,167,212
TOTAL		97	2,830	77,577	1,425,504
		BEE COUNTY			
Blanconia	1,700-1,950	0	0	382,611	3,070,161
Burkes Ridge	1,850-1,900	0	0	0	12,633
Burkhollow W.	1,900	0	0	0	51,788
Cannan S.	900	0	0	77,021	94,372
Fortitude	800-1,400	0	0	13,279	22,800
Tynan E.	900-1,550	0	0	20,527	1,016,749
TOTAL				493,438	4,268,503
		CALHOUN COUNTY			
Espiritu	1,858-2,702	0	0	0	268,936
Heyser	2,650-3,300	0	0	0	3,730,732
Magnolia Beach	1,960	0	0	28,272	197,099
Matagorda Bay	1,740-3,620	0	0	2,297,541	8,411,535
Saluria	3,050-4,050	0	0	262,672	8,583,309
Sherman offshore	3,000-4,200	0	0	6,126,698	13,727,935
Steamboat Pass	1,205-2,861	0	0	1,538,371	9,916,590
TOTAL				10,253,554	44,836,136
		COLORADO COUNTY			
Garwood Miocene	1,300-2,100	0	0	37,584	37,584
Garwood N., N.E.	1,900-2,100	0	0	106,730	106,730
Garwood N.W.	1,250-2,100	0	0	353,494	4,232,170
Krueger Miocene	1,600	0	0	189,028	1,297,179
Skull Creek	1,700	0	0	137,124	410,114
TOTAL				823,960	6,083,777
		DE WITT COUNTY			
Amador	1,000	0	0	0	1,122,146
TOTAL				0	1,122,146
		DUVAL COUNTY			
Agua Prieta	980-1,020	0	0	64,418	92,020
Palangana dome	1,628-1,650	29	23,088	109,410	1,201,521
Robinson	850- 900	0	0	55,917	111,996
TOTAL		29	23,088	229,745	1,405,537

*Source: Texas Railroad Commission and International Scouts.

APPENDIX C
(continued)

Field	Depth top producing zone (ft)	OIL (BBLS) 1977	OIL (BBLS) Cumulative	GAS (MCF) 1977	GAS (MCF) Cumulative
GOLIAD COUNTY					
ABR Miocene	1,662	0	0	107,451	179,745
Bomba	800-1,300	0	0	0	25,870
Byron Hoff	1,400	0	0	0	279
Gantt	1,916	0	0	16,576	16,576
Maetze	1,650	0	0	0	50,150
Mission Valley (Goliad and Victoria Counties)	780-1,100	0	0	9,782	50,120
Schroeder	1,040-1,500	0	0	44,047	95,017
Sitton	1,500-1,900	0	0	31,571	43,206
TOTAL				209,427	460,963
JACKSON COUNTY					
Carancahua Creek	1,880	0	0	102,077	147,035
Collier	2,169-2,285	0	921,582	0	2,764
Cordele E.	2,300-2,430	0	0	66,944	104,579
Cordele W.	2,250-2,400	0	0	74,214	743,926
Morales	1,550-1,750	0	0	70,349	100,703
Morales N. (Jack Lavaca)	1,320-1,600	0	0	220,440	830,841
Navidad	1,400-2,100	0	0	686,358	6,231,111
Venado Lakes	2,726	0	0	0	618,678
West Ranch 80-A	2,959	0	0	0	1,984,012
TOTAL			921,582	1,220,382	10,763,649
JIM WELLS COUNTY					
Alfred	1,800	0	0	7,073	13,923
Alice	1,400	0	0	631	48,486
Keemac 1,800	1,872	0	0	0	707,222
Orange Grove	1,200-1,450	0	0	3,732	784,218
Quinto Creek	1,250	0	0	0	17,146
Tecolote	1,800-2,200	0	0	98,245	349,326
TOTAL				109,681	1,920,321
LAVACA COUNTY					
Borchers	1,370-1,500	0	0	1,592,672	3,896,342
Borchers E.	1,250	0	0	83,311	83,311
Borchers S.	1,300	0	0	6,513	55,815
Hope	700-1,250	0	0	562,137	1,560,144
Speaks	1,250	0	0	1,166,354	210,704
TOTAL				3,410,987	5,806,316
LIVE OAK COUNTY					
Littleton	300	0	0	0	35
Mt. Lucas	920-1,200	0	0	80,867	273,562
TOTAL				80,867	273,597
MATAGORDA COUNTY					
Big Hill (Gulf)	870-1,300	0	211,000	?	?
Collegeport (1A-6A)	3,625-4,283	0	15,331	5,826,660	18,853,362+?
Collegeport	1,900-4,000	0	0	497,279	15,156,699
Collegeport S.W.	1,958	0	0	165	21,804
Colorado Delta	3,784	27	27	0	5,698
Gulf 4,400	4,400	0	476	0	0
Markham	2,300-3,995	0	17,437,230	0	1,460
Matagorda Bay N.E.	2,650-2,750	0	0	62,188	62,188+?
Matagorda Bay S. and blks. 161, 193, 202	2,550-4,100	0	0	4,106,114	17,586,279
Oliver Point	3,800-4,200	0	0	482,544	2,204,053
Oyster Lake	4,000-4,144	0	36,951	572,623	18,062,177
TOTAL		27	17,701,015	11,547,573	71,953,720
NUECES COUNTY					
Agua Dulce	1,880-2,200	0	0	408,672	3,447,992
Arnold David	3,800	0	0	13,042	181,282
Baldwin	2,100-3,150	0	0	24,890	4,137,232
Chapman Ranch	2,700-3,600	0	0	45,432	3,860,638

APPENDIX C
(continued)

Field	Depth top producing zone (ft)	OIL (BBLS) 1977	OIL (BBLS) Cumulative	GAS (MCF) 1977	GAS (MCF) Cumulative
Clara Driscoll	1,700-2,400	0	0	1,170	2,445,690
Cody	2,100-3,300	0	0	0	135,182
Flour Bluff	1,258	0	0	0	1,692,951
Luby	3,000	0	0	245,213	805,318
Nueces Bay	1,900-2,800	0	0	57,835	1,049,674
Ramada	2,800-2,900	0	161,637	0	77,108
Richard King	1,370	0	281	0	53,429
Riverside	1,900-2,200	0	0	37,496	891,674
Saxet	1,000-3,100	0	0	843,131	3,913,910
Shield	2,849-3,011	0	161,289	9,677	954,591
Violet South	2,600	0	0	0	25,435
TOTAL			323,207	1,686,558	23,672,106
		REFUGIO COUNTY			
Fagan	1,900-3,000	0	0	1,288,671	7,919,572
Greta L (1-17)	1,699-2,744	0	0	3,639,553	15,633,430
Greta	1,080-2,460	0	0	271,562	2,204,036
Huff	1,503-2,946	1,951	47,138	2,755,089	18,845,878
Lake Pasture (E, W, L)	2,022-2,904	0	0	3,689,542	6,152,872
Marion Lagarto	2,500	0	0	0	438,159
Refugio Heard	1,600-2,850	0	88	323,702	2,329,964
Refugio New	1,450-2,800	0	0	369,096	1,253,528
Refugio Fox	1,675-2,800	80	80	11,299	129,363
Refugio Old	1,500-2,400	0	0	274,470	2,117,961
Sharpslake North	2,400	0	0	0	5,349
Tom O'Connor	1,700-2,700	0	0	0	1,110,373
TOTAL		2,031	47,306	12,622,984	58,140,485
		SAN PATRICIO COUNTY			
Dragon	2,457	0	0	0	42,018
Ewins	1,887	0	0	0	753,700
Gaines	2,500-3,450	0	0	0	866,954
Het	2,504-2,758	0	14,329	0	1,288,077
McNair	2,930	0	23,571	0	0
Midway	1,072-3,600	0	0	21,595	595,329
Midway N.	3,300	0	0	0	9,161
Odem	1,400-2,160	0	0	329,189	1,746,616
O'Neil	3,270	0	0	124,824	1,342,188
Reymet	2,000-3,000	0	0	81,813	9,432,500
Sinton N.	1,126-2,360	10,035	2,035,314	68,310	462,372
Sinton W.	1,140-2,300	0	0	24,371	483,374
Sodville	1,990	0	0	0	6,438
Taft S.	1,800-3,050	0	0	2,564	452,122
White Point	1,600-3,200	0	0	26,454	28,125
White Point E.	1,350-3,200	0	130,769	963,553	14,347,877
Wohlers Pond	3,550	0	0	0	7,935
TOTAL		10,035	2,203,983	1,642,673	31,864,786
		VICTORIA COUNTY			
Anagua	2,650	0	0	19,551	19,551
Coletto Creek	1,174-2,083	0	0	146,668	1,243,800
Coletto Creek S.	1,400	0	0	0	882,954
Cologne	500-1,950	0	0	354,977	17,191,875
Dreyer	1,300	0	0	22,726	25,106
Garcitas Creek	2,400	0	0	30,296	540,927
Helen Gohlke	850-1,400	0	0	172,207	3,050,702
Kay Creek	2,150-2,800	0	0	375,899	805,663+?
Marcado Creek and Marcado Creek E.	2,000-2,900	0	0	19,092	2,716,938
McFaddin (Victoria and Refugio Counties)	1,800-2,900	0	0	1,905,109	38,088,799
Nursery	500- 600	0	0	146,900	552,132
Nursery S.	1,000-1,450	0	0	392,581	661,821
Patricia	2,300-2,500	0	0	0	482,124
Pridham Lake	1,300-1,800	0	0	77,655	3,137,754
Salem	1,000-1,800	0	0	421,932	6,126,078
Telferner N.	2,000-2,100	0	0	64,472	1,436,520

APPENDIX C
(continued)

Field	Depth top producing zone (ft)	OIL (BBLS) 1977	OIL (BBLS) Cumulative	GAS (MCF) 1977	GAS (MCF) Cumulative
Tolson	1,800-1,900	0	0	0	321,577
Victoria	1,880-2,300	0	0	43,132	239,343
Vic-Witt	2,800	0	0	200,061	260,218
Weber	1,000-1,200	0	0	0	3,602,118
Welder Ranch	2,000	0	0	0	10,374
TOTAL				4,393,258	81,396,374
	WHARTON COUNTY				
Bernus	3,000	0	0	0	539,650
Blue Basin S.	961	0	0	145,206	2,525,003
Duffy	1,350-1,400	0	0	0	1,242,118
El Campo N.	3,014-3,384	1,164	128,180	89,430	1,061,125
El Campo W.	3,322	0	0	0	210,776
Hutchins Kubela-Lakeview	3,040	0	0	115,637	237,154+?
Karstedt Oak	2,750	0	0	331,855	420,660
Louise North	2,650-2,900	0	0	498,413	7,687,038+?
Magnet Withers S. M.	838-3,109	0	0	823	534,504
Magnet Withers	2,030-3,250	0	51	94,101	11,796,166
New Taiton	2,488-2,985	0	0	378,200	27,408,504
Swanson	2,950	0	0	0	161,756
Trans-Tex	2,500-3,000	0	0	714,219	28,160,382
Twin Basin	1,000-1,400	0	0	0	1,077,652
Winterman	2,400	0	0	0	440,452
TOTAL		1,164	128,231	2,367,884	83,502,940
GRAND TOTAL		13,383	21,351,242	51,170,548	428,896,860

APPENDIX D

WELL INFORMATION FOR CROSS SECTIONS

Map index no.	Well source no.	Operator	Well name	Depths covered (ft)	Elevation KB or DF (ft)
		ARANSAS COUNTY			
2	B-2*	Western Natural Gas Co.	St. Charles #14	138-11,616	29
3	B-3	Union Prod. Co.	Tatton #9	90-10,305	24
4	Q-1**	Gulf Board Oil Corp.	St. tr. 239-1	99- 9,001	12
15	Q-51	The Atlantic Ref. Co.	V. G. Gwynn #1	115- 7,750	17
16	Q-52	Ladd Oil Co.	J. R. Barry est. #1	160- 2,301	25
17	Q-53	F. W. Shield & Allen Morris	C. B. Shaffer est. #1	40- 8,576	12
22	Q-309	Western Natural Gas Co.	St. Charles #24	120-10,486	32
26	Q-332	Union Producing Co.	Tatton #6	90- 7,478	23
28	Q-348	Quintana Petr. Corp. (+Q-249)	Bankers Mortgage Co. #1	100- 9,726	25
		BEE COUNTY			
4	Q-16	Stanolind Oil & Gas Co.	F. McCollon #1	40- 8,152	380
16	Q-65	H. H. Howell & Rudman	Ed. Kubala #1	103- 4,310	221
19	Q-88	C. C. Winn	Truman Gill #11	100- 4,489	265
22	Q-95	Ramada Oil & Gas Co.	M. F. Schubert #1	125- 5,011	189
36	Q-148	Humble Oil & Ref. Co.	Laura T. Barrow #2	80- 6,150	102
39	Q-171	Smith-Story & Wood Corp.	P. A. Mitzen #1	70- 4,460	335
42	Q-178	Humble Oil & Ref. Co.	B. W. Adams #B-3	35- 3,510	344
75	Q-368	Celtic Oil Corp.	Magnus Beck #1	35- 7,510	441
85	Q-493	William Cones and others	R. V. Stubenthal and others #1	115- 4,010	140
89	Q-512	W. Moore Brelsford & J. O'Hara	McPeterson #2	70- 3,106	165
90	Q-520	Stanolind Oil & Gas Co.	Mrs. K. D. Roche #1	50- 5,020	122
		CALHOUN COUNTY			
8	Q-33	Quintana Petr. Corp.	Stanley Mattson #1	100- 9,126	49
11	Q-50	M. E. Douglas, etc.	McDonald-Frels #1	212- 9,506	32

*Bureau of Economic Geology Well Log Collection.
**Texas Department of Water Resources Well Log Collection.
KB = Kelly bushing; DF = Derrick floor; GL = Ground level.

APPENDIX D
(continued)

Map index no.	Well source no.	Operator	Well name	Depths covered (ft)	Elevation KB or DF (ft)
14	Q-54	Pat J. Murphy and others	F. M. Ryan #1	150- 3,825	22
16	Q-57	Alcoa Mining	Mrs. Mary A. Hubbard #1	90- 9,462	24
21	Q-63	Brazos Oil & Gas Co.	American Natl. #1	72- 9,000	23
25	Q-68	Humble Oil & Ref. Co.	Elizabeth K. Hardie #6	100- 8,681	18
32	Q-75	Humble Oil & Ref. Co.	St. tr. 202 Well #1	207- 3,886	18
38	Q-82	Quintana Petr. Corp.	J. Hynes #1	80- 9,864	23
52	Q-110	Humble Oil & Ref. Co.	Appling Gas Unit #2 Well #1	323- 9,003	26
		COLORADO COUNTY			
4	Q-6	Brazos Oil & Gas Co.	W. A. Struss #1	95-10,988	213
5	Q-9	C. N. Housh	Zwiegel #1	52-10,302	220
18	Q-105	Magnolia Petr. Co.	E. J. Gracey #1	167- 9,734	163
23	Q-134	Quintana Petr. Corp.	Cullen and others #1	108-10,484	258
25	Q-148	Cities Service Oil Co.	B. Wooten #1	70- 3,195	177
43	Q-323	The Pure Oil Company	Frieda Yogelsang #1		311
50	Q-443	Shenandoah Oil Corp.	Alice Tait #1	80- 8,517	204
		DE WITT COUNTY			
3	Q-3	Atlantic Ref. Co.	Anna M. Vaughn #1	50- 8,100	220
15	Q-48	Lamar Hunt Trust	O. Rathamp #1	52- 8,015	297
24	Q-74	Wescol Oil & Gas Co.	Leister #1, Nordheim Unit	40- 8,449	370
47	Q-196	Sookey-Nick Oil Corp.	W. C. Steinmann #1	97- 2,268	262
50	Q-217	The Superior Oil Co.	M. A. Kerlick Salt. Wd. #1	78- 3,177	332
58	Q-279	The Atlantic Ref. Co.	Sidney Daniels #1	100-12,501	268
		DUVAL COUNTY			
18	Q-431	Camp Oil Co. and others	Huizar #2	112- 3,940	467
32	Q-777	Taylor Ref. Co.	A. Parr #A-8	443- 5,401	406
35	Q-1153	Circle O. Co.	A. Reyes and others #1	45- 3,500	597
71	Q-1598	American Republics Corp.	Richardson #B-1	95- 3,243	487
		FAYETTE COUNTY			
2	Q-140	Pomykal Drlg. Co.	City of Ellinger	90- 967	360
		GOLIAD COUNTY			
14	Q-50	Commercial Prod. Co.	Carl Kohler #1	50- 5,738	242
18	Q-69	G. Parker	Hardeman #2 (and #1)	311- 2,782	121
20	Q-78	Pontiac Ref. Corp. and others	Mrs. W. Farley "B" #1	110- 4,113	176
25	Q-88	Blair-Vreeland	B. B. Gayle #1	170- 4,015	212
50	Q-269	Carl Vickers, Inc.	Dietzel #1	111- 4,015	177
52	Q-279	Ginther, Warren & Co.	Gibb #1	330- 4,710	148
59	Q-368	Humble Oil & Ref. Co.	A. Henke Estate #1	76- 8,287	248
70	Q-520	C. B. Hamill Assoc. Oil & Gas Co.	L. B. Von Domlen #1	90-11,284	221
79	Q-655	Bahia Oil & Gas and others	Raymond Bego #1	195- 3,000	168
		JACKSON COUNTY			
20	Q-190	Peltex Petr. Co., Inc.	Moody #1	1,222- 9,971	39
21	Q-198	Tobin & Begeman	G.S. Gayle #B-1	155- 6,368	60
35	Q-362	Murphy Oil Co., Oklahoma, Inc.	"L" Ranch #1	176- 7,524	46
36	Q-363	Texas Gas Explo. Corp.	E. F. Sheblack #1	215- 6,931	60
46	Q-402	Magnolia Petr. Co.	O. B. Fenner #1	100- 4,810	140
71	Q-646	Pan American Petr. Corp.	J. A. Graves #1	200- 2,110	50 (GL)
	Q-646	Sunray Midcon. Oil Co.	J. A. Graves #1	1,032- 6,782	62
80	Q-798	H. J. Porter	Kearn #1	188- 2,943	115
104	Q-1208	Forest Oil Corp.	Paul Henderson #1	200- 2,718	113
105	Q-1210	E. G. Catlett	Boling #1	316- 7,015	22
		JIM WELLS COUNTY			
20	Q-148	Eddey & Messer	Chester Warren #1	230- 5,548	251
28	Q-194	O. B. Kiel, Jr.	B. W. Cox #1-A	260- 5,764	121
37	Q-240	Mason & Co.	Jacob Floyd #1	202- 5,294	132
40	Q-282	Frank Waters	Garcia # 1	149- 6,004	184
44	Q-587	Blanco Oil Co. & Al Buchanan	Bagnall #2	100- 4,921	159
55	Q-880	Dellwood Oil Co.	D. W. Risinger and others #1	118- 5,614	307

APPENDIX D
(continued)

Map index no.	Well source no.	Operator	Well name	Depths covered (ft)	Elevation KB or DF (ft)
59	Q-937	Daubert Oil & Gas Co.	Lovella Wade A-1	150- 4,200	134
61	Q-976	H. R. Smith	N. O. Adams #5	128- 4,013	176
76	Q-1142	Kirkwood Drlg. Co.	Kosel #1	150- 5,880	155
77	Q-1143	H. J. Parker & Howell and others	R. C. Miller #1	108- 4,800	185
		KLEBERG COUNTY			
1	Q-1	Pure Oil Co.	State #1	194- 9,635	17
5	Q-58	Humble Oil & Ref. Co.	King Ranch - East Laureles G-9	110- 9,004	35
10	Q-110	Humble Oil & Ref. Co.	King Ranch, Lobo Pasture #1	90- 5,962	39
14	Q-391	Standard Oil Co.	State 948 #53	312- 9,974	57
		LAVACA COUNTY			
1	B-1	Fidelity Oil and Royalty Co.	F. G. Olsovsky #1	100- 8,804	380
31	Q-83	San Jacinto Oil & Gas Co.	Dohl #1	100-11,015	231
33	Q-105	H. L. Hunt Oil Co. & Shell	R. K. Smothers #1	80- 5,555	179
38	Q-146	Forest Oil Corp.	H. C. Obelgoner #1	39- 9,001	285
40	Q-167	Boyce, Smiser & Runion Oil Co.	Pohl #1	212- 3,009	253
46	Q-225	Houston Nat. Gas Prod. Co.	Matula #2	315- 3,912	309
51	Q-276	Kilroy Co. of Texas and others	L. J. Zappe #1	820- 9,315	349
		LIVE OAK COUNTY			
41	Q-210	Continental Oil Co.	G. W. Burns #2	33- 8,888	280
58	Q-310	O. G. McClain and others	Nueces Co. Sch. land #1	167- 4,775	205
65	Q-349	J. N. Kirksmith	Brocker Transfer & Storage #1	115- 4,010	320
68	Q-366	Hughes & Hughes	R. & W. Hinnant #1	112- 2,404	195
77	Q-522	Smith & Story	T. J. Lyne #2	86- 3,350	330
79	Q-549	Earl Callaway	George West #1	71- 4,655	315
139	Q-916	Rhodes & Hicks Drlg. Corp. and others	H. Hinnant "A" #1	133- 5,164	236
		MATAGORDA COUNTY			
16	Q-52	Humble Oil & Ref. Co.	N. Matagorda Bay S. T. 295 #1	314- 5,999	17
18	Q-62	Phillips Petr. Co.	L. V. Stoddard and others #1	107-11,980	64
27	Q-137	Magnolia Petr. Co.	Scarborough #1	314-10,993	34
29	Q-176	Phillips Petr. Co.	Buckeye #1	120-10,550	59
30	Q-201	Cosden Petr. Corp.	Farthing-Thompson Unit #1	126- 2,010	69
33	Q-244	Co. Phillips Petroleum Co.	Pierce Estate #1	119-12,491	50
47	Q-571	Texas Gulf Sulphur Co.	Fee #17	99- 4,547	18
49	Q-588	Mobil Oil Co.	Ryman Unit #1	100- 2,054	40
50	Q-590	Viking Drlg. Co. and others	J. Camp #1	526- 8,008	78
51	Q-598	Trull Russell & Thompson	Sam G. Selkirk and others #1	560- 6,022	28
52	Q-599	The Texas Co.	Pauline Huebner #1	100- 7,099	19
53	Q-600	Magnolia Petr. Co.	Cornelius #1	90-11,005	36
68	Q-831	Sun Oil Co.	Braman #D-1	107-11,499	68
71	Q-857	The Texas Co.	Baer State #2	100- 6,675	13
93	Q-972	American Water Co.	Water well, Rogers #1	75- 758	28
95	Q-1060	Brazos Oil & Gas Co.	ST 195 "X-A" #2	284- 6,504	24
		NUECES COUNTY			
28	Q-82	Gulf Oil Corp.	Well #1	210-12,495	66
35	Q-143	Forest Oil Corp.	St. tr. 708-A #1	207- 4,042	22
39	Q-165	Pan American Petr. Co.	W. M. Spessard #41	1,083-10,205	51
39	Q-165	Stanolind Oil & Gas Co.	W. M. Spessard #14	32- 1,252	45
45	Q-183	Humble Oil & Ref. Co.	A. G. Jones #1	89- 8,003	85
67	Q-329	The Atlantic Ref. Co. and others	S. E. Wilson Jr. #595 Well #1	160-10,002	20
70	Q-358	The Atlantic Ref. Co.	A. T. Pearse #1	80- 8,499	31
72	Q-363	Layne-Texas Co.	City of Bishop Well #8	70- 874	55 (GL)
80	Q-488	The Chicago Corp.	G. P. Wardner #55	80- 5,952	119
83	Q-701	Magnolia Petr. Co.	Alvin Schubert #1	133-10,430	57
88	Q-863	The Atlantic Ref. Co.	S. E. Wilson #1	121- 8,477	22
97	Q-990	Phillips Petr. Co.	Smith #2	1,357- 5,816	61
107	Q-1161	Zapata C. & K.	St. lse. 57742 Well #3	268- 8,309	75
108	Q-1174	Cities Service Oil Co. and others	St. tr. 49 Well #1 & #2	159-13,509	33

APPENDIX D
(continued)

Map index no.	Well source no.	Operator	Well name	Depths covered (ft)	Elevation KB or DF (ft)
		REFUGIO COUNTY			
12	Q-62	Seaboard Oil Co.	H. R. Smaystria #1	44- 6,366	33
25	Q-191	Southland Drlg. Co. and others	H. W. Schmidt #1	274- 8,770	22
28	Q-198	Humble Oil & Ref. Co.	M. A. Power Shay #2	90- 6,494	98
44	Q-509	Southern Minerals	Woodworth #1	80- 5,818	62
45	Q-514	Stanolind Oil & Gas Co.	B. D. Rooke #36	47-10,710	62
48	Q-549	Kirkwood Drlg. Co.	Rooke #1	128- 5,113	60
		SAN PATRICIO COUNTY			
23	Q-154	Stanolind Oil & Gas Co.	L. L. McCampbell #1	100- 9,988	30
34	Q-207	Continental Oil Co.	J. F. Welder #S-2 +(S-3)	40- 8,006	24
35	Q-210	Humble Oil & Ref. Co.	F. D. Wilson #1	82- 6,500	18
60	Q-470	Milton Oil Co.	A. H. Hasiran #1	20- 6,720	38
77	Q-760	Heep Oil Corp. & H. F. Heep	R. H. Welder K-3	74- 3,820	37
79	Q-784	Orion Oil Co.	F. H. Vahlsing #1	115- 5,050	155
		VICTORIA COUNTY			
4	Q-9	Arnold O. Morgan	R. H. Welder C-1	80- 9,113	205
9	Q-26	Portilla Drlg. Co.	P. H. Welder #1-D	27- 6,527	53
32	Q-209	Layne Texas Co.	City of Victoria #1-10	80- 1,507	80
33	Q-212	Rowan & Hope	Bucher #1	285- 4,505	143
38	Q-224	Sunray Continental Oil Co.	L. L. Wedemeier #1	305->4,000	92
52	Q-364	Fidelity Oil & Royalty Co.	S. W. McCormick #1	70- 9,228	151
67	Q-487	F. M. Davis, Inc.	Levi #2	380- 7,239	68
88	Q-700	Bahia Oil & Gas Co. and others	J. S. West #1	125- 4,120	130
		WHARTON COUNTY			
2	Q-97	Magnolia Petr. Co.	Ilse Miller #1	100- 5,413	130
3	Q-141	Houston Natural Gas Prod. Co.	Etta Wigginton SWD #1	20- 7,837	85
16	Q-488	C. D. Atchison	Earle G. Jackson #1	304- 5,001	129
18	Q-493	C. C. Winn	Guy Ammann #1	137- 4,700	147
21	Q-558	Acco Oil & Gas Corp.	Schmidt #1	300- 4,960	119
26	Q-653	General Crude Oil Co.	M. Northington #1	97- 3,925	176
29	Q-788	Leonard Mickelson	Nilson #1	80- 375	110 (GL)
	Q-789	The Texas Co.	Nilson #5	1,100-	120