Final Report

**WILCOX SANDSTONE RESERVOIRS IN THE DEEP
SUBSURFACE ALONG THE TEXAS GULF COAST,
THEIR POTENTIAL FOR PRODUCTION
OF GEOPRESSURED GEOTHERMAL ENERGY**

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INTRODUCTION

Areas with the potential for containing geopressed geothermal fluids in economic quantities (geothermal fairways) occur in the Wilcox Group of Texas where the gulfward-dipping sandstone/shale wedge thickens abruptly across a complex growth-fault system.

This regional study of the distribution of sandstone within the Wilcox Group (fig. 1) is part of a much broader investigation aimed at assessing the potential for producing geothermal energy from the deep subsurface geopressed zone of onshore Tertiary strata along the Texas Gulf Coast (Dorfman and Deller, eds., 1975, 1976). The objective of the study is to identify areas along the Wilcox trend in Texas most favorable for testing this potential resource. An ideal geopressed geothermal reservoir should have 5 km^3 (3 mi^3) of sandstone reservoir, fluid temperature greater than 149°C (300°F), and permeability of more than $20 \times 10^{-3} \text{ } \mu\text{m}^2$ (20 md).

Reports summarizing similar regional assessments of the Frio Formation and of a prospective test-well site have been published by the Bureau of Economic Geology, The University of Texas at Austin (Bebout, Dorfman, and Agagu, 1975; Bebout, Agagu, and Dorfman, 1975; Bebout, Loucks, Bosch, and Dorfman, 1976; Bebout, Loucks, and Gregory, 1978). The geothermal potential of the Vicksburg Formation was summarized by Loucks (1978). Funding for the entire Wilcox geopressed geothermal assessment program has been provided by the Division of Geothermal Energy, U. S. Department of Energy.

The Wilcox and Midway Groups, Lower Eocene, comprise the oldest thick sandstone/shale sequence within the Gulf Coast Tertiary System. Wilcox sandstones and shales crop out in a 16 to 32 km (10 to 20 mi) wide band that is subparallel to and 160 to 320 km (100 to 200 mi) inland from the present-day coastline (fig. 2). From the outcrop, the Wilcox dips coastward into the subsurface. It is one of at least eight thick wedges of Tertiary sandstone/shale (Hardin and Hardin, 1961). Sediments within the updip portion of the wedges were deposited primarily by fluvial processes. Downdip, the sediments that were transported across the Wilcox fluvial plain were deposited in huge deltaic systems; some deltaic sediments were reworked and transported along shore by marine processes where they were redeposited on barrier bars and strandplains. An understanding of the environmental setting of the Wilcox was developed almost 40 years ago by Deussen and Owen (1939) and has been improved by Culbertson (1940), Echols and Malkin (1948), and Hargis (1962) and demonstrated most recently by Fisher and McGowen (1967).

Growth faults developed at the shorelines of several of the larger delta lobes where thick wedges of sand and mud were deposited on unconsolidated offshore mud of the previous wedge (fig. 3). During burial, subsidence and offset along these faults resulted in the isolation of thick sandstone and shale sequences which prevented lateral escape of pore fluids during subsequent compaction resulting from loading. Vertical escape of pore fluids was prevented by low vertical permeability of superposed shales. Limited fluid circulation within these growth-faulted blocks is responsible for the downward increase in pressure gradient from a normal hydrostatic pressure of 10.5 kPa/m to between 15.8 and 22.6 kPa/m (0.465 psi/ft to between 0.7 and 1.0 psi/ft) and for an increase in temperature gradient from a normal 1.8°C/100 m (1.0°F/100 ft) to between 2.7 and 3.6°C/100 m (1.5 and 2.0°F/100 ft). This faulted, downdip section of the Wilcox Group, which exhibits a high pressure gradient and temperature exceeding 149°C (300 °F), comprises the Wilcox geothermal corridor (fig. 2).

SYSTEM	SERIES	GROUP/FORMATION
Quaternary	Recent	Undifferentiated
	Pleistocene	Houston
Tertiary	Pliocene	Goliad
	Miocene	Fleming
		Anahuac
	?	?
	Oligocene	Frio
		Vicksburg
	Eocene	Jackson
		Claiborne
		Wilcox
		Midway

Figure 1. Tertiary formations, Gulf Coast of Texas. The Wilcox Group, the subject of this geothermal report, is shown by the diagonal pattern; the geothermal potential of the Frio and Vicksburg Formations, shown by the dot pattern, has been reviewed in other Bureau of Economic Geology reports (Bebout and others, 1975a, 1975b, 1976, 1978; Loucks, 1978).

Figure 2. Wilcox geothermal corridor.

Figure 3. Depositional/structural style of the Tertiary along the Texas Gulf Coast.

SUMMARY AND CONCLUSIONS

Regional and site-specific geological and engineering studies of the Wilcox Group of Texas have resulted in the selection of geopressed geothermal prospects in the Cuero area, De Witt Fairway, and Eagle Lake area, Colorado Fairway.

Areas with the potential for containing geopressed geothermal fluids in economic quantities occur in the Wilcox Group where the gulfward-dipping sandstone/shale wedge thickens abruptly across a complex growth-fault system. As a result of the contemporaneous structure, the Wilcox is less than 600 m (2,000 ft) thick updip near the outcrop and more than 2,400 m (8,000 ft) thick downdip deeper than 3,000 m (10,000 ft). The Wilcox is divided into three parts--the sandstone-rich upper and lower parts, which represent two major progradational cycles, and the shale-rich middle part, which represents a major transgression. In the lower Wilcox, thick sandstone and shale sequences occur in lobate patterns along the Middle and Upper Texas Gulf Coast; in the upper Wilcox, on the other hand, similar thick deltaic sandstones and shales occur along the Lower Texas Gulf Coast.

The objective of this study is to identify areas along the Wilcox trend favorable for testing the potential for producing large quantities of hot water from the geopressed zone in order to separate methane from solution and to produce electrical energy from heat. An ideal geopressed geothermal reservoir should have 5 km³ (3 mi³) of sandstone reservoir, fluid temperature greater than 149°C (300°F), and permeability of more than 20×10^{-3} μm (20 md).

The top of geopressure occurs at depths of 2,400 to 3,000 m (8,000 to 10,000 ft) where shale is dominant and at 3,400 to 4,000 m (11,000 to 13,000 ft) where sandstone is dominant. Formation temperatures also vary within the Wilcox depending upon the position along dip, lithology, location of growth faults, and location along the Texas Gulf Coast, but temperatures higher than 149°C (300°F) generally occur at approximately 3,300 m (11,000 ft).

Six geothermal fairways have been delineated along the Texas Gulf Coast by combining the sandstone distribution and isotherm maps--Zapata, Duval, Live Oak, De Witt, Colorado, and Harris. In these fairway areas sandstone-rich sections occur with formation temperature greater than 149°C (300°F). Detailed studies have been conducted in these fairways in order to identify the most favorable areas for drilling geothermal test wells.

The Zapata, Duval, and Live Oak Fairways (table 1) contain thick, laterally extensive sandstone units in the upper Wilcox. The sections in which these sandstones occur are extremely thick as a result of contemporaneous subsidence along large

growth faults. Fluid temperatures are greater than 149°C (300°F) in the Zapata and Duval Fairways but lower in the Live Oak Fairway. Core analyses indicate that porosity and permeability are low in these deep sandstone units and, for this reason, these fairways are not at present being considered as potential for geopressed geothermal test-well sites.

The De Witt Fairway is considered the prime area for a geopressed geothermal test in the Wilcox in Texas. The fairway is located in the complex growth-faulted portion of the lower Wilcox trend just downdip of the underlying Lower Cretaceous Stuart City Trend. The Cuero Prospect, within the De Witt Fairway, contains more than 170 m (550 ft) of geopressed sandstone, which is expected to extend over an area of approximately 36 km² (14 mi²). The prospective sandstones deposited in a wide variety of deltaic environments occur at the tops of at least eight coarsening-upward cycles; progressively shallower cycles contain sandstones deposited in more proximal deltaic environments. Fluid temperatures of 149°C (300°F) have been recorded within the reservoir section. Core analyses from the fairway indicate that the permeabilities range from less than 2.1×10^{-3} to more than 100×10^{-3} μm^2 (2.1 to more than 100 md). The highest permeability occurs at the top of the prospective reservoir section where the most proximal deltaic facies occur.

In the Colorado Fairway 370 to 490 m (1,200 to 1,600 ft) of sandstone with fluid temperature greater than 149°C (300°F) occur in the lower Wilcox Group in an area that is considered prospective for the location of a geopressed geothermal test. Few growth faults have been recognized in the fairway area, perhaps in part because of lack of adequate deep well control. Approximately 380 m (1,240 ft) of sandstone are expected in the area of the proposed Eagle Lake test-well site. Pressure gradients in the Colorado Fairway are generally low, and many wells in the area do not penetrate the top of geopressure. Most permeabilities are lower than 5×10^{-3} μm^2 (5 md), but some range up to 545×10^{-3} μm^2 (545 md) in thin, isolated sandstones. Although the Colorado Fairway is considered prospective as a potential geopressed geothermal test-well site, there is question as to the presence of adequate thickness of high-permeability zones.

The Harris Fairway contains a massive sandstone section with more than 610 m (2,000 ft) of net sandstone in the lower Wilcox. Most of the lower Wilcox in the downdip part of the fairway is geopressed and has fluid temperatures greater than 149°C (300°F). However, most permeabilities are less than 5×10^{-3} μm^2 (5 md), and many are less than 1×10^{-3} μm^2 (1 md). Although the Harris Fairway contains by far the thickest sandstone section of all Wilcox fairways, it is not recommended for testing at present because of extremely low permeability recordings.

Table 1. Summary of the physical characteristics of the six geopressed geothermal fairways.

	ZAPATA	DUVAL	LIVE OAK	DE WITT	COLORADO	HARRIS
PART OF WILCOX	Upper	Upper	Upper	Lower	Lower	Lower
DEPTH TO TOP OF PROSPECTIVE SANDSTONE	2,930 m (9,600 ft) to 3,200 m (10,500 ft)	3,355 m (11,000 ft) to 3,660 m (12,000 ft)	2,805 m (9,200 ft) to 3,355 m (11,000 ft)	3,200 m (10,490 ft) to 3,250 m (10,660 ft)	3,340 m (10,960 ft) to 3,475 m (11,400 ft)	3,810 m (12,500 ft) to 4,055 m (13,300 ft)
THICKNESS OF PROSPECTIVE SANDSTONE	85 m (280 ft) to 190 m (620 ft)	More than 185 m (600 ft)	More than 185 m (600 ft)	170 m (550 ft)	490 m (1,600 ft)	More than 610 m (2,000 ft)
TOP OF GEOPRESSURE 15.8 kPa/m (0.7 psi/ft)	3,265 m (10,700 ft)	3,050 m (10,000 ft)	3,035 m (9,950 ft)	3,050 m (10,000 ft)	3,660 m (12,000 ft)	3,520 m (11,550 ft)
TEMPERATURE	149°C (300°F) at 3,475 m (11,400 ft)	149°C (300°F) at 3,280 m (10,750 ft)	149°C (300°F) at 3,355 m (11,000 ft)	149°C (300°F) at 3,310 m (10,850 ft)	149°C (300°F) at 3590 m (11,780 ft)	149°C (300°F) at 3,960 m (12,990 ft)
POROSITY	17 to 22%	7 to 14%	16 to 24%	6 to 25%	4 to 19%	Average 15%
PERMEABILITY	0 to $19 \times 10^{-3} \mu\text{m}^2$ (0 to 19 md)	0.1 to $44 \times 10^{-3} \mu\text{m}^2$ (0.1 to 44 md)	0.5 to $40 \times 10^{-3} \mu\text{m}^2$ (5 to 40 md)	$.01 \times 10^{-3}$ to $242 \times 10^{-3} \mu\text{m}^2$ (0.01 to 242 md)	Most less than $5 \times 10^{-3} \mu\text{m}^2$ (5 md) locally up to $545 \times 10^{-3} \mu\text{m}^2$ (545 md)	$1 \times 10^{-3} \mu\text{m}^2$ to $5 \times 10^{-3} \mu\text{m}^2$ (1 to 5 md)
MOST FAVORABLE PROSPECT IDENTIFIED	None Low Permeability	None Low Permeability	None Low Permeability	Cuero Prospect	Eagle Lake Prospect	None Low Permeability

REGIONAL SETTING

The Wilcox Group is less than 600 m (2,000 ft) thick updip near the outcrop and more than 2,400 m (8,000 ft) thick downdip at depths greater than 3,000 m (10,000 ft).

The Wilcox Group is composed of a thick wedge of sandstone and shale which crops out several hundred feet above sea level at its updip limit. More than 160 km (100 mi) downdip, the Wilcox is 3,000 m (10,000 ft) below sea level (figs. 4, 5). Regional dip averages 19 m/km (100 ft/mi). Where the Wilcox depocenter prograded gulfward of the underlying Lower Cretaceous Stuart City shelf margin (Edwards and Sligo Formations), a band of growth faults 32 km (20 mi) wide developed (fig. 6), indicating that the gulfward edge of the shelf controlled the location of the Wilcox growth faults. Sandstones and shales of the Wilcox thicken abruptly downdip of the Stuart City shelf margin (fig. 4, wells 7 to 8). The zone of steeper (closely spaced) contours on the structure and thickness maps (figs. 5, 7) coincides with the location of the best developed growth faults.

The base of the Wilcox Group is transitional with the underlying marine Midway Group. The upper part of the Midway is believed by many to be a marine facies of the lowermost Wilcox fluvial and deltaic facies (Culbertson, 1940; Echols and Malkin, 1948; Johnston, 1977; Townsend, 1954). The top of the Wilcox Group is placed by us and by many others (Culbertson, 1940; Echols and Malkin, 1948; Fisher, 1969; and Murray, 1955) at the top of the Carrizo Sandstone.

Figure 4. Regional dip section (Bebout, Luttrell, and Seo, 1975; section HH'). The Wilcox Group thickens abruptly just downdip of the Lower Cretaceous Stuart City shelf margin by means of a complex system of growth faults.

Figure 5. Structure on top of the Wilcox Group.

Figure 6. Faults in the Wilcox Group. Most of these faults are growth faults which were active during deposition of the Wilcox. Courtesy of Geomap Company, Houston, Texas.

Figure 7. Total thickness of the Wilcox Group.

STRATIGRAPHIC SECTIONS

The sandstone-rich upper and lower parts of the Wilcox represent two major progradational cycles separated by shaley middle Wilcox transgressive deposits.

Twenty-one regional stratigraphic dip sections, spaced 25 to 35 km (15 to 20 mi) apart, were constructed using electrical logs from wells located along the entire Texas Gulf Coast (fig. 8). On each well log, the top of the Wilcox and two regional markers have been identified (fig. 9); these markers were selected through the detailed correlations of closely spaced wells in the fairway areas discussed later in this report. The markers were then projected onto the regional cross sections and extended throughout the Wilcox trend. The lower regional marker corresponds to the top of the lower Wilcox of Fisher and McGowen (1967); the upper regional marker is at the base of the upper Wilcox of Fisher and McGowen. Maps showing the regional distribution of sandstone in the lower and upper Wilcox have been published by Fisher and McGowen (1967) and Fisher (1969), respectively.

The dip sections (figs. 10 to 30) include 10 to 15 wells each and extend from near the outcrop to the downdip limit of Wilcox sandstones or well control. Strike sections (figs. 31 and 32) were constructed to ensure correlation among dip sections. Datum for the sections is the top of the Wilcox Group. Growth faults present at the downdip end of the sections have been omitted so as not to obscure well-to-well correlation of sandstones. Data from these sections are supplemented by denser well control used by Fisher and McGowen (1967).

The top of geopressure (shallowest depth of pressure gradient of 15.8 kPa/m, or 0.7 psi/ft), marked by the black arrow on stratigraphic sections (figs. 10 to 32), occurs well beneath the base of the updip part of the Wilcox. Downdip, within the zone of growth faulting, the top of geopressure generally occurs within the upper part of the Wilcox Group. Subsurface fluid temperature of 149°C (300°F), also indicated on the cross sections, occurs 300 to 460 m (1,000 to 1,500 ft) beneath the top of the geopressured zone.

Figure 8. Well-log control and location of sections (figs. 10-32). Supplemental well data from Fisher and McGowen (1967) and Fisher (1969) are not shown.

Figure 9. Electrical log showing division of the Wilcox Group into the sandstone-rich lower and upper parts, each of which represents a major progradational cycle, separated by middle Wilcox shales deposited during a marine transgression.

Figure 10. Stratigraphic dip section 1. The locations of this section and those that follow (figs. 11 to 32) are shown in figure 8. The datum for each section is the top of the Wilcox Group and the transition between the Wilcox and the underlying Midway is shown by the dashed line. The top of geopressure is shown by the black arrows and the approximate point at which 149°C (300°F) is reached is shown by the arrows labeled 300°F.

Figure 11. Stratigraphic dip section 2.

Figure 12. Stratigraphic dip section 3.

Figure 13. Stratigraphic dip section 4.

Figure 14. Stratigraphic dip section 5.

Figure 15. Stratigraphic dip section 6.

Figure 16. Stratigraphic dip section 7.

Figure 17. Stratigraphic dip section 8.

Figure 18. Stratigraphic dip section 9.

Figure 19. Stratigraphic dip section Figure 10.

Figure 20. Stratigraphic dip section 11.

Figure 21. Stratigraphic dip section Figure 12.

Figure 22. Stratigraphic dip section Figure 13.

Figure 23. Stratigraphic dip section Figure 14.

Figure 24. Stratigraphic dip section Figure 15.

Figure 25. Stratigraphic dip section Figure 16.

Figure 26. Stratigraphic dip section Figure 17.

Figure 27. Stratigraphic dip section Figure 18.

Figure 28. Stratigraphic dip section Figure 19.

Figure 29. Stratigraphic dip section 20.

Figure 30. Stratigraphic dip section 21.

Figure 31. Stratigraphic strike section A.

Figure 32. Stratigraphic strike section B.

LOWER WILCOX SANDSTONE DISTRIBUTION

The regional net-sandstone map outlines a sandstone trend which is broad and lobate along the Upper and Middle Texas Gulf Coast and narrow and elongate along the Lower Texas Gulf Coast.

The net-sandstone map of the lower Wilcox (fig. 33) is based on control provided by wells used in this investigation and by maps previously prepared by the Bureau of Economic Geology as part of an extensive study of the lower Wilcox (Fisher and McGowen, 1967). The maps in this report and those of Fisher and McGowen show that areas of maximum net sandstone trend subparallel to the modern Gulf Coast. The sandstone trends are broad and lobate along the Upper and Middle Texas Gulf Coast (up to 29 km, or 80 mi, wide) and narrow and elongate along the Lower Texas Gulf Coast (approximately 32 km, or 20 mi, wide). Net-sandstone values range from greater than 610 m (2,000 ft) to the north to slightly more than 122 m (400 ft) to the south.

Along the northern two-thirds of the Wilcox trend, the net-sandstone map (fig. 33) exhibits a lobate pattern from DeWitt County on the south to Sabine County on the north. This lobate pattern is similar to that mapped by Fisher and McGowen (1967) who interpreted it to represent a high-constructive delta system (the Rockdale Delta System). The southernmost delta lobe, the Guadalupe Delta of Fisher and McGowen, was subsequently cut by a large erosional feature named the Yoakum Channel by Hoyt (1959). Fisher and McGowen believe the Yoakum Channel is a submarine canyon which resulted from density flow of reworked deltaic sediments down depositional slope. In the axis of the channel, the entire lower Wilcox sandstone section has been removed and replaced by a dominantly shale section (figs. 31, 32).

South from DeWitt County, the lower Wilcox exhibits a narrow, elongate net-sandstone trend that contrasts with the broad, lobate trend to the north. Fisher and McGowen (1967) suggested that this strike-dominated trend was deposited within strandplain and barrier-bar depositional systems. The trend was named the San Marcos Strandplain and Cotulla Barrier-Bar Systems.

The emphasis of this geothermal assessment is directed toward the most down-dip Wilcox sandstone units where reservoirs exist with potential for production of 149°C (300°F) geothermal water. The sandstone lobes of the lower Wilcox coincide closely with interpretation by Fisher and McGowen (1967).

Figure 33. Net sandstone, lower Wilcox.

UPPER WILCOX SANDSTONE DISTRIBUTION

The upper Wilcox is very thick along the Lower Texas Gulf Coast due to extensive growth faulting; in contrast, along the Middle and Upper Texas Gulf Coast, it is relatively thin and unaffected by growth faulting.

The upper Wilcox along the Lower Texas Gulf Coast consists of sandstone and shale and thickens gradually from the outcrop toward the Gulf of Mexico (fig. 34). Down dip, across a distance of about 16 to 24 km (10 to 15 mi), the upper Wilcox abruptly thickens as a result of deposition contemporaneous with growth faulting. Along the Middle and Upper Texas Gulf Coast, on the other hand, the upper Wilcox is thinner and not extensively growth faulted (fig. 34). This difference in development of the upper Wilcox is related to the depositional and structural history of the underlying lower Wilcox.

During lower Wilcox deposition, great volumes of sand and mud were transported into the basin in the enormous Rockdale Delta System of the Middle and Upper Texas Gulf Coast (Fisher and McGowen, 1967). However, the Lower Texas Gulf Coast was the site of a large embayment with comparatively modest progradation into the basin. The coastal sediments deposited along this embayment were termed by Fisher and McGowen (1967) as the San Marcos Strandplain Bay System and the Cotulla Barrier-Bar System; the embayment was bordered toward the Gulf Basin by the South Texas Shelf System, composed predominantly of mud facies. Fisher and McGowen (1967) also identified a shelf-edge sand facies, which was presumed to occur at the seaward margin of the South Texas Shelf System. However, this linear trend, an important gas trend in Lower Texas, is not lower Wilcox; it consists of upper Wilcox deposits which have been growth faulted to great depths.

Consequently, along the Lower Texas Gulf Coast, the upper Wilcox deltas prograded over muddy, unstable sediments of the lower Wilcox shelf margin and were extensively affected by growth faulting. Along the Middle and Upper Texas Gulf Coast, in contrast, upper Wilcox deltas prograded over relatively sandy lower Wilcox deposits which, although themselves extensively growth faulted, provided a stable platform; thus, in these areas, upper Wilcox strata are not extensively growth faulted in the area of well control and the deltas do not appear to have transported appreciable quantities of sand to the lower Wilcox shelf margin.

The upper Wilcox growth fault zone is about 16 to 24 km (10 to 15 mi) wide, and dip sections transect many faults. Just updip of the fault zone, the top of the Wilcox is generally at a depth of about 1,800 m (6,000 ft). In this zone, the upper Wilcox

ranges in thickness from 430 m (1,400 ft) in the north to 580 m (1,900 ft) in the south. Across the fault zone, the top of the Wilcox occurs at depths as great as 2,750 to 3,660 m (9,000 to 12,000 ft). Downdip, total thickness for the upper Wilcox cannot be determined because of the lack of sufficiently deep wells, but correlation of selected intervals of the upper part of the Wilcox indicates growth ratios ranging from about 6 to 10 and the deepest downdip wells penetrate 1,800 m (6,000 ft) of upper Wilcox.

A strike stratigraphic section from Zapata to Karnes Counties relates the sandstone-bearing intervals of the three fairways in South Texas (fig. 35). The section shows that the high-sandstone areas of the fairways extend 21 to 100 km (13 to 60 mi) along strike, and that the prospective sandstones present in the fairways developed at different times and do not correlate. Thus, the oldest sandstone unit, situated in the lower part of the upper Wilcox, occurs in the Duval Fairway, below marker Du3. The intermediate sandstone, situated in the middle part of the upper Wilcox, occurs in the Zapata Fairway, between markers Z2 and Z3. The youngest sandstone, at the top of the upper Wilcox, occurs in the Live Oak Fairway, above marker L2.

Along strike to the northeast in Karnes County, the upper Wilcox is commonly developed as a massive sandstone, with only minor, thin shale intervals. The homogeneous development renders long-distance correlation impossible. As mentioned earlier, these sandstone-rich sequences in the upper Wilcox of central and eastern areas rapidly shale out downdip across the growth-faulted zone. In contrast to this, sandstone and shale intervals in the upper Wilcox of South Texas are comparatively easy to correlate. Downdip, across the growth-fault zone, shales become more dominant, but this generally occurs at great depth. Detailed examination of logs from both sides of major growth faults shows that the sandstone/shale ratio is not appreciably altered by the growth faults, even where the thickness is increased by a factor of two or more.

The geographic restriction of sandstone depocenters along strike indicates that the dispersal system was not strike oriented on a regional scale. Furthermore, evidence against strike-transport of sediment from a Middle to Upper Texas Gulf Coast source is provided by the dominance of volcanic over metamorphic rock fragments in Lower Texas Wilcox sandstones, the reverse of which is observed in Middle and Upper Texas Gulf Coast. These volcanic rock fragments were probably derived from volcanic centers in Northern Mexico and West Texas (Loucks, Bebout, and Galloway, 1977). In updip areas, log patterns generally show a blocky pattern with sudden changes laterally, and the sediments are interpreted as having been deposited in distributary channels. In contrast, sediments in downdip areas which show coarsening-upward trends are interpreted as having been deposited as delta-front and distributary-mouth bar facies.

Figure 34. Net sandstone, upper Wilcox.

Figure 35. Stratigraphic strike section of the upper Wilcox, Lower Texas Gulf Coast.

FORMATION PRESSURE

The top of geopressure, determined from resistivity logs and drilling-mud weights, occurs at depths of 2,400 to 3,000 m (8,000 to 10,000 ft) in areas where the Wilcox is dominantly shale and at depths of 3,400 to 4,000 m (11,000 to 13,000 ft) where the Wilcox is dominantly sandstone.

Bottom-hole shut-in pressure (BHSIP) data from drill-stem tests (DST) obtained from completion cards are available only from producing wells. To supplement these measured pressure data, fluid pressure in shales was determined primarily by using data from resistivity logs. Detection and evaluation of geopressed formations using the short-normal curve or amplified short-normal curve of the electrical log (Hottmann and Johnson, 1965) relies on the observation that, under conditions of normal compaction, shale resistivity R_{sh} increases with depth as the porosity and water content of shales decrease. Geopressed shale resistivities depart from the normal trend and lower values of R_{sh} are recorded because of the increased porosity and water content of the geopressed shales. The amount of divergence of R_{sh} from the established normal compaction trend is a measure of the pore-fluid pressure in the shale and adjacent sandstone. Normal procedure for detecting geopressures involves a semilog plot with R_{sh} plotted on the logarithmic scale and depth on the linear scale (fig. 36). Shale with higher than normal resistivity (cap rock) is frequently observed above the top of geopressure. This transition zone from hydropressed to geopressed conditions may be sharp and definitive or gradual and equivocal.

Divergence of R_{sh} from the normal compaction trend is related to the observed pressure gradient in adjacent sandstone formations. A plot of the gradient for ratio $R_{sh} \text{ (normal)}/R_{sh} \text{ (observed)}$ versus pressure (observed) for Eocene formations (fig. 37) was developed for DeWitt County. Using this curve, geopressure profiles can be constructed for individual wells in the area.

Top of geopressure in the Wilcox was interpreted primarily by analysis of resistivity logs (fig. 38). Supplementary data from sonic logs and drill-stem tests were also used. To establish the trend line, only shales greater than 10 m (30 ft) thick were picked; silty, calcareous, and washed-out shales were avoided. Resistivity data for shales at depths less than 1,200 to 1,500 m (4,000 to 5,000 ft) were disregarded because these shallow formations contain fresh water with high resistivity values that cannot be used to establish the compaction trend; the presence of gas-cut mud or mud containing additives to combat lost circulation also contributes to spurious resistivity

data. Other discontinuities observed in the trend line may be caused by an abrupt change in lithology (such as bentonitic shales), difference in the geologic age with consequent drastic changes in shale properties, or major changes in bit size. Shales located near salt masses were avoided because their low resistivity (high salinity) may falsely indicate higher than normal pressure.

Mud weight versus depth recorded on resistivity plots (fig. 36) provides a first approximation of the location of the transition zone. Although mud weights alone are inaccurate and can be misleading for picking geopressure tops, a mud weight of 14.8 to 16.0 kPa/m (12.6 to 13.6 lbs/gal) is used to first approximate the depth of the transition zone when the quality of well log data is questionable. Depth to geopressure top can then be adjusted after correlations with suitable logs and pressure data from nearby wells. Mud weights from well logs are not recommended for quantitative evaluation of geopressure.

In fresh-water zones, sonic logs are considered more reliable than electrical logs for locating and evaluating geopressures. By plotting on semilog paper shale transit time-versus-depth (fig. 36), the normal compaction curve (NNC) is established and the geopressure top is located at the depth where shale transit time departs from the normal trend. Usually there is good correlation between top of geopressure picked from shale resistivity and from shale interval-transit times. In the example from the Atlantic No. 1 Kerlick, however, the pick from the transit time plot is about 183 m (600 ft) above the pick from shale resistivity.

In this report, top of geopressure was picked from bottom-hole pressure data for county areas and from shale-resistivity data for individual wells. The possibility of ambiguity exists because definitions of top of geopressure differ for the two cases depending on the intended application. Top of geopressure from bottom-hole shut-in pressures refers to an average pressure gradient of 10.5 kPa/m (0.465 psi/ft) determined by least squares fit to data for wells located in a given area. Other average pressure gradients can also be determined from the curve (fig. 140). Top of geopressure from shale-resistivity data (fig. 36a) refers to the depths at which R_{sh} is reduced to values which fall to the left of the normal compaction curve. If a cap rock is present, top of geopressure is picked at its base. At this point pressure gradients average 15.8 kPa/m (0.7 psi/ft) and are large enough to provide driving forces that will produce geothermal waters. A pressure gradient of 10.5 kPa/m (0.465 psi/ft) occurs at the top of the cap rock.

Figure 36. Top of geopressure picked from shale resistivity and transit times for a well in De Witt County.

Figure 37. Shale resistivity ratio curve obtained for De Witt County.

Figure 38. Top of geopressure within the Wilcox Group, Texas Gulf Coast.

FORMATION TEMPERATURE USED TO DELINEATE GEOTHERMAL FAIRWAYS

Geothermal fairways are areas in which thick sandstones occur deeper than the depth at which formation temperatures are 149°C (300°F).

Formation temperatures have been recorded in this study primarily as a tool to delineate areas where thick sandstone reservoirs have temperatures greater than 149°C (300°F). However, knowledge of the formation temperatures is also essential in calculating the amount of methane in solution in the water and in studying the changes in diagenesis of the sandstone, shale, and organic material with depth (Burst, 1959, 1969; Dow, 1978). Thus, temperature has a profound effect on controls of porosity, permeability, and elastic properties of prospective reservoir rocks.

The depth below which subsurface temperatures exceed 149°C (300°F) is indicated on all wells on the stratigraphic sections (figs. 10 to 32). Geothermal fairways were identified by plotting the 149°C (300°F) isotherm on the net-sandstone maps of lower and upper Wilcox (figs. 39 and 40). Minimum thickness of sandstone penetrated by deep wells with temperatures higher than 149°C (300°F) are shown gulfward of this isotherm. Six fairways have been outlined in this manner (fig. 41)--Harris, Colorado, DeWitt, Live Oak, Duval, and Zapata.

Plots showing the geothermal gradient of wells in these fairways along the Wilcox trend illustrate three changes of slope with depth, referred to here as shallow, medium, and deep (figs. 42 to 44). In addition, gradients increase and higher temperatures occur shallower toward the southwest along the Wilcox trend.

Temperature data used to obtain gradients for this report were taken from well logs and corrected to approximate thermal equilibrium by the empirical relation developed by Kehle (1971).

$$T_E = T_L - 8.819 \times 10^{-12} D^3 - 2.143 \times 10^{-8} D^2 + 4.375 \times 10^{-3} D - 1.018 \quad (1)$$

where

T_E = equilibrium temperature, °F

T_L = bottom-hole temperature from well logs, °F and

D = depth, feet

Figure 39. Net sandstone of the lower Wilcox with the 93 and 149°C (200 and 300°F) isotherms.

Figure 40. Net sandstone of the upper Wilcox with the 93 and 149°C (200 and 300°F) isotherms.

Figure 41. Wilcox geothermal fairways.

Figure 42. Temperatures and geothermal gradients for the Harris County Fairway area.

Figure 43. Temperatures and geothermal gradients for the De Witt County Fairway area.

Figure 44. Temperatures and geothermal gradients for the area including parts of Live Oak, McMullen, Duval, Webb, and Zapata Counties.

ZAPATA FAIRWAY

In the Zapata Fairway several prospective geothermal reservoirs in the upper Wilcox have been identified which are laterally extensive along the down-faulted side of major growth faults and which contain fluid temperatures greater than 149°C (300°F); however, all core analyses indicate porosity and permeability are very low.

The Zapata Fairway, elongated north-south, is located primarily in Zapata County but also extends to the south into Starr County (figs. 45 and 46). The fairway is approximately 43 km (27 mi) long and 10 km (6 mi) wide and has an area of 285 km² (110 mi²). The fairway was delineated as an area of possible geopressed geothermal reservoirs during regional study of the Wilcox Group along the Texas Gulf Coast (Bebout, Gavenda, and Gregory, 1978). Selection of this study area was based on the presence of considerable thickness of sandstone with fluid temperatures higher than 149 C (300°F). The sandstones of the Zapata Fairway are from the upper Wilcox and are part of a general, gradual coarsening-upward sequence about 610 m (2,000 ft) thick.

This sequence was subdivided and correlated in the fairway area using many correlation markers; only five are shown in this report (figs. 47 to 49). Most of the markers are in sections with rapidly alternating sandstone and shale, some of which appear to be persistent over large areas. The two principal markers, which have been correlated throughout the Texas Gulf Coast, are the top of the Wilcox and the base of the upper Wilcox (fig. 35). Three additional markers are shown: (1) marker Z1 occurs at the top of the main sandstone-bearing interval and below an uppermost shale-rich interval (fig. 47); (2) marker Z2 is above the sandstone units in the middle part of the upper Wilcox, which are the prime target of this geothermal-oriented study; and (3) the Z3 marker is below the main sandstone-bearing part of the upper Wilcox. Correlation of these markers with those of the Duval and Live Oak Fairways is shown on the following chart.

	ZAPATA FAIRWAY	DUVAL FAIRWAY	LIVE OAK FAIRWAY
UPPER WILCOX MARKERS	TOP	OF WILCOX	"Slick Sand"
	Z1	Du1	L1 "Luling Sand"
	Z2		L2 "Mackhank"-"Massive"
	Z3	Du2	L3
		Du3	L4
	BASE	OF UPPER WILCOX (REGIONAL MARKER)	

The prospective reservoirs of the Zapata Fairway are two distinct sandstone bodies which occur immediately below marker Z2. These sandstones range from about 85 m (280 ft) to 200 m (620 ft) thick and occur at depths of 2,375 m (7,800 ft) to 3,090 m (10,150 ft). Wells farthest downdip show some shaling out of the sandstone bodies.

The Zapata Fairway is located on the growth-faulted upper Wilcox shelf edge which includes two to three major growth faults, with displacements of up to 900 m (3,000 ft) at the level of the Z2 marker, and more than 10 other smaller faults. The zone of growth faulting is at least 21 km (13 mi) wide. Sedimentary units in the upper part of the Wilcox increase in thickness by a factor of three because of this contemporaneous faulting during sedimentation.

The top of geopressure, chosen where the pressure gradient exceeds the hydrostatic pressure gradient of 10.5 kPa/m (0.465 psi/ft), occurs at an average depth of 1,829 m (6,000 ft) in Zapata County (fig. 50). However, some reservoirs as deep as 3,260 m (10,700 ft) are not geopressured. The gradient of 15.8 kPa/m (0.7 psi/ft), referred to as the operational top of geopressure in previous reports (Bebout, Dorfman, and Agagu, 1975; Bebout, Agagu, and Dorfman, 1975; Bebout, Loucks, Bosch, and Dorfman, 1976; Bebout, Loucks, and Gregory, 1978), occurs at an average depth of 2,743 m (9,000 ft). Maximum pressure gradients of about 19.2 kPa/m (0.85 psi/ft), determined from shut-in pressures measured during drill-stem tests, are found in a few reservoirs (fig. 50) below 3,048 m (10,000 ft). Maximum gradients up to 21.7 kPa/m (0.96 psi/ft) are indicated by geopressure profiles computed for individual wells (fig. 51).

Temperatures of 93°C (200°F) and 149°C (300°F) occur at average depths of 2,134 m (7,000 ft) and 3,474 m (11,400 ft), respectively (fig. 52). Geothermal gradients of 2.9°C/100 m (1.59°F/100 ft) are common above 2,438 m (8,000 ft) and 3.83°C/100 m (2.1°F/100 ft), below 2,438 m.

Salinity of shallow reservoir waters varies widely from 10,000 to 75,000 ppm NaCl. Upper Wilcox sandstones in Zapata County have water salinities which range from 17,000 to 60,000 and average 40,000 ppm NaCl, based on computations for five wells (fig. 53).

Few core analyses are available for Zapata County, but sidewall-core data for limited depth intervals in two wells are listed on the following page.

<u>DEPTH</u>		<u>PERMEABILITY</u>	<u>POROSITY</u>
Meters	(feet)	$10^{-3} \mu\text{m}^2(\text{md})$	percent
2,900-2,913	(9,153-9,558)	0 to 2.9 (ave. 0.5)	17 to 21 (ave. 18.0)
3,056-3,241	(10,027-10,634)	0 to 6.6 (ave. 2.0)	18 to 22 (ave. 20.0)
3,200	(10,498-10,499)	8 to 19	18 to 20

Figure 45. Well control, faults at the top of the Wilcox, and area of prospective reservoir sandstones, Zapata Fairway.

Figure 46. Well control and lines of stratigraphic and structural sections, Zapata Fairway. Heavy line indicates the section included in this report.

Figure 47. Structural dip section AA', southern part of the Zapata Fairway.

Figure 48. Structural dip section CC', central part of the Zapata Fairway.

Figure 49. Structural dip section EE', northern part of the Zapata Fairway.

Figure 50. Bottom-hole shut-in pressures from drill stem tests as a function of depth for Zapata County.

Figure 51. Top of geopressure and geopressure gradients from shale resistivity data for a well in Zapata County.

Figure 52. Temperatures and geothermal gradients for Zapata County Fairway area.

Figure 53. Salinity versus depth for five wells in Zapata County.

DUVAL FAIRWAY

The Duval Fairway contains thick, laterally extensive sandstone units in the geopressured zone with fluid temperatures higher than 149°C (300°F), but porosity and permeability are generally very low.

The Duval Fairway is a southwest-trending elongate area located principally in Duval and Webb Counties but also extending south into Jim Hogg County and north into McMullen County (figs. 54 and 55). The fairway, which was originally designated as two separate fairways (Duval and Webb) as a result of the regional geopressured geothermal study of the Texas Gulf Coast Wilcox Group (Bebout, Gavenda, and Gregory, 1978), is approximately 97 km (60 mi) long and 15 km (9 mi) wide. During the course of the present study, it was determined that these two areas form one continuous stratigraphic unit of geopressured Wilcox sandstones with fluid temperatures greater than 149°C (300°F).

In the Duval Fairway area, the prospective thick sandstones occur in the lower part of the upper Wilcox; shallower sandstones are relatively thin. The Rosita and Seven Sisters gas fields are located along this trend. In updip areas, the upper Wilcox is about 610 m (2,000 ft) thick and increases downdip to at least 1,829 m (6,000 ft). In the fairway area, the upper Wilcox was subdivided and correlated with three markers (Du1, Du2, Du3), in addition to the top and base of the upper Wilcox (fig. 56). All of these markers have been correlated into those of the Zapata and Live Oak Fairways as follows:

	ZAPATA FAIRWAY		DUVAL FAIRWAY		LIVE OAK FAIRWAY
	TOP	OF	WILCOX		"Slick Sand"
UPPER WILCOX MARKERS	Z1		Du1		L1 "Luling Sand"
	Z2				L2 "Mackhank"-"Massive"
	Z3		Du2		L3
			Du3		L4
	BASE	OF	UPPER	WILCOX (REGIONAL MARKER)	

The most important marker in the Duval Fairway is the Du3 marker, which occurs at the top of the main sandstone-bearing interval. This interval, which extends downward to the regional marker at the base of the upper Wilcox, comprises very massive sandstones over a large part of the updip area of the fairway. Downdip, the sandstones are separated by thick shale sequences and are arranged into coarsening-upward sequences.

The prospective sandstones of the Duval Fairway occur in the Rosita Field area at a depth of about 3,353 m (11,000 ft) and continue down to at least 4,572 m (15,000 ft) in the Du2 - Du3 interval. At least 183 m (600 ft) of sandstone in this fairway contain fluids with temperatures greater than 149°C (300°F). Wells farthest downdip do not show significant shaling out of sandstone bodies.

The elongate trend of the Duval Fairway approximately coincides with the belt of linear to arcuate growth faults which developed along the upper Wilcox shelf edge contemporaneous with deposition (fig. 54). This hinge-zone includes five to seven faults along any dip-oriented cross section with displacement at the level of the Du2 and Du3 markers attaining 610 to 914 m (2,000 to 3,000 ft). With present well control, the growth-faulted zone appears to be 18 to 23 km (11 to 14 mi) wide, but the downdip limit of the fairway is poorly outlined. The upper Wilcox increases in thickness across the growth-faulted zone by a factor of approximately six as a result of these growth faults. Lack of adequate well control in the Duval Fairway is a serious limitation to proper evaluation of this area as a potential geopressured geothermal prospect.

The top of geopressure, defined as the depth at which the pressure gradient exceeds 10.5 kPa/m (0.465 psi/ft), occurs at an average depth of 2,620 m (8,600 ft) in Duval County (fig. 57); the gradient of 15.8 kPa/m (0.7 psi/ft) occurs at an average depth of 3,048 m (10,000 ft). Gradients reach 20.4 kPa/m (0.9 psi/ft) at 3,597 m (11,800 ft). Top of geopressure from shale resistivity plots for three wells in Duval County is picked between depths of 2,484 and 2,987 m (8,150 and 9,800 ft) (figs. 58, 59, and 60).

In Duval County (fig. 61) the geothermal gradient is 2.9°C/100 m (1.6°F/100 ft) above 2,438 m (8,000 ft); below 2,438 m the gradient increases to 5.7°C/100 m (3.1°F/100 ft) in the geopressured zone, and is higher than the average gradient of 4.9°C/100 m found in the fairway area (fig. 44). A temperature of 149°C (300°F) occurs at an average depth of 3,277 m (10,750 ft).

Salinities ranging from 10,000 to 55,000 ppm NaCl were calculated from water resistivities derived from the SP log from five wells in Duval County (fig. 62).

Diamond-core data from five wells in Duval County are listed below.

<u>Depth</u>		<u>Permeability</u>	<u>Porosity</u>
Meters	(Feet)	$10^{-3} \mu m^2$ (md) (ave.)	Percent (ave.)
2,896-2,905	(9,500-9,530)	253	23.5
3,208-3,213	(10,524-10,542)	2	15
3,463-3,465	(11,362-11,368)	5 to 44	8 to 14
3,613-3,668	(11,853-12,033)	0.17	6.8
3,698-3,759	(12,133-12,333)	0.29	12.6
4,206-4,267	(13,800-14,000)	0.1	12.0

Figure 54. Well control, faults at the top of the Wilcox, and area of prospective reservoirs, Duval Fairway.

Figure 55. Well control and lines of stratigraphic and structural sections, Duval Fairway. Heavy lines indicate the section included in this report.

Figure 57. Bottom-hole shut-in pressures from drill stem tests as a function of depth for Duval County.

Figure 58. Top of geopressure and geopressure gradients from shale resistivity data for a well on section AA', (fig. 56), Duval County.

Figure 59. Top of geopressure and geopressure gradients from shale resistivity for a well in Duval County.

Figure 60. Top of geopressure and geopressure gradients from shale resistivity data for a well in Duval County.

Figure 61. Temperatures and geothermal gradients for Duval County.

Figure 62. Salinity versus depth for five wells in Duval County.

LIVE OAK FAIRWAY

The Live Oak Fairway contains several laterally extensive sandstone units with a net thickness exceeding 180 m (600 ft), but temperatures are mostly lower than 149°C (300°F), and porosity and permeability are very low.

The Live Oak Fairway, Live Oak County, Texas (figs. 63 and 64), is approximately 21 km (13 mi) long and 10 km (6 mi) wide and has an area of approximately 180 km² (70 mi²). This fairway was delineated as an area of possible geopressed geothermal reservoirs through the regional study of the Texas Gulf Coast Wilcox Group (Bebout and others, 1978) on the basis of the presence of thick, laterally extensive sandstones with fluid temperatures greater than 149°C (300°F) in the geopressed zone.

Most of the prospective sandstones occur in the upper Wilcox; updip the upper Wilcox is about 400 m (1,300 ft) thick and downdip, where only the uppermost part of the upper Wilcox has been penetrated, it is at least 900 m (3,000 ft) thick (figs. 65 through 67). Important fields producing hydrocarbons from the upper Wilcox in this area include the Tom Lyne Field updip and the Katz-Slick Field downdip. In the Live Oak Fairway, four markers were used to subdivide the upper Wilcox; two of the markers (L1 and L2) are near the top of the Wilcox and have been correlated throughout the fairway, and two lower markers (L3 and L4) have been identified only in updip wells. Additional markers are the top of the Wilcox and base of the upper Wilcox regional markers.

Several of the correlation markers identified during this study have been recognized by industry and have been assigned names; the correlation of these markers with industry names and with the correlation markers of the other fairways is as follows:

	ZAPATA FAIRWAY		DUVAL FAIRWAY		LIVE OAK FAIRWAY
	TOP	OF	WILCOX		"Slick Sand"
UPPER WILCOX MARKERS	Z1		Du1		L1 "Luling Sand"
	Z2				L2 "Mackhank"-"Massive"
	Z3		Du2		L3
			Du3		L4
	BASE	OF	UPPER	WILCOX	(REGIONAL MARKER)

Only the top of the upper Wilcox has been penetrated in downdip parts of the Live Oak Fairway. Together, the sandstones from the top of the Wilcox to the L2 marker comprise the prospective reservoirs for the Live Oak Fairway (figs. 68 through 70). Most of the sandstone units occur as complex coarsening-upward sequences. The well farthest downdip suggests appreciable shaling out of sandstones at the very top of the Wilcox.

The L2 sandstone is 90 m (300 ft) thick in updip wells and has not been penetrated downdip. Marker L4 occurs at the top of another section containing sandstones and shales developed into coarsening-upward sequences, but in that section the sandstone units are thicker than in the overlying interval.

In the downdip parts of the Live Oak Fairway, the prospective sandstone-bearing interval begins at the top of the Wilcox at approximately 2,800 m (9,200 ft) to 3,230 m (10,600 ft), and extends downward at least 1,220 m (4,000 ft) and possibly as much as 2,440 m (8,000 ft). However, only the upper part of this interval has been penetrated, where it contains 180 m (600 ft) of sandstone.

The Live Oak Fairway is developed in an area characterized by a series of arcuate growth faults, probably developed at the margin of a rapidly prograding lobate delta (fig. 64). The growth-faulted zone has a total known width of about 25 km (16 mi), but the downdip margin is poorly known and the largest faults occur in the central and downdip areas. Approximately nine faults are present across this zone. Passing from the updip to the downdip margin of the growth-faulted zone, the upper part of the Wilcox (the "Slick" sands) increases in thickness from 43 m (140 ft) to 430 m (1,400 ft) indicating an unusually large growth factor of 10 caused by faulting and subsidence contemporaneous with sedimentation (figs. 68 through 70).

The top of geopressure, where geopressure gradients exceed 10.5 kPa/m (0.465 psi/ft), occurs from 2,134 to 2,438 m (7,000 to 8,000 ft), based on bottom-hole shut-in pressures from drill stem tests for 26 wells in Live Oak County (fig. 71). A gradient of 15.8 kPa/m (0.7 psi/ft) occurs at an average depth of 3,033 m (9,950 ft). The maximum pressure gradient observed was about 17.6 kPa/m (0.78 psi/ft) at 3,185 m (10,450 ft).

Top of geopressure picked from shale-resistivity plots (figs. 72 through 74) for three wells on the cross section AA' (fig. 75) demonstrate that some of these wells were not geopressured. Tops of isopiestic gradient surfaces along cross section AA' show that only the two wells farthest downdip penetrate highly geopressured zones (fig. 75).

The geothermal gradient shallower than 2,740 m (8,990 ft) in the Live Oak County (fig. 76) is $3.5^{\circ}\text{C}/100\text{ m}$ ($1.9^{\circ}\text{F}/100\text{ ft}$). Deeper than 2,740 m in the geopressured zone the gradient increases to $5.8^{\circ}\text{C}/100\text{ m}$ ($3.2^{\circ}\text{F}/100\text{ ft}$), higher than the average gradient of $4.9^{\circ}\text{C}/100\text{ m}$ ($2.7^{\circ}\text{F}/100\text{ ft}$) for the larger fairway area including parts of Live Oak, McMullen, Duval, Webb, and Zapata Counties (fig. 77). Temperature-versus-depth plots and isothermal surfaces of 93°C (200°F), 121°C (250°F), and 149°C (300°F) are shown for control wells in cross section AA' (fig. 75).

Salinities of formation waters in the six wells on cross section AA' increase to a maximum value of 150,000 ppm NaCl (figs. 78 and 75) at a depth of 1,341 m (4,400 ft). Limited data showing low salinities between 1,341 and 2,377 m (4,400 and 7,800 ft) are of doubtful quality. Below 2,377 m, salinities decrease to an average value of about 38,000 ppm NaCl at 3,353 m (11,000 ft).

Porosities computed from formation-resistivity factors for six wells on cross section AA' (figs. 79 and 75) decrease from about 35 percent at 914 m (3,000 ft) to about 10 percent at 3,353 m (11,000 ft). Limited diamond-core data from two wells in Live Oak County show an average porosity of 21 percent and permeability of $20 \times 10^{-3} \mu\text{m}^2$ (20 md) in the 5-m sandstone interval from 2,433 to 2,438 m (7,982 to 8,000 ft). From 3,191 to 3,194 m the porosity and permeability average 16 percent and $8 \times 10^{-3} \mu\text{m}^2$ (8 md). Sidewall cores from 3,048 to 3,658 m (10,000 to 12,000 ft) indicated a porosity range of 17 to 24 percent and a permeability range of $5 \times 10^{-3} \mu\text{m}^2$ (5 to 40 md).

EXPLANATION

- Area of most prospective reservoirs
- Well control
- Limit of structural control

Figure 63. Well control, faults at the top of the Wilcox, and area of prospective sandstones, Live Oak Fairway.

Figure 64. Well control and lines of stratigraphic and structural sections, Live Oak Fairway and area to the northeast. Heavy lines indicate the sections included in this report.

Figure 65. Structural dip section AA , southern part of the Live Oak Fairway.

Figure 66. Structural dip section BB', central part of the Live Oak Fairway.

Figure 67. Structural dip section CC', northern part of the Live Oak Fairway.

Figure 68. Stratigraphic dip section AA', southern part of the Live Oak Fairway. Growth faults are not shown in order to better show correlation between wells.

Figure 69. Stratigraphic dip section BB', central part of the Live Oak Fairway.

Figure 70. Stratigraphic dip section CC', northern part of the Live Oak Fairway.

Figure 71. Bottom-hole shut-in pressures from drill-stem tests as a function of depth for 26 wells in Live Oak County.

Figure 72. Shale resistivity-versus-depth plot for a non-geopressed well located updip on section AA', Live Oak County.

Figure 73. Shale resistivity-versus-depth plot for a non-geopressed well located on section AA', Live Oak County.

Figure 74. Top of geopressure and geopressure gradients from shale resistivity for a well on section AA', Live Oak County.

Figure 75. Parameter well profile plots showing variation of formation and fluid properties along section AA', Live Oak County.

Figure 76. Temperatures and geothermal gradients for Live Oak County Fairway area.

Figure 77. Temperatures and geothermal gradients for fairway area including parts of Live Oak, McMullen, Duval, Webb, and Zapata Counties.

Figure 78. Salinity versus depth for six wells in Live Oak County.

Figure 79. A plot of porosity versus depth for six wells in Live Oak County.

DE WITT FAIRWAY - DEPOSITIONAL AND STRUCTURAL STYLE

The prospective geopressured geothermal reservoirs in the De Witt Fairway occur in the lower Wilcox in the complexly growth-faulted portion of the trend just downdip of the Lower Cretaceous Stuart City Trend.

The De Witt Fairway, located in southeastern De Witt County (fig. 80), is 64 km (40 mi) long northeast-southwest and 10 km (6 mi) wide and was first recognized with widely spaced well control on the regional cross sections. Detailed study of the De Witt Fairway is based on analysis of electrical logs from all wells which penetrate the lower Wilcox (fig. 80). Five stratigraphic dip sections and one stratigraphic strike section established the correlation grid into which all well logs were correlated; only stratigraphic section DD' is included in this report (fig. 81). Closely spaced wells in the fairway can be correlated with confidence with electrical logs primarily by means of resistivity markers within the shale and siltstone sections. Several of these markers have been carried across the entire fairway area and are the basis for subdividing the formation into five units in the De Witt Fairway. Two of these markers (D1 and D2) are considered regional markers and have been carried throughout the Wilcox trend in Texas as indicated on the regional cross sections (figs. 10 through 32). The others are local to this fairway and do not correspond to markers used in the other fairways in this report. These markers do, however, provide a basis for subdividing the formation into thinner map units, which are more useful in delineating sandstone and shale trends and interpreting general depositional environments. Potential geopressured geothermal sandstone reservoirs occur beneath the D4 marker where temperatures are greater than 149°C (300°F).

The Wilcox Group in the De Witt Fairway is readily divisible vertically into three main parts: the lower part beneath the D4 marker, the middle part between the D4 and D1 markers, and the upper part from the D1 marker to the top of the Wilcox (fig. 81). The lower part is characterized by high sandstone content which is highly variable laterally as a result of rapid facies changes. The middle part consists dominantly of shale and thin sandstone units that are dominantly strike aligned (fig. 82), and persistent over a large area, and provide excellent correlation markers. The upper part is mainly massive sandstone, which, when mapped, shows a dominant dip-oriented component (fig. 83); detailed correlations are possible only in the thin sandstones and shale of the lower part.

The depositional/structural style of the Gulf Coast Basin is controlled by growth faults which form contemporaneously with deposition. The De Witt Fairway is located in the complexly growth-faulted portion of the Wilcox trend (figs. 6 and 82) just downdip of the Lower Cretaceous Stuart City carbonate shelf edge. The faults trend northwest parallel to the carbonate shelf edge and to the strike of the Wilcox. Displacement across the faults ranges from tens of feet to several hundred feet (figs. 83 to 89), but, in general, fault displacement and section thickening is greatest in the lower part of the Wilcox deeper than the D3 marker.

Local thickening of the sandstone and shale section updip into the bounding growth fault is a characteristic feature of growth faults but is not commonly documented because of a lack of well control close to the faults. In the De Witt Fairway, thickening is particularly well documented on line EE' (fig. 89) where the section thickens between markers D1 and D3 updip from well 15 to well 11. Regional thickening of the sections on the downdip side of growth faults is common and is illustrated on all of the dip cross sections (figs. 85 through 91).

Figure 80. Location of wells and lines of section, De Witt Fairway.

D

D'

Figure 81. Stratigraphic dip section DD', De Witt Fairway.

Figure 82. Net sandstone between correlation markers D2 and D3, middle Wilcox, De Witt Fairway.

Figure 83. Net sandstone between the top of the Wilcox and the D1 marker, De Witt Fairway.

Figure 84a. Structure on top of the D4 marker, De Witt Fairway.

Figure 84b. Index cross section showing mapping horizon in figure 84a.

Figure 85. Structural dip section AA', De Witt Fairway.

Figure 113. Stratigraphic strike section and proposed location of test well.

Figure 114. Net sandstone in correlation unit B, Cuero Prospect.

Figure 115. Net sandstone in correlation unit C, Cuero Prospect.

Figure 116. Net sandstone in correlation unit D, Cuero Prospect.

Figure 117. Net sandstone in correlation unit E, Cuero Prospect.

Figure 118. Net sandstone in correlation unit F, Cuero Prospect.

Figure 119. Net sandstone in correlation unit G, Cuero Prospect.

COLORADO FAIRWAY - DEPOSITIONAL AND STRUCTURAL STYLE

The Colorado Fairway contains a number of thick, lower Wilcox sandstone units with temperatures greater than 149°C (300°F), but these units generally are only slightly geopressed and have low permeabilities.

The Colorado Fairway extends over approximately 1,140 km² (440 mi²) in parts of Colorado, Austin, and Wharton Counties (fig. 120). The area was recognized as a geopressed geothermal fairway in the study of the Texas Gulf Coast Wilcox Group by Bebout, Gavenda, and Gregory (1978). A thick section of sandstones, with net-sandstone values of 370 to 490 m (1,200 to 1,600 ft) occurs in the lower Wilcox in parts of the fairway (fig. 33). Although most of the wells in the area do not penetrate the geopressed zone, certain wells show that the deepest sandstones of the lower Wilcox are geopressed and have fluid temperatures greater than 149°C (300°F).

The Wilcox section in the Colorado Fairway is similar to that of the De Witt Fairway; the upper and lower Wilcox, intervals of thick sandstones, are separated by the more shaly section of the middle Wilcox (fig. 121). A correlation marker, C1, occurs near the base of the sandy section of the upper Wilcox and can be carried into other fairways. This marker is the "regional marker" shown on the regional cross sections (figs. 10 through 32) and is the stratigraphic equivalent of D1 in the De Witt Fairway and H1 in the Harris Fairway, for examples. Three other Wilcox stratigraphic markers, C2, C3, and C4 were carried within the Colorado Fairway (fig. 121); the C3 marker, which corresponds stratigraphically to the H3 marker in the Harris Fairway, was the only one of these three markers to be traced outside the Colorado Fairway.

The C4 marker occurs at depths 49 to 76 m (160 to 250 ft) above the top of the lower Wilcox shown on the regional cross sections 13 and 14 (figs. 22 and 23). Throughout most of the Colorado Fairway, the lower Wilcox shows massive sandstones. Rapid facies changes, however, in addition to faults and sparse deep well control, make the lower Wilcox section difficult to correlate. Only within the prospect area was the lower Wilcox subdivided.

Down-to-the-coast faults are common in the Colorado Fairway, as shown by the structure map of the C4 marker (fig. 122) and cross sections AA', BB', and CC' (figs. 123, 124, and 125). The very large Wilcox growth faults characteristic of the fairways of the Lower Texas Gulf Coast, however, are lacking in the Colorado Fairway. Growth faults affecting the lower Wilcox probably exist but are not detected because of the sparse deep well control.

Figure 120. Location of wells and lines of section, Colorado Fairway.

Figure 121. Stratigraphic dip section BB, Colorado Fairway.

Figure 122a. Structural map, Colorado Fairway.

Figure 122b. Index section, Colorado Fairway. Mapping horizon is the C4 marker, which approximates the top of the lower Wilcox.

Figure 123. Structural dip section AA', Colorado Fairway.

Figure 124. Structural dip section BB', Colorado Fairway.

Figure 125. Structural dip section CC', Colorado Fairway.

COLORADO FAIRWAY - FORMATION AND FLUID PROPERTIES

In the Colorado Fairway, pressure gradients are generally low, temperatures of 149°C (300°F) occur at an average depth of 3,800 m (12,467 ft), porosities range between 4 and 30 percent, and permeabilities commonly are less than $5 \times 10^{-3} \mu\text{m}^2$ (5 md) but may be over $500 \times 10^{-3} \mu\text{m}^2$ (500 md) in isolated thin sandstone units.

Many wells in Colorado County are not geopressured. Some wells are only slightly geopressured, possibly because they were not drilled deep enough to penetrate formations with higher pressures. Shale resistivity-versus-depth plots for six selected wells are typical of wells in the Colorado Fairway (figs. 126 to 131). The Mutex #3-B Wintermann, located on cross section BB' (fig. 124), was a dry hole drilled to a total depth of 3,659 m (12,005 ft). Shale resistivity data show no evidence of high geopressures and this conclusion is confirmed by low mud weights used in drilling (fig. 126). The Union #A-1 Thomas (fig. 127), located on cross section MM' (fig. 136), was also a dry hole drilled to a total depth of 3,627 m (11,901 ft). The maximum pressure gradient, based on mud weight used in this type well for the Eagle Lake Prospect, was 14.34 kPa/m (0.634 psi/ft). The Skelly #1 Wintermann (fig. 128), located on cross section MM' (fig. 136), was drilled to a total depth of 3,390 m (11,122 ft). Evidence of a cap rock exists in the depth interval 2,591 to 3,231 m (8,500 to 10,600 ft) but the well does not penetrate geopressured zones. Three additional wells with shale resistivity plots (figs. 129 to 131), not located on cross sections, were all drilled with low mud weights and did not encounter geopressured formations.

An equilibrium temperature of 149°C (300°F) occurs at an average depth of 3,801 m (12,470 ft) in Colorado County (fig. 132). Geothermal gradients average 2.59°C/100 m (1.40°F/100 ft) to 2,438 m (8,000 ft). Below 2,438 m the gradient is 4.87°C/100 m (2.67°F/100 ft).

Salinities were computed only for the Union #A-1 Thomas (fig. 133). In shallow formations, values of salinity increase from about 19,000 to a maximum of 180,000 ppm NaCl at a depth of 2,042 m (6,700 ft) where the temperature approaches 93°C (200°F). Below 2,042 m, salinities decline to a minimum value of 55,000 ppm NaCl at a depth of 2,896 m (9,500 ft) then increase again to 180,000 ppm NaCl at a depth of 3,642 m (11,950 ft) where the temperature is about 150°C (302°F).

Porosities from diamond bit core measurements lie between 4 and 19 percent in the depth interval 3,386 to 3,554 m (11,109 to 11,660 ft) in the Union #A-1 Thomas (fig. 134), type well for the Eagle Lake Prospect. Most permeabilities are below $5 \times 10^{-3} \mu\text{m}^2$ (5 md). However, permeabilities range from 89×10^{-3} to $545 \times 10^{-3} \mu\text{m}^2$

(89 to 545 md) and average $275 \times 10^{-3} \mu\text{m}^2$ (275 md) in the thin sandstone interval between 3,541.8 and 3,543 m (11,620 and 11,624 ft). There are several other isolated thin sandstones with permeabilities from 10×10^{-3} to $100 \times 10^{-3} \mu\text{m}^2$ (10 to 100 md). Average porosity and permeability in the depth interval 3,000 to 3,003.5 m (9,840 to 9,854 ft) in the Shell #1 Engstrom (5S-29E-9) 27 km (17 mi) to the southwest of the prospect area was 15.9 percent and $16.8 \times 10^{-3} \mu\text{m}^2$ (16.8 md). Sidewall core measurements from several wells indicate porosities of 20 to 30 percent and permeabilities up to $450 \times 10^{-3} \mu\text{m}^2$ (450 md) in sandstone intervals occurring between 2,438 and 3,353 m (8,000 and 11,000 ft).

Figure 126. Shale resistivity versus depth for nongeopressed well located on section BB' (fig. 124), Colorado County.

Figure 127. Shale resistivity versus depth for well located on cross section MM' (fig. 136), Colorado County.

Figure 128. Shale resistivity versus depth for a nongeopressed well located on cross section MM' (fig. 136), Colorado County.

Figure 129. Shale resistivity versus depth for a nongeopressed well in Colorado County.

Figure 130. Shale resistivity versus depth for a nongeopressed well in Colorado County.

Figure 131. Shale resistivity versus depth for a nongeopressed well in Colorado County.

Figure 132. Temperatures and geothermal gradients for 48 wells located in Colorado County.

Figure 133. Salinity profile for the type well (Eagle Lake Prospect), located on cross section MM' (fig. 136), Colorado County.

Figure 134. Porosity versus permeability for the type well (Eagle Lake Prospect) located on cross section MM' (fig. 136), Colorado County.

COLORADO FAIRWAY - EAGLE LAKE PROSPECT

In the Eagle Lake Prospect of the Colorado Fairway, a site has been selected for a geothermal test well that will have over 366 m (1,200 ft) of net sandstone in the reservoir interval, with temperatures of 138°C (280°F) to 163°C (325°F) but with generally low permeabilities and fluids that are only slightly geopressured.

The Eagle Lake Prospect extends over an elongate area of approximately 26 km² (10 mi²) within the Colorado Fairway in eastern Colorado County (fig. 135). The prospect area is bounded on the northwest and southeast by major faults and on the northeast and southwest by structural highs. A proposed test-well site is located within the Eagle Lake Prospect area 2 mi northeast of the town of Eagle Lake.

The top of the reservoir sandstone in the type well (Union #A-1 Thomas, fig. 136) for the prospect area is at a depth of 3,410 m (11,180 ft). Within the prospect area, the top of the reservoir sandstone interval ranges in depth from 3,340 m (10,960 ft) to 3,475 m (11,400 ft). Although none of the existing wells in the prospect area penetrated the entire prospective interval, wells along strike but several miles from the prospect area indicate the total thickness of the prospective sandstone section to be at least 490 m (1,600 ft). Trends of the lower Wilcox sandstone (fig. 134, units A through F) thickening into the syncline in the prospect area, however, indicate that the total prospective interval may be as much as 580 m (1,900 ft) thick in the test well (fig. 137). Thus, the base of the reservoir sandstone in the prospect area should be at depths ranging from about 3,840 to 4,060 m (12,600 to 13,300 ft). In the test well, the reservoir sandstone should occupy the interval from 3,440 to 4,020 m (11,280 to 13,180 ft).

On the basis of the sandstone percentage in the prospective interval of the type well, the total interval thickness in adjacent areas, and thickening of the section into the syncline, the net sandstone in the prospective reservoir of the test well is expected to be approximately 380 m (1,240 ft). The sandstone beds range in thickness from 2.5 to 21 m (8 to 70 ft), and the intervening shale beds are from 1.5 to 12 m (5 to 40 ft) thick.

Whole-core analyses from the prospective interval in the type well show that porosity ranges from 4 to 19 percent and averages 13 percent. Most of the reservoir sandstone section is characterized by low permeabilities less than $5 \times 10^{-3} \mu\text{m}^2$ (5 md); high permeabilities up to $545 \times 10^{-3} \mu\text{m}^2$ (545 md) are found only in the core taken from 3,536 m (11,600 ft) to 3,554 m (11,660 ft).

In the type well, fluid temperatures of 93°C (200°F) and 149°C (300°F) occur at depths of 1,860 m (6,100 ft) and 3,590 m (11,780 ft), respectively. Temperatures in the reservoir section of the type well range from 135°C (275°F) calculated for the top of the reservoir interval at 3,408 m (11,180 ft) to 150°C (302°F) recorded at the total depth of 3,605 m (11,826 ft). In the test well, temperatures should range from approximately 138°C (280°F) at the top of the reservoir interval to 163°C (325°F) at the base.

As determined from mud weights, the highest pressure gradient in the type well is 14.34 kPa/m (0.634 psi/ft), which was reached at a depth of 3,444 m (11,300 ft). Bottom-hole pressure was calculated to be 49,394 kPa (7,164 psi) on the basis of that gradient. In the test well, the top of geopressure is expected to be at 3,660 m (12,000 ft).

Salinities computed for the type well, Union #A-1 Thomas, were discussed in the previous section on formation and fluid properties of the Colorado Fairway. The test well is expected to have a similar salinity profile.

Figure 135. Eagle Lake Prospect, type-well site, and proposed test-well site, Colorado Fairway. Mapping horizon is the C4 marker, which approximates the top of the lower Wilcox. Contour interval is 30 m (100 ft).

Figure 136. Structural strike section MM', Colorado Fairway.

Figure 137. Stratigraphic strike section MM', Colorado Fairway. Datum is the C4 marker. The reservoir section below the C4 marker is correlated in detail (units A through F).

HARRIS FAIRWAY

The Harris Fairway contains thick geopressured sandstone units with temperatures greater than 149°C (300°F), but permeabilities in these units are consistently less than $1 \times 10^{-3} \mu\text{m}^2$ (1md).

The Harris Fairway, trending northeastward, extends over parts of Waller, Fort Bend, Harris, Grimes, Montgomery, Liberty, and San Jacinto Counties (fig. 138). The fairway study area is approximately 123 km (77 mi) long and 54 km (34 mi) wide. This fairway was delineated as an area of potential geopressured-geothermal reservoirs during the regional study of the Texas Gulf Coast Wilcox Group (Bebout, Gavenda, and Gregory, 1978). Selection of this area for study was made on the basis of the great thickness of massive sandstones in the lower Wilcox. Maximum net-sandstone values (more than 610 m, or 2,000 ft) for the lower Wilcox of Texas occur within the Harris Fairway (fig. 33). Much of the lower Wilcox sandstone in the downdip parts of this area is geopressured and shows temperatures greater than 149°C (300°F).

The Harris study area extends farther updip than do the Colorado or De Witt study areas. The Wilcox in these updip parts of the Harris area is sandy throughout, as shown by the logs of wells farthest updip on the stratigraphic section DD' (fig. 139). Downdip, however, the Wilcox section in the Harris Fairway is similar to that in the Colorado and De Witt Fairways; the middle Wilcox section is shaly, and the upper and lower Wilcox sandy intervals are much more distinct.

The upper Wilcox is characterized by massive sandstone over the entire Harris Fairway. The H1 marker occurs near the base of this upper sandstone-rich section of the Wilcox (fig. 139) and can be correlated into other fairways. This marker is the "regional marker" shown on the regional cross sections (figs. 10 through 32) and is equivalent to C1 in the Colorado Fairway and D1 in the De Witt Fairway, for examples. Three other Wilcox stratigraphic markers, H2, H3, and H4, have been recognized within the Harris Fairway (fig. 139); the H3 marker, which corresponds stratigraphically to the C3 marker in the Colorado Fairway (fig. 121) was the only one of these three markers to be traced outside the Harris Fairway.

The H4 marker occurs at depths of 12 to 110 m (40 to 360 ft) below the top of the lower Wilcox shown on the regional cross sections 15 through 19 (figs. 24 through 28). Throughout most of the Harris Fairway, the lower Wilcox shows massive sandstones. As in the De Witt and Colorado Fairways, however, rapid facies changes, faults, and sparse deep well control make the lower Wilcox section difficult to

correlate. Thus, the thick section of interest for geopressured-geothermal reservoirs could not be subdivided for more detailed study and construction of meaningful net-sandstone maps. Cross sections, however, indicate areas of maximum sandstone. Lower Wilcox intervals of thick net sandstone, all or much of it geopressured and with fluid temperatures greater than 149°C (300°F), are shown on the Humble #31 Katy Gas Field well log on cross section DD' (fig. 140) and the Texaco #1 Mergele and Texaco #1 Sweeney Estate logs on section EE' (fig. 141).

The Harris Fairway is an area of salt domes and salt withdrawal basins. Parts of the middle and upper Wilcox section thin over a few of the domes. The thinning was most probably the result of lack of deposition rather than erosion. Therefore, growth of some of the domes had begun during or before Wilcox deposition, while others did not affect Wilcox structure until after deposition and burial. Unfortunately, few wells on the domes are deep enough to penetrate the lower Wilcox, thus hampering detailed study of the effect of the domes on lower Wilcox deposition.

Down-to-the-coast faults are common in the Harris Fairway, but large Wilcox growth faults are much rarer than in most of the other fairways to the southwest. The upper and middle Wilcox show no differential growth caused by fault movement except in the areas farthest downdip (southeastward). Stratigraphic section DD' (fig. 139) illustrates the gradual downdip thickening of the intervals defined by the various correlation markers. Examples of growth faults occurring in the most basinward part of the fairway are shown on the Scurlock #1 Meek well log on structural cross section DD' (fig. 140) and on the Superior #1 Hightower well log on section HH' (fig. 142). Growth faults affecting the lower Wilcox within the fairway may be more numerous and of greater magnitude but are much more difficult to analyze because of the sparse deep well control.

Average depths to the top of geopressure gradients 10.5 and 15.8 kPa/m (0.465 and 0.70 psi/ft) are 2,790 and 3,520 m (9,150 and 11,550 ft), respectively (fig. 143) based on bottom-hole shut-in pressure measurements for 23 wells in Harris County. Pressure gradients increased with depth to a maximum of 19.0 kPa/m (0.84 psi/ft) at a depth of 4,070 m (13,350 ft). Top of geopressure was picked from shale resistivity plots (figs. 144 through 150) for selected wells on geological cross sections DD', EE', and HH' (figs. 140 to 142). Wells with shale resistivities that fall on or to the right of the normal compaction curve (NCC) were not considered to be geopressured in this report (figs. 144, 146, and 148). Geopressure profiles were computed for wells with shale resistivity values that were less than normal. Wells with highly geopressured

formations include the Humble #W-21 Katy Gas Field, Unit #1 (fig. 145), Texaco #1 J. J. Sweeney Estate (fig. 147), and Superior Oil Co., #1 T. J. Hightower (fig. 150).

Equilibrium temperatures and geothermal gradients have been calculated for an area that includes parts of Harris, Liberty, Austin, and Colorado Counties and portions of adjacent counties (fig. 151). The geothermal gradient in the upper Wilcox is about $3.8^{\circ}\text{C}/100\text{ m}$ ($2.10^{\circ}\text{F}/100\text{ ft}$) in the depth interval 2,530 to 4,267 m (8,300 to 14,000 ft). The lower Wilcox from 4,267 to 5,486 m (14,000 to 18,000 ft) has a gradient of about $2.2^{\circ}\text{C}/100\text{ m}$ ($1.20^{\circ}\text{F}/100\text{ ft}$). Formations above the Wilcox from 0 to 3,048 m (0 to 10,000 ft) have a geothermal gradient of about $2.6^{\circ}\text{C}/100\text{ m}$ ($1.40^{\circ}\text{F}/100\text{ ft}$). A subsurface temperature of 150°C (302°F) occurs at 3,978 m (13,050 ft) below sea level.

Temperature versus depth plotted (fig. 152) for wells on geological cross sections DD', EE', and HH' have a distribution of data points with a geothermal gradient of $2.88^{\circ}\text{C}/100\text{ m}$ ($1.58^{\circ}\text{F}/100\text{ ft}$) from 0 to 3,658 m (0 to 12,000 ft). A gradient of $3.94^{\circ}\text{C}/100\text{ m}$ ($2.16^{\circ}\text{F}/100\text{ ft}$) is found in deeper formations down to 5,335 m (17,500 ft). A temperature of 149°C (300°F) occurs at about 3,960 m (12,990 ft).

Data for 14 wells located in the Harris County Geothermal Fairway (fig. 153) show a trend of decreasing salinity from 2,316 to 3,962 m (7,600 to 13,000 ft). Maximum salinities of 197,000 ppm NaCl occur at 2,590 m (8,500 ft) and minimum values of 11,500 to 20,000 ppm NaCl occur at depths between 3,232 and 4,400 m (10,600 and 14,450 ft). Few salinity values were calculated for shallow sandstones, but the normal trend is one of increasing salinity from 600 to about 2,500 m (2,000 to 8,200 ft).

Available whole-core data for several wells in Harris County show that most permeabilities of sandstones in the deep subsurface are less than $5 \times 10^{-3} \mu\text{m}^2$ (5 md) and many are less than $1 \times 10^{-3} \mu\text{m}^2$ (1 md). Moderately good permeabilities of 1.5×10^{-3} to $19 \times 10^{-3} \mu\text{m}^2$ (1.5 to 19 md) are found in a few thin sandstone intervals at depths exceeding 4,000 m (13,120 ft).

Porosities in these thin sandstones average about 15 percent. Sidewall cores from the same wells have measured average permeabilities and porosities of $241 \times 10^{-3} \mu\text{m}^2$ (241 md) and 32 percent in the depth interval 1,957 to 2,073 m (6,420 to 6,800 ft).

Figure 138. Location of wells and lines of section, Harris Fairway.

Figure 139. Stratigraphic dip section DD', Harris Fairway.

Figure 140. Structural dip section DD', Harris Fairway.

Figure 141. Structural dip section EE', Harris Fairway.

Figure 142. Structural dip section HH', Harris Fairway.

Figure 143. Bottom-hole shut-in pressures from drill stem tests as a function of depth for 23 wells located in Harris County.

Figure 144. Shale resistivity versus depth for a nongeopressured well located on cross section DD' (fig. 139), Waller County.

Figure 145. Top of geopressure and geopressure gradients from shale resistivity data for well located on cross section DD' (fig. 139), Waller County.

Figure 146. Shale resistivity versus depth for a nongeopressed well located on cross section EE' (fig. 141), Grimes County.

Figure 147. Top of geopressure and geopressure gradients from shale resistivity data for well located on cross section EE' (fig. 141), Harris County.

Figure 148. Shale resistivity versus depth for a nongeopressed well located on cross section HH' (fig. 142), San Jacinto County.

Figure 149. Shale resistivity versus depth for a well located on cross section HH' (fig. 142), Montgomery County.

Figure 150. Top of geopressure and geopressure gradients from shale resistivity data for well located on cross section HH' (fig. 142), Liberty County.

Figure 151. Temperatures and geothermal gradients for the Harris County Fairway area.

Figure 152. Temperatures and geothermal gradients for wells located on three fairway cross sections, Harris County.

Figure 153. Salinity versus depth for 14 wells located in Harris County Fairway area.

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APPENDIX

LIVE OAK FAIRWAY

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
11S-18E-9	2	Cox & Haring #1 Copeland
11S-18E-5	3	Union #2 Spielhagen
11S-18E-8	5	Pennzoil #79 Ray
11S-18E-2	6	Sohio, et al. #1 Nichols Est.
11S-18E-5/6, 8/7	7	Pennzoil #10 Ray
11S-18E-7	8	Union #6 Ray
12S-17E-9	1	Northern Pump & Hunt #A-1 Hall
12S-17E-2	5	Forest #1 "B-C" Borroum
12S-17E-2	6	Southland #1 Barber, et al.
12S-17E-1	7	Stanolind #1 Atkinson
12S-17E-3	8	Shell #1 Gordon
12S-17E-9	10	Dyco #1 Ballard
12S-17E-4	12	Texas Oil & Gas #A-1 Knight
12S-17E-5	13	Texas Oil & Gas #1 Rodriguez Gas Unit
12S-17E-2	14	Carri Oil, et al. #1 Copeland
12S-17E-6	16	Clover #1 South Texas Children's Home
12S-17E-6	17	Arkansas Fuel Oil, R. D. Goodrich, Harkins & Co., and The Texas Co. #1 Booth
12S-17E-7	18	Gasoline Production Division-Zachry #A-1 Bast
12S-18E-2/3	10	Frankfort (Texas Pacific) #10 Walton
12S-18E-1	17	Texas Oil and Gas #A-1 McKinney
12S-18E-2	25	Texas Pacific (Rowan & Tong) #9 Freeland
12S-19E-3	1	MPS #1 McKinney
12S-19E-4	3	Hewit, et al. #1 Weiss
12S-19E-4	5	Miller #1 Farish
12S-19E-8	7	Coastal States #1 Farish
13S-16E-1	1	Sinclair #3 Dilworth
13S-16E-6	2	Newman Bros. #1 Edwards, et al.
13S-16E-7	3	Jones, Coates, & Kirkwood #1 Dunn
13S-16E-7	4	National Exploration #1 McKinney et al.
13S-16E-1	6	Hanson & MacDonald #1 Maguglin
13S-16E-6	8	Blanco #1 Gillette
13S-16E-1	9	Texas Oil & Gas #1 Maguglin
13S-16E-2	10	Venus #1 Goebel
13S-16E-2	11	Service Contracting & Longhorn #1 Goebel
13S-16E-6	13	Ryan, Mays & Burke #1 Gillett
13S-16E-6	14	Stanolind #1 Henderson-Coquat
13S-16E-6	15	Davis #1 Dunn
13S-16E-6	16	The Texas Co. #1 Cochran
13S-16E-6	17	Abercrombie, Henshaw, & Smith #1 Dunn

LIVE OAK

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
13S-16E-8	19	Coastal States #1 Morrison
13S-17E-1	2	Hughes & Hughes #1 MacDon-Holzmark
13S-17E-1	3	Hughes & Hughes #1 Pouloit "A"
13S-17E-6	5	Carl #1 Gillett
13S-17E-6	6	Carl #1 Turnbow
13S-17E-6	8	Dow Chemical (Southland) #1 McCollem
13S-17E-5/6, 8/7	9	North Central, Greenbrier 66, Hanson #1 Bomar
13S-17E-7	10	Coastal States #1 McCord
13S-17E-8	11	Argo #1 Huegler
13S-17E-8	13	Colorado Oil & Gas #1 Choate
13S-17E-9	14	Quintana #1 Vickers
13S-17E-9	15	Atlantic #1 Coward
13S-17E-2	17	Hamon #1 Ragsdale
13S-17E-1	18	Viking de Lange #1 Williams
13S-17E-3	20	Warren #1 Dove
13S-17E-2	21	Bright and Schiff #1 Schoolfield
13S-17E-2	22	Stanolind #1 McCollum
13S-18E-4	6	White Shield #1 Martin
13S-18E-4	9	Tidewater #1 Taylor
13S-18E-8	10	Tamarack #1 Humberson
13S-18E-4	11	Halbouty #1 Gillett, et al.
14S-14E-4	1	Texam #1 Hayes-Ezzell
14S-14E-6	4	Magnolia (Troporo) #1 Means
14S-14E-9	5	Jones #1 Shiner
14S-14E-1	6	Kilroy of Texas #1 Herring
14S-14E-6	7	Tenneco #1 Stephens
14S-14E-6	8	Scoggins & Troporo #1 Schmid
14S-14E-8	9	Magnolia #1 Jones
14S-14E-9	10	Jones #C-2 Ezzell
14S-14E-9	11	Jones #C-4 Ezzell
14S-14E-8	12	Meeker #1 Lebman
14S-14E-5	13	Magnolia #1 Block 86
14S-15E-6	1	Humble #1 Coker
14S-15E-6	2	Mosbacher (Hughes & Hughes) #1 Kendall
14S-15E-6	3	Hanson #1 Prosen, et al.
14S-15E-6	4	Mosbacher #1 Garza Unit 1
14S-15E-8	5	Continental #2 Burns
14S-15E-8	7	Atlantic #8 Lyne
14S-15E-7	8	Getty #1 Christenson
14S-15E-8	13	La Gloria, et al. #1 Bush
14S-15E-8	14	Kilroy & Southland #1 Bierwirth, et al.
14S-15E-9	16	Atlantic-Richfield #12 Lyne
14S-15E-9	17	Atlantic #9 Lyne
14S-15E-2	18	Jones #1 West Est.
14S-15E-2	19	Texas Eastern #1 Schreiner
14S-15E-3	20	Argo #1 Schreiner
14S-15E-3	21	Kilroy of Tex. #A-1 Herring

LIVE OAK

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
14S-15E-3/4	22	Interamerican Funds #2 Herring
14S-15E-3	23	Venus #1 Schreiner
14S-15E-9	24	Argo, et al. #1 Houdman
14S-15E-9	25	Warren #1 Whitley-Johnson
14S-15E-9	26	Atlantic #11 Lyne
14S-15E-9	27	Mesa #1 Johnson
14S-15E-8	28	Gulf Coast (L. M. Fischer) #1 Korczinsky-Wojtaszyk
14S-16E-1	1	Cherryville #1 Williams
14S-16E-3	3	Gulf #1 Lee
14S-16E-4	4	Pan American #B-1 West
14S-16E-6	5	Brown #1 Hayes
14S-16E-8	8	Atlantic #1 Riser
14S-16E-8	9	Pan American #1 Randall
14S-16E-8	10	Union of California #1 Riser
14S-16E-9	11	Abercrombie #1 West & Perkins
14S-16E-9	12	Patrick #1 Abbey
14S-16E-4	13	Hanson & Hurt #1 Perkins
14S-16E-4	17	Hughes & Hughes #2 Kendall
14S-16E-4	18	American Petrofina #1 Perkins
15S-14E-1	1	Davis #2 Lyne
15S-14E-1	3	El Chorro & Lawley #1 Paul, et al.
15S-14E-5	4	Atlantic #1 Morris
15S-14E-6	5	Davis #1 Sanger Heirs
15S-14E-6	6	Atlantic-Richfield #1 El Paso
15S-14E-7	7	Continental #4 Somerset
15S-14E-7	8	Continental #5 Somerset
15S-14E-7	9	Coastal States & Zoch, et al. #1 Lehmberg
15S-14E-7	10	Southland #1 El Paso
15S-14E-8	11	Argo #1 Baker
15S-14E-8	12	Rutherford #2-A Baker, et al.
15S-15E-2	1	Coastal States & King #2-A Lennox
15S-15E-2	2	Atlantic #1 Burns
15S-15E-2	4	Pace #1 Burns
15S-15E-2	5	Continental #A-1 Burns
15S-15E-2	6	Cox #1 Sparkman
15S-15E-2	7	Hanson & Hurt #1 Sparkman
15S-15E-3	10	Hanson #1 National Bank of Commerce
15S-15E-3	11	Austral #1 Lyne
15S-15E-3	12	Standard Oil of Texas #1 Lyne, et al.
15S-15E-3	13	Midwest #1 Lyne
15S-15E-3	14	S.R.G. #1 Lyne
15S-15E-4	15	Atlantic #2 Lyne
15S-15E-4	16	Katz #1-B Slick
15S-15E-4	17	Sands #1 Dolan
15S-15E-4	19	Cherryville #1 Lyne
15S-15E-4	20	Coastal States #1 Ferrell
15S-15E-5	22	Tidewater #1 Burns
15S-15E-6	23	Huber #1 Tullis

LIVE OAK

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
15S-15E-6	24	Tidewater #1 Tullis
15S-15E-6	25	Cherryville #1 Tullis
15S-15E-6	26	Cities Service #1 Bailey "C"
15S-15E-8	27	Tenneco #1 Jones Gas Unit
15S-15E-8	28	Placid #1 Patteson
15S-15E-9	29	Cities Service #1 Hendrick "B"
15S-15E-9	30	Hamill #1 McClure
15S-15E-9	31	Continental #3 Somerset
15S-15E-9	32	Katz #C-1 Slick
15S-15E-9	33	Coastal States #1 Slick
15S-16E-2	1	Lone Star #1 Watson
15S-16E-3	2	Hanson & McCormick #1 Johnson
15S-16E-4	3	Tidewater #1-A Hall Est.=A
15S-16E-4	4	Highland #1 Crocker
15S-16E-8	5	Austral #1 Hinnant "A"
16S-14E-1	1	Skelly #1 "A" Weil
16S-14E-3	3	Atlantic-Richfield #4 Baker
16S-14E-3	4	Argo #1 de Arman
16S-14E-4	5	Argo #2 de Arman
16S-14E-6	6	Humble #1 Brookshire
16S-14E-9	7	Austral #1 Baker
16S-15E-3	2	Hamon #1 Hefner

DUVAL FAIRWAY

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
14S-13E-7	1	Archer #1 Wheeler
15S-13E-1	1	Delange & Neathery #B-1 Brown
15S-13E-3	2	Davenport #1-A Dolph
15S-13E-7	3	Argo #V-1 Edrington
15S-13E-2	5	Pace & Vreeland #1 La Jolla
15S-13E-5	6	Southland, Delange & Ellis #1 Caron
15S-13E-5	7	Olson #1 Whitfield
15S-13E-5/8	8	The Texas Company #1 Rhode
15S-13E-8	9	Argo #R-1 Edrington Est.
16S-12E-1	1	Cox #1 Atkinson
16S-12E-9	2	Atlantic #1 Hagist Ranch
16S-12E-4	3	Hawkins & Ranger #1 Hagist Ranch
16S-12E-8	4	Marion #1 Welder Heirs
16S-12E-8	5	Humble #26 Dowdy Fee
16S-12E-1	6	Atlantic #1 Atkinson
16S-12E-6	7	Rutherford #1 Pursch
16S-13E-3	1	Argo #1 Roos
16S-13E-4	2	Harkins #1-112 Murphy Estate
16S-13E-4	3	Coastal States #1 Ragsdale
16S-13E-6	4	Humble #1 Yeager
16S-13E-6	5	Sun Oil-DX Division #4 Penn
16S-13E-6	6	Sunray #1 American National Insurance Co.
16S-13E-6	7	Seaboard of Delaware #1 Lowe
16S-13E-7	8	Siegfried #1 Lowe
16S-13E-7	9	Petro-Lewis #1 Bindewald
16S-13E-8	10	Mobil #1 Labbe Ranch
16S-13E-9	11	Harkins & Humble #1 Ragsdale
16S-13E-6	12	The Texas Co. #2 Gouger Gas Unit #3
16S-13E-2	13	Argo #Q-1 Edrington
16S-13E-1	14	Sunray #1 Penn
17S-11E-7	1	Trans Texas #1 Hahl-Burch
17S-11E-7	2	Mavin #1 Hahl-Wiederkehr
17S-11E-9	3	Magnolia #9 D.C.R.C.
17S-11E-6	4	Horizon #1 Lundell
17S-11E-7	5	Fair & Woodward #1 Luptack
17S-12E-1	2	Argo & Haring #1 Gorman
17S-12E-1	3	Texaco #1 Marshall
17S-12E-5	4	Humble #B-1 Welder Heirs
17S-12E-5	5	Ramada #1-B Welder Heirs
17S-12E-6	6	Ramada, et al. #1 Welder Heirs
17S-12E-1	7	Atlantic-Richfield #1 Arco, et al. Humble Fee
17S-12E-1	8	Atlantic-Richfield #B-7 Welder

DUVAL

Township
Range

Well No.

Well Name

17S-12E-1/2, 5/6	9	Humble #2 Welder Heirs "F"
17S-12E-1	10	Cherryville #1 Gorman
17S-12E-1	12	Atlantic-Richfield #F-1 Welder Heirs
17S-13E-5	1	Stanolind #1-D Farmers Life Insurance
18S-10E-5	1	Shell #1 Duval County Ranch Co.
18S-11E-2	1	Humble #98 White "B"
18S-11E-8	2	Waggoner Est. #1 Arnstein, et al.
18S-12E-2	1	Huber, Colorado & Shell #1 Hubberd
18S-12E-5	2	Shell #1 Penwell
18S-12E-5	4	Shell #1 Hubberd "B"
18S-12E-5	5	Shell #A-3 Weatherby
18S-12E-6	6	Shell #1 L. C. Weatherby "A"
18S-12E-6	7	Shell #1 Stegall "A"
18S-12E-5	10	Shell #A-2 Weatherby
18S-12E-6	11	Huber & Shell #1 Stegall
18S-12E-6	13	Socony Mobil & Lacy #1 Weatherby
18S-12E-9	15	Hamm, et al. #15 Duval-Hoffman
18S-12E-6	16	Huber #1 Hoffman, et al.
19S-9E-5/6	1	Sundance #1 Frost
19S-10E-9	1	Atlantic #1-A Billings Ranch
19S-10E-2	2	Mayfair #1 Kirkpatrick, et al.
19S-10E-9	3	Houston Oil & Minerals #1 Billings
19S-10E-5	4	Rowe #1 Pearl Est.
19S-10E-8	5	Harrell, Holbrook & Coastal States #1 Lopez
19S-10E-7	6	Humble #100 Kohler "A"
19S-11E-9	1	Eason-Harper #1-160 Peters Est.
19S-11E-9	2	Eason #1 Peters Est.
19S-11E-4	4	Monterey #1 Peters
20S-9E-4	1	Frost, et al. #1 Walker
20S-9E-4	2	Sunray #1 Walker
20S-10E-4	2	Shell #1 El Paso-Benavides Ranch
20S-10E-5	3	Hamon #1 Perez, et al.
20S-10E-5	4	Hamon #1 Pedro (STH) Lea
20S-10E-6	5	Houston Oil & Minerals #1 Dinn
20S-10E-6	7	Morgan #3-B Richardson
20S-10E-8	8	Mobil #1 Dinn
20S-11E-3	3	Gulf #1 Gulf-Peters
21S-8E-7	2	Texaco #28 Da Camara
21S-8E-8/9	3	Skelly #6 Martin
21S-8E-8/9	4	Skelly #1 Martin
21S-8E-1	5	Gulf #1 Villareal
21S-9E-5	1	Brown, DelMar, & Dennis #1 Laurel Heirs
21S-9E-9	2	Atlantic #1 "A" Garcia Est.
21S-9E-5	3	Pauley #1 Laurel Fee
21S-9E-5	4	Amistad #1 "A" White
21S-10E-2	1	Hamon #1 de Benavides
21S-10E-4	2	McCulloch & Venus #1 Cuellar

DUVAL

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
21S-10E-5	3	Getty #1 de Benavides
21S-10E-7	4	Union #1 Brennan-Benavides
21S-10E-3	5	Standard of Texas #1-B de Benavides
21S-10E-3	6	Morgan #2-B de Benavides
22S-8E-8	1	Shell #1 Bruni Trust & Killam Trust
22S-9E-2	1	Atlantic #1 Garcia Est.
22S-9E-2	3	Coastal States #2 Puig
22S-9E-3	4	Atlantic #1 Puig Gas Unit
22S-9E-4	6	Hamon #1 Ramirez
22S-9E-4	8	Pickens #1 Bruni
22S-9E-7	10	Atlantic #2 Bruni Gas Unit #1
22S-9E-7	11	Atlantic & Austral #1 Stroman-Armstrong
22S-9E-7	12	Atlantic #2 Stroman-Armstrong
22S-9E-7	13	Austral #1 Marrs McLean Trust
22S-9E-7	15	Atlantic-Richfield #3 Marrs McLean "C"
22S-9E-7	17	Austral #2 Marrs McLean
22S-9E-7	18	Coastal States #1 Yeager-Armstrong
22S-9E-9	20	Atlantic #A-1 Hinnant
22S-9E-2	21	4-B Trust #1 Laredo National Bank
22S-9E-4	22	Atlantic #1-A Puig

DE WITT FAIRWAY

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
7S-23E-5	1	Avalanche Journal #1 Palmer, Seekamp, and Rittner
7S-23E-7	2	Rowe #2 Parker
7S-23E-7	3	Apache & N. Central #1 Daniels
7S-23E-7	4	Patrick #1 Daniels
7S-23E-7	5	Weaver #1 Belton
7S-24E-3	2	Mobile #1 Hagen
7S-24E-7	5	Shell #1 Carroll
7S-24E-8	6	Argo #1 Granberry
7S-24E-9	7	Humble #1 Kunetka
7S-24E-5	8	Lone Star #1 McManus
7S-24E-8	9	Lone Star #1 Garrett
7S-24E-7	10	Humble #1 Matthews
8S-21E-1	1	Gulf #1 Mueller
8S-21E-4	3	Shell #1 Brown
8S-21E-4	4	Lone Star #1 Alex
8S-21E-5	5	Atlantic #1 Smith
8S-21E-6	6	International Nuclear #1 Weber
8S-21E-7	7	Commonwealth #1 Richards
8S-21E-7	8	Scurlock #1 Murray
8S-21E-8	9	Highland #1 Wood
8S-21E-8	11	• McCulloch #1 Domann
8S-21E-8	12	Brown #1 Jablonski
8S-21E-9	14	Shell #1 Roehl
8S-21E-6	15	Superior #1 Blackwell
8S-21E-4	16	Esperaza #1 Sheppard
8S-22E-3	1	Sterling #1 Hamilton
8S-22E-9	2	Humble #1 Cook
8S-22E-5	4	Argo #1 Keseling
8S-22E-5/6	5	Coastal States #1 Lackey
8S-22E-6	6	Viking #1 Ward
8S-22E-6	7	Venus #1 Hartman
8S-22E-6	8	Gas Producing Enterprises #1 Musselman Gas Unit
8S-22E-6	9	Texaco #1 Jernigan
8S-22E-6	10	Harkins #1 Jernigan
8S-22E-6	11	Harkins #1 Henneke
8S-22E-6	12	Sun #1 Henneke Gas Unit
8S-22E-7	13	Lone Star #1 Mueller
8S-22E-7	14	Humble #1 Hartman
8S-22E-7	15	Humble #1 Keseling
8S-22E-7	16	Edwards #1 Keseling
8S-22E-7	17	Angelina, Owen & Smith #1 Keseling (Unit #3)
8S-22E-8	18	Tesoro #1 Keseling-Johnson
8S-22E-8	19	Humble #1 Schorlemer
8S-22E-9	21	Tana #1 White
8S-22E-5	22	Scheig #1 Brown
8S-22E-5	23	Abercrombie #1 Williams

DE WITT

Township Range

Well No.

Well Name

8S-22E-8	25	Braman #1 Keseling
8S-22E-8	27	Harkins and Humble #1 Keseling
8S-22E-9	28	Lone Star #1 Angerstein
8S-22E-9	29	Atlantic #1 Schorre
8S-22E-5	30	Catlett & Ferguson #1 Thomas
8S-22E-5	31	Monsanto #1 Ley
8S-22E-1	32	Bridewell #1 Burns
8S-22E-6	33	Hanover #1 Sager
8S-22E-2	34	Tesoro #1 Kirkham, et al.
8S-23E-1	1	Arco #1 Daniels
8S-23E-1	2	Zinn, Mitchell, Lone Star #1 Daniels
8S-23E-1	3	Seeligson #1 Friar
8S-23E-2	4	Apache & North Central #1 Friar
8S-23E-2	6	Coastal States #1 Friar
8S-23E-2	7	Sinclair & Coastal States #1 Stiles
8S-23E-2	8	Brown 10 #1 Friar
8S-23E-3	9	Texas Gas #1 Adams
8S-23E-3	10	Viking #1 Schultz
8S-23E-3	11	Osborn #1 Wesley
8S-23E-4	12	Tidewater #1 Adams
8S-23E-4	13	Argo #1 McDougal
8S-23E-4	15	Lone Star #1 Hiller
8S-23E-4	16	Viking #1 Reuss
8S-23E-5	17	Texaco #1 Probst
8S-23E-5	18	Texaco #1 Cheatham
8S-23E-5	19	Coastal States #1 Legalley and Harwood
8S-23E-6	20	Whiffen #1 Legalley
8S-23E-8	21	Atlantic #1 Hartman
8S-23E-9	22	Humble #1 Goebel
8S-23E-9	23	Mitchell #1 Koenig
8S-23E-9	24	Zachry #1 Rath
8S-23E-9	25	Bright-Schiff #1 Brown
8S-23E-4	26	Hunt #1 Garza
8S-24E-2	1	Avalanche Journal #1 Boothe
8S-24E-3	2	Lone Star #1 Means
8S-24E-3	3	Lone Star #3 Friar
8S-24E-4	4	Humble #1 Pridgen
8S-24E-4	5	Shell #1 Blackwell
8S-24E-6	8	Shell #1 Collum
9S-18E-6	1	Occidental #1 Osterloh
9S-19E-6	2	Hunt Trust #1 Schuenemann
9S-19E-6	3	Texas Eastern #2 Voelkel (#1 Gas Unit)
9S-19E-6	4	Texas Eastern #1 Mugge
9S-19E-6	5	Standard of Texas #1 Mugge

DE WITT

Township
RangeWell No.Well Name

9S-19E-8	6	Lamar Hunt #1 Flenniken
9S-19E-8	7	Standard of Texas #1 Tipton
9S-19E-2	9	Union Texas #1 Musselman Bank unit
9S-19E-7	11	Stone #1 Waskow Unit
9S-20E-1	1	Harper-Smith #1 Gips
9S-20E-1	3	Southland #1 Gips
9S-20E-1	4	Haxwell #1 Gips
9S-20E-2	6	Magnolia #1 Kleberg
9S-20E-2	7	Hamon and Ehman #1 Kleberg
9S-20E-3	8	Dixel #1 Roeder
9S-20E-3	9	Union Texas #1 Warwas
9S-20E-5	10	Monsanto & Ada #1 Roberts
9S-20E-5	11	Tidewater #1 Korth
9S-20E-6	12	Harkins #1 Korth
9S-20E-6	13	Holmes #1 Mann
9S-20E-6	14	Mortimer #1 Butler (#1 Gas Unit)
9S-20E-7	15	McCulloch #1 Hurst
9S-20E-7	16	Monsanto #1 Estrella
9S-20E-7	17	Humble #1 Guaranty
9S-20E-7	18	McCulloch #1 Franke
9S-20E-7	19	Monsanto & Bridger #1 Green
9S-20E-7	20	Cox #1 Clark
9S-20E-8	21	Colorado #1 Clark
9S-20E-8	22	Monsanto #1 Hilgartner
9S-20E-8	23	Cox & Hewitt #1 Kleine
9S-20E-8	24	Coloma #1 Buesing
9S-20E-8	25	Hanson, Monsanto, & MacDonald #1 Waskow
9S-20E-8	26	Hanson & Cox #1 Buesing
9S-20E-8	27	Hanson, Cox and MacDonald #1 Altman
9S-20E-8	28	Hanson, Monsanto, Ada & MacDonald #1 Kolodzey
9S-20E-8	29	M.K. Oil (Hanson) #1 Dean Trust
9S-20E-8	30	Hanson, Cox, Monsanto, Ada & McDonald #1 Rav
9S-20E-8	31	Hanson, Cox & Monsanto #1 Matejek
9S-20E-9	32	Hanson #1 Schlosser
9S-20E-9	33	Brown #1 Leister
9S-21E-1	1	Austral #1 Schroeter
9S-21E-1	2	Argo #1 Schroeter
9S-21E-1	3	Harkins, Gulf, & Musselman #1 Duderstadt
9S-21E-1	4	Harkins, Musselman & Gulf #2 Duderstadt
9S-21E-2	9	Houston Nat. Gas #3 Boldt
9S-21E-2	10	Quintana #1 Jochen
9S-21E-2	11	Monsanto, et al. #1 Boldt
9S-21E-2	12	Commonwealth, Harkins, & Humble #1 Machost
9S-21E-3	15	Mobil #1 Berck
9S-21E-3	16	Harkins #1 Sauermilch

DE WITT

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
9S-21E-3	17	Musselman #1 Danysh, et al. Gas Unit
9S-21E-3	18	Brown #1 Henze Gas Unit
9S-21E-4	20	Amarillo #1 Gips
9S-21E-4	21	Lone Star & Musselman #1 Gips
9S-21E-4	22	Hanson #1 Gips Gas Unit
9S-21E-4	23	Lone Star #1 Gips
9S-21E-4	24	Lone Star #1 Felter
9S-21E-4	25	Monsanto and Hughes & Hughes #1 Norris
9S-21E-4	26	Greenbrier #1 Alves
9S-21E-4	27	Skelly #1 Menn
9S-21E-5	28	Monsanto #1 Witte
9S-21E-5	29	Monsanto #2 Houchins
9S-21E-5	31	Monsanto #1 Fromme
9S-21E-5	32	Monsanto #3 Kulawik
9S-21E-6	33	Brazos (Dow Chem.) #1 Sievers
9S-21E-8	34	Alcoa #1 Casper
9S-21E-9	35	Atlantic #1 Ladner
9S-21E-9	36	Lone Star #1 Gips
9S-21E-9	38	Atlantic #1 Kerlick
9S-21E-5	41	Monsanto #2 Kulawik
9S-21E-2/5	42	Texaco #2 Broughton
9S-21E-6	43	Pace #1 Coleman
9S-21E-4	44	Monsanto #1 Alves
9S-21E-3	45	Ada #1 Jendrzey
9S-22E-3	2	Kilroy of Texas #1 Mueller
9S-22E-3	3	LaGloria #1 Ferguson
9S-22E-3	4	Austral and Crown Central #1 Ferguson
9S-22E-5	5	Texaco #1 Angerstein
10S-17E-7	1	General Crude #1 Gruntwald
10S-18E-6	3	General Crude #1 Wessendorff
10S-18E-7	4	Atlantic #1 Pullin, et al.
10S-18E-5/8	5	Hunt #1 Huckman
10S-18E-9	8	General Crude #1 McDowell
10S-19E-1/2, 5/6	1	Cities Service #1-A Stanchos
10S-19E-2	2	Argo #1 Dittmer
10S-19E-2	3	Mobil #1 Speary
10S-19E-6	4	Cities Service #1 Janssen
10S-19E-7	5	National Exploration #1 Effenberger
10S-19E-9	6	Shell #1 Atkinson
10S-19E-9	7	Shell #1-R Atkinson
10S-19E-1/6	8	Cities Service #1-A Gaus
10S-19E-1	9	Kirk and Need #1 Mueller Est.
10S-19E-2	10	Mobil #1 Meyer
10S-19E-4	11	Cities Service #1 "B" Wood
10S-19E-8/9	13	Hunt #1 Zavesky

DE WITT

Township
Range

Well No.

Well Name

10S-20E-2	1	Atlantic #1 Skinner
10S-20E-3	2	Humble #1 Nordheim Gas Unit
10S-20E-3	3	Getty #13 Nordheim
10S-20E-3	4	Getty #11 Nordheim
10S-20E-6	5	Lone Star #1 Jank
10S-20E-3	6	Southland #1 Fuhrken
10S-20E-2/3	7	Cox #1 Riedel
10S-21E-2/3	2	Humble #1 Meyer
10S-21E-3	3	Humble #2 McMillan
10S-21E-3	5	Lone Star #1 Haynes Estate
10S-22E-9	3	Chevron #1 Jacobs
11S-19E-1	1	Samedan #1 Berckenhoff
11S-19E-1	4	Haring, Alcoa & Superior #1 Powell
11S-20E-6	2	Humble #1 Neese
11S-21E-1	4	Associated Oil & Halbouty #1 Von Dohlen
11S-22E-4	1	Shell #1 Friedrichs

COLORADO AREA

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
2S-31E-8	1	Mound #1 Newsome
2S-31E-8	2	Delhi-Taylor #1 Hillboldt
2S-31E-8	3	Shell #1 Hintz
2S-31E-8	4	Shell #2 Hillboldt
2S-31E-8	5	Shell #1 Cole
2S-31E-8	6	Mound #1 Hillboldt
2S-31E-9	7	Delhi-Taylor #1 Findeisen
2S-31E-9	9	Shell #1 Sealy Gas Unit
2S-31E-8	10	Mound #1 Konesheck
2S-31E-8	11	Ranger #3 Hintz Estate "A"
2S-31E-8	12	Ranger #1 Finke
2S-31E-8	14	Shell #5 Hillboldt
2S-31E-9	15	Scurlock #1 Kulow-Bielefeld Unit
3S-29E-4	2	Evans #1 Wilson
3S-29E-3	3	House and Amer. Republics #1 Tolbirt
3S-29E-2	4	Cummins and Walker #1 Nelson
3S-29E-6	5	Skelly #1 Stringer
3S-29E-2	6	Texas #1 Coddou
3S-29E-8	7	King Resources #1 Lyle
3S-29E-7	8	Prairie #1 Thomas
3S-29E-7	9	Cities Service #B-2 Stephens
3S-29E-7	10	Cities Service #1 Pode
3S-29E-7	11	Cities Service #A-2 Pode
3S-30E-1	1	Carthay #1 Ludwig
3S-30E-1	2	Boston #A-1 Frobelt
3S-30E-1	3	Alcoa and Boston #1 Amthor
3S-30E-2	4	Intercoastal #1 Krueger
3S-30E-2	5	Hanson and McCormick #1 Krueger
3S-30E-2	6	International Nuclear #1 Weishun
3S-30E-2	7	Union #1 Glueck
3S-30E-4	8	King Resources #1 Wintermann
3S-30E-4	9	Natural Resources #2 Wintermann
3S-30E-4	10	King Resources #1 Herder
3S-30E-7	12	Gray #1 Vineyard and Foster
3S-30E-9	13	National Resources #1 Birdwell
3S-30E-5	15	Newmont and Tidewater #1 Everett
3S-30E-5	16	Apexco #1 Meir
3S-30E-9	18	Cico #2-A Wintermann
3S-30E-9	19	Hanson #1 Wintermann
3S-31E-4	1	Gray #1 Bonnette
3S-31E-7	3	International Nuclear #1 Odom
3S-31E-8	5	Humble #1 Hillboldt
3S-31E-4	6	Hillard #1 Hillboldt
3S-31E-5	7	Sundance and Stuarco #3-A Best
3S-31E-5	8	Sundance, May, and Stuarco #2 Best
3S-31E-8	9	Texas #1 Kaechele
3S-31E-8	10	Humble #1 Kaechele
3S-32E-9	2	Southern #1 Unyrek

COLORADO

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well name</u>
4S-29E-3	1	Superior #D-1 Tait
4S-29E-3	2	Superior #D-2 Tait
4S-29E-4	3	Skelly #1 Johnson
4S-29E-8	4	Shell #1 Kyle Est.
4S-29E-5	5	Brazos #1 Struss
4S-29E-2	6	Tidewater #1 Brandon
4S-29E-2	7	Skelly #1 Walker
4S-29E-9	8	Bright and Schiff #1 Struss
4S-29E-8	9	Texas #1 Johnson
4S-29E-8	10	Texas #1 Bunge
4S-29E-1	11	Skelly #1 Wintermann
4S-29E-7	12	Rain and Buck#1 Duncan
4S-29E-3	14	British-American #1 Wells
4S-29E-2	15	Continental #1 Tait
4S-29E-3	16	Superior #1 Tait
4S-29E-3	17	Superior #1 Tait
4S-29E-4	18	Fidelity #1 Dodson
4S-29E-1	19	Dow #1 Lange
4S-29E-3	20	Superior "D" 3 Tait
4S-29E-4	21	Superior #1 Meyer
4S-29E-4	22	Parker Bros. #1 Parker Bros. Fee
4S-29E-9	23	Fidelity #1 Struss
4S-29E-2	24	Mosbacher #1 Tait
4S-30E-1	1	Shell #2 Hayes Stephens
4S-30E-1	2	Clark-Sherwood #1 Stephens Gas Unit
4S-30E-2	3	Union #1 Thomas
4S-30E-4	4	Brown #1 Wintermann
4S-30E-5	5	Tex-Star #1 Haley Trust
4S-30E-5	6	Mosbacher and Harkins #1 Foster
4S-30E-6	7	Shell #1 Martin
4S-30E-6	8	Fidelity #1 Hoyo
4S-30E-7	9	Midwest #1 Haley
4S-e0E-8	14	Mosbacher #1 Duncan
4S-30E-8	15	Starr #1 Wintermann
4S-30E-8	16	Frio #1 Waddell
4S-30E-9	17	Fidelity #1 Duncan
4S-30E-9	18	Cherry #1 Wintermann Est.
4S-30E-8	19	Sun #1 Duncan
4S-30E-3	20	Mutex #3-B Wintermann
4S-30E-3	21	Chicago Co. and Skelly Oil #1 Dennis
4S-30E-5	22	Flaitz #1 Hoyo
4S-30E-7	23	Clover and Hanover #1 Harrison
4S-30E-8	24	Scurlock #1 Duncan-Wintermann Unit
4S-30E-6	25	Barnwell #1 Colorado
4S-30E-6	26	Fidelity #1 Bridge
4S-31E-4	1	Crosby #1 Poole
4S-31E-7	2	Getty #1 Leveridge
4S-31E-9	3	Newmont #1 Poole
4S-31E-4	4	Humble #1 Thomas
4S-31E-9	5	Magnolia #1 Poole
4S-31E-4	6	Humble #1 Isenhowe

COLORADO

<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
5S-29E-1	1	Socony-Mobil #5 Gracey
5S-29E-3	2	Halbouty #1 Lehrer
5S-29E-1	3	Shell #1 Thompson
5S-29E-2	4	Shell #1 Hudson
5S-29E-3	6	Mosbacher, Superior and National #1 Zinn Lehrer
5S-30E-1	1	General Crude #1 Wintermann
5S-30E-1	2	General Crude #3 Wintermann
5S-30E-3	3	Brazos #1 Matthews
5S-30E-3	4	Magnolia #1 Gracey-Wegenhoff

HARRIS AREA

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
5N-38E-5	1	Cities Service #B-1 Browder
5N-38E-7	2	Texas City #1 Elmore
5N-38E-8	3	Dominion #2 Elmore, et al.
5N-38E-8	4	Dominion #1 Elmore
5N-38E-8	5	Houston #1 Lewis Unit
5N-38E-8	6	Cities Service #1 Ellisor
5N-38E-8	7	Triton #1 Roche-Ellisor
5N-38E-8	8	Barnes #1 Johnson
5N-38E-8	9	Cities Service #1 Melvin Unit
5N-38E-8	10	Cities Service # 1 Browder
5N-39E-3	1	Glen Rose #1 Cary Heirs
5N-39E-7	3	Standard of Texas #1 Foster
5N-39E-7/8	4	Shell #1 Coline
5N-39E-8	6	Reserve #2 Richards
5N-40E-6	1	Sun #1 McGowan Unit 1
5N-40E-6	2	Viking & De Lange #1 Langham Gas Unit
5N-41E-4	1	Amoco #A-3 Langham
5N-41E-4	3	Pan American #B-2 Langham
5N-41E-4	5	Stanolind #B-1 Langham
5N-41E-4	6	Stanolind #C-1 Langham
5N-42E-9	2	Sunray #1 Bell
4N-35E-7	1	Capital #1 Alliance Trust
4N-36E-6	1	Superior & Speed #1 Elam
4N-36E-6	2	Super & Speed #1 Sykes
4N-36E-6	3	Moran #1 Sykes
4N-36E-9	4	Cities Service #1 Madeley
4N-36E-6	5	Sunset International #1 Shaver
4N-37E-6	1	Oil Reserves #1 Foster Est.
4N-37E-7	2	Moran #3-A Hutchins-Sealy Nat. Bk.
4N-37E-7	3	Moran #3 Hutchins-Sealy Nat. Bk.
4N-37E-7	4	Moran #2-A Hutchins-Sealy Nat. Bk.
4N-37E-8	5	Texmo #1 Hutchins-Sealy Nat. Bk.
4N-37E-8	6	Texmo-Brown #1 Gas Unit #2
4N-37E-8	7	Kirby (McKay & Donkin, et al.) #1 Rawson
4N-37E-7	8	Glen Rosè #1 Champion
4N-37E-7	9	Moran #1-B Hutchins-Sealy Nat. Bk.
4N-38E-1	1	Continental #1 Gibbs
4N-38E-1	2	Continental #2 Gibbs
4N-38E-1	3	Huber Co. #1 Gibbs
4N-38E-1	4	Texas City #1 Foster Est.
4N-38E-2	5	Cities Service #1 Frazer & Campbell
4N-38E-2	6	Dominion #1 Campbell
4N-38E-3	7	Continental #1 Frazier
4N-38E-4	8	Donkin & Smith #1 Browder

HARRIS

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
4N-38E-4	9	Moran #1 Browder
4N-39E-3	1	Prairie & Convest #1 Gibbs, et al.
4N-39E-3	2	Impact #1 Mays
4N-39E-4	3	Continental #1 Mays, et al.
4N-39E-7	5	Amerada & Mid-States #1 Central Coal & Coke
4N-39E-7	6	Russell & Moran # 1 Central Coal & Coke
4N-39E-8	7	Shell #11 Central Coal & Coke
4N-39E-8	8	Superior #1 Foster
4N-39E-8	9	Manning #1 Central Coal & Coke
4N-39E-9	10	Fain #1 Baldwin
4N-40E-1	1	Texas Gas Exploration #1 Ogletree
4N-40E-1	2	Magnolia #2 Dixon-Falvey
4N-40E-4	3	Magnolia #1 Hinchliff-Simms
4N-40E-8	4	Magnolia & Ambercrombie #1 Brewer
4N-40E-8	5	Davis #1 Sims
4N-41E-9	1	Oil Reserves #1 Jefferson
4N-41E-1	2	Continental & Speed #1 Frost
4N-41E-6	3	Pan American #1 Moore Est.
3N-33E-8	1	Gulf #2 Gardner
3N-33E-8	2	Millican #1 Gardner
3N-33E-8	3	Gulf #1 Gardner
3N-33E-8	4	Atlantic #1 Sanders
3N-33E-8	5	Millican #1 Baner
3N-34E-7	1	Colorado #1 Rice University
3N-34E-7	2	Gallery #1 Thompson
3N-34E-8	3	McCarthy #1 Gibbs-Elgin, et al.
3N-34E-8	4	Standard of Texas #2 Sanders, et al.
3N-36E-1	1	Feldman #1 Teas
3N-36E-4	2	Socony-Mobil #1 Sealy-Smith Fd.
3N-36E-7	3	Prairie & Convest #1 Madeley, et al.
3N-36E-7	4	Delhi-Taylor #2 Sealy-Smith Fd.
3N-36E-7/8	5	Delhi-Taylor #1 Sealy-Smith Fd.
3N-36E-8	6	McCulloch & Venus #1 Frost
3N-36E-8	7	Prairie #1 Frost, et al.
3N-36E-8	8	Superior #3 Frost
3N-36E-8	9	Superior #1 Frost
3N-36E-8/9	10	Mecam #1 Bertrand
3N-36E-9	11	Stanolind #1 William
3N-36E-9	12	Sinclair #1 Grogan
3N-36E-9	13	Mitchell #1 Asche, et al.
3N-37E-4	1	Moran #1 Cartwright
3N-37E-5	2	Hagen & Litchfield #1 Harris & Freeman

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Township
RangeWell No.Well Name

3N-37E-8	3	Skelly #1 Tipton
3N-37E-8	4	Humble #1 Grande Lake Gas Unit #2
3N-37E-9	5	Humble #1 Grande Lake Gas Unit #1
3N-37E-9	6	Humble #2 Grande Lake Gas Unit #1
3N-37E-9	7	Humble #1 Council
3N-38E-1	1	Cazoline Hunt Sands #1 San Jacinto Trust
3N-38E-5	2	Texaco #1 Griffin
3N-39E-1	1	Atlantic #1 White
3N-39E-1	2	Trice #1 Foster
3N-39E-2	3	Cauble #1 Combe Heirs
3N-39E-2	4	Gulf #1-A Foster
3N-39E-5	5	Rowan #1 Dunnam
3N-39E-5	6	Atlantic #1 Foster
3N-39E-5	7	Halbouty #1 Foster-Gulf
3N-39E-8	8	Pure Oil #1 Foster
3N-39E-5	9	Halbouty #1-B Foster
3N-39E-5	10	Habouty #2 Foster
3N-39E-5	11	Halbouty #1-A Foster
3N-39E-8	12	Union & Halbouty #E-1 Foster
3N-39E-6	13	Amerada #1 Foster
3N-39E-6	14	Halbouty #1 Godejohn
3N-39E-6	15	Amerada #1 Godejohn
3N-39E-6	16	Halbouty #1 Burkett
3N-39E-7	17	Halbouty #1 Leggett
3N-39E-8	18	Halbouty #1 Southland Paper
3N-39E-5	19	Sohio & Leben #1 Kingswood, et al.
3N-39E-6	20	Sanchez-O'Brien #1 Friendswood
3N-39E-6	21	Sanchez-O'Brien #1 Friendswood
3N-39E-7	22	Halbouty #1 Todd
3N-40E-1	1	Sun #1 Quinn
3N-40E-1	2	Karsten #5-A Quinn
3N-40E-1	3	Houston Mineral #1 Ott Gas Unit
3N-40E-1	4	Pan American #1 Howard
3N-40E-1	5	Ohio #1 Quinn
3N-40E-1	6	Pan American #A-1 Kirby
3N-40E-2	7	Sundance #1 Davis
3N-40E-3	8	Mitchell #1 Cherry
3N-40E-8	9	Superior #1 Bosworth
3N-40E-8	10	Hunt #1 Grogan
3N-40E-9	11	Superior #1 Hightower
3N-40E-9	12	Superior #1 Hightower
3N-40E-9	13	Humble #1 McDonald
3N-41E-3	1	Humble #1 Smith
3N-41E-3	2	Cherryville #1 Jackson
3N-41E-3	3	Brazos #1 Ballard
3N-41E-4	4	Porter & Phillips #1 Champion
2N-32E-5	1	Continental Thomas & Scardino
2N-32E-6	2	Harrison #1 Gaines

HARRIS

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
2N-32E-7	3	Sinclair #1 McDade
2N-33E-4	1	Brazos #1 Sledge
2N-33E-4	2	Sun #1 Von Blucher
2N-33E-4	3	Mana #1 Smith
2N-33E-2	4	Brazos #1-A Connell
2N-33E-2	5	Sun-Indiola #1 Connell
2N-34E-3	1	Strake #1 Humphries
2N-34E-3	2	Speed #1 Sauerbrunn, et al.,
2N-34E-3	3	Texas #1 Humphries
2N-34E-4	4	Associate, et al. #1-A Rice University
2N-34E-4	5	Texas #1 Rice University
2N-34E-5/6	6	Superior #1 Brown
2N-34E-5/6	7	McCarthy #1 Tucker
2N-34E-7	8	Enterprises #1 Welch Foundation
2N-34E-7	9	Ashland #1 Welch Foundation
2N-35E-2	5	Gray Wolfe #4 Pan Am
2N-35E-2	6	Gray Wolfe #3 Pan Am
2N-35E-2	7	Pan Am #1 Posey
2N-35E-2	8	La Gloria #2 Cochran
2N-35E-3	9	Hawkins & Hawkins #1 Von Streety
2N-35E-3	10	Christie, Mitchell, & Mitchell #1 Von Streety
2N-35E-3	11	Standard of Texas #1 Dean, et al.
2N-35E-4	12	Humble #1 Lewis, et al.
2N-35E-4	14	Superior #1 Kramer
2N-35E-4	15	Gose #1 Kramer
2N-34E-4	16	Mitchell #1 Hagen
2N-35E-5	17	Superior Oil #3-A Dean
2N-35E-5	18	Superior #A-1 Dean
2N-35E-4	19	Gray Wolfe #6 Pinehurst
2N-35E-5	20	Superior #2-A Dean
2N-35E-5	21	Gray Wolfe #3 Pinehurst
2N-35E-5	22	Gray Wolfe #4 Pinehurst
2N-35E-8	23	Commercial #1 Pills & Leyle
2N-35E-9	24	Pan Am #1 Welch Foundation
2N-35E-1	26	Superior #A-5 McWhorter
2N-35E-1	27	Superior #2-C McWhorter
2N-35E-1	31	Superior #1-C McWhorter
2N-35E-1	32	Superior #1-D McWhorter
2N-35E-1	34	Superior #4-A McWhorter
2N-35E-1	36	Progress #1 Winslow
2N-36E-1	1	Superior #1 McMahon
2N-36E-1	2	Texaco #1 Winslow

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<u>Township Range</u>	<u>Well No.</u>	<u>Well Name</u>
2N-36E-2	3	International Nuclear & Prairie #1 M & M
2N-36E-2	4	Stanolind # 1 McMahon
2N-36E-2	5	Royal # M & M
2N-36E-2	6	Magnolia #1 Chase National Bank
2N-36E-3	7	Superior #A-7 McWhorter
2N-36E-3	8	Stanolind #A-1 South Texas
2N-36E-3	9	Superior #1 Brown
2N-36E-3	10	Superior #30 Lake Creek
2N-36E-3	11	Superior #1 South Texas
2N-36E-3	12	Superior #1 M & M
2N-36E-3	13	Del Mar #1 South Texas
2N-36E-5	14	Moran #1 M & M
2N-36E-6	15	Superior #1 Foley
2N-36E-6	16	Sohio, Mesa & Southern #1 1936 Development
2N-36E-7	17	Shell #1 Peden
2N-36E-8	18	Shell #1 Holderreith
2N-36E-2	19	Vaquero #B-1 M & M
2N-36E-3	20	Superior #3 South Texas
2N-36E-3	21	Superior #2 South Texas
2N-37E-4	1	Sinclair #1 Grogan-Cockran
2N-37E-4	2	Sinclair #1 Porter
2N-37E-7	3	Texaco #1 Bender
2N-37E-9	4	Shenandoah #1 Evans
2N-37E-9	6	McDaniel #1 Baldwin
2N-38E-1	1	Atlantic #1 South Texas
2N-38E-5	3	Standard of Texas #1 Anderson, et al.
2N-38E-7	4	Winwell #1 Schwing
2N-38E-7	5	Lacal #1 Schwing
2N-38E-7	6	Humble #1 Wickizer
2N-38E-2	8	Humble #1 Hines
2N-38E-2	9	Goodale Bertman #1 Maynard
2N-39E-1	1	Samedan #1 Coleman
2N-39E-2	3	Humble #B-1 Long Leaf
2/3N-39E-2/8	4	Kurth Trustee #4 Southland Paper
2N-39E-4	5	Humble #1 Ovalline
2N-39E-4	6	Sinclair #1 Foster
2N-39E-5	7	Humble #1 Patton
2N-39E-6	8	Union #1 Foster
2N-39E-6	9	Atlantic #1 Foster
2N-40E-2	1	Humble #B-1 Quinn
2N-40E-2	2	Sun #2 Quinn
2N-40E-2	3	Sundance #1 Quinn
2N-40E-2	4	Sun #1 Quinn
2N-40E-2	5	Gulf #C-1 Quinn
2N-40E-2	6	Allday & Hammax #1 Quinn
2N-40E-5	7	Sun #1 Friendswood

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<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
1N-30E-5	1	Holmes & Mosbacher #1 Wright
1N-31E-1	1	Karsten #1 Menke
1N-31E-9	2	Skelly #1 Sander
1N-33E-1	1	Sinclair #1 Krezdorn
1N-35E-8	1	Texaco #1 Mergele
1N-37E-1/2	1	Humble #1 Bender
1N-37E-2/3	2	Humble #1 Baldwin
1N-37E-8	4	Houston Nat. Gas #1 Tanneberger
1N-38E-3	1	Mobile #1 Bender Est.
1N-38E-3	2	Continental #1 Bender Est.
1N-38E-3	3	Texaco #1 Bender
1S-32E-3	1	Humble #17-B Hardy "B"
1S-33E-6	1	Humble #1 Sparks
1S-33E-8	2	Halbouty #1 Harris, et al.
1S-33E-7	3	Exxon HW-46 K.G.F.U. #2
1S-33E-8	4	Pet-Tex #1 Harris
1S-35E-4	1	Standard of Texas #1-1 Logenbaugh
1S-35E-4	2	Standard of Texas #1 Josey, et al.
1S-35E-4	3	Scurlock #1 Josey
1S-35E-5	4	Texaco #1 Sweeney Est.
1S-35E-8	7	Standard of Texas #1 Millinger, et al. #4
1S-35E-2	9	Roeser & Pendleton #1 Townes
1S-36E-8	1	Pan American #1 Brown
1S-37E-1	1	Meredith, et al. #1 Ross, et al.
1S-37E-2	2	Ginther, Warren #1 Taub-Dwyer-McCall Unit #1
1S-37E-2	3	Sunset #1 Hamill
1S-37E-3	4	Houston Nat. Gas #1 Hamill Gas Unit #1
1S-37E-3	5	Texaco #1 Sweeney Gas Unit #1
1S-37E-1	6	Texaco #1 Sharman Gas Unit #1
1S-37E-4	7	Texaco #1 Rodgers
1S-37E-3	8	Houston Nat. Gas #1 Hamill Gas Unit #1
1S-37E-3	9	Houston Nat. Gas #1 Hamill Gas Unit #3
2S-33E-1	1	Exxon #W-45 K.G.F.U.
2S-33E-5	2	Houston Nat. Gas & Halbouty #1 Ainsworth
2S-33E-6	3	Stanolind #1 Freeman (#8 K.G.F.U. Unit 1)
2S-33E-6	4	Humble #W-31 K.G.F.U.
2S-33E-6	5	Humble #W-32 K.G.F.U.
2S-33E-6	6	Exxon #W-44 K.G.F.U.
2S-33E-6	7	Exxon #W-38 K.G.F.U.
2S-33E-6	8	Humble #W-34 K.G.F.U.
2S-33E-6	9	Exxon #W-41 K.G.F.U.
2S-33E-6	10	Humble #33 K.G.F.U. #1
2S-34E-8	1	Scurlock #1 Arnold
2S-34E-9	2	Scurlock #1 McMillian
2S-34E-4	3	Exxon #W-43 K.G.F.U.
2S-34E-4	4	Exxon #W-35 K.G.F.U.
2S-34E-4	5	Exxon #W-42 K.G.F.U.
2S-34E-9	6	Exxon #W-36 K.G.F.U.
2S-35E-8		Conroe #1 Addicks
3S-33E-3	1	Mound #1 England, et al.
3S-34E-2	1	Scurlock #1 Meek
3S-34E-9	2	Ensearch #1 Foster Farms
3S-34E-9	3	Mobil #1 Foster Farms

ZAPATA FAIRWAY

<u>Township</u> <u>Range</u>	<u>Well No.</u>	<u>Well Name</u>
23S-8E-5	1	Belco #1 Frost Bank
23S-8E-2	2	Killam and Hurd #1 Fulbright, et al.
23S-8E-6	4	Atlantic #1 Lopez
23S-8E-7	5	Union #1 Cuellar
23S-8E-9	6	Hughes and Hughes & Pennzoil #1 Martinez
23S-8E-6	7	Hughes and Hughes #1 Fulbright
23S-8E-5	8	Hughes and Hughes #A-1 Uribe Est.
23S-8E-1	9	Killam and Hurd #1-16 Killam Fee
23S-8E-8	10	Hughes and Hughes #1-B Cuellar Est.
23S-8E-1	11	Killam and Hurd #1 Uribe
23S-8E-1	12	Atlantic #1 Hinnant
23S-9E-1	1	Atlantic Richfield #4-C Marrs McLean
23S-9E-1	2	Atlantic Richfield #2-C McLean
23S-9E-1	4	Standard #2 Holbein
23S-9E-2	5	Hamon #2 Holbein
23S-9E-3	6	Atlantic #1-B Hinnant
23S-9E-1	7	Atlantic Richfield #2-C McLean Trust
24S-7E-1	1	Blanco #1 Jennings
24S-8E-7	1	Halbouty and Jonnel #1 Garza
24S-8E-7	2	Lively and Fountain #1 Trevino, et al.
24S-8E-7	3	Halbouty #1 Trevino
24S-8E-7	4	Halbouty and Jonnel #D-1 Garza
24S-8E-6	5	Gulf #1 Trevino
24S-9E-1	1	Standard #1 Frost
24S-9E-3	2	Gulf #1 Vela
24S-9E-3	3	Union #18 Jennings
24S-9E-3	4	Gulf #1 Garza
24S-9E-8/9	5	Standard #1 Blanco
25S-7E-2	1	Gulf #1 Flores
25S-7E-3	2	Gulf #1 Ramirez
25S-7E-6	3	General Crude (Gulf) #1 Romero
25S-7E-3	4	Killam and Hurd-Ryan, et al. #1 Flores Heirs
25S-7E-6	5	Samedan #1 Matles
25S-7E-4	6	Coastal States #1 Flores
25S-7E-6	7	Rutter, Wilbanks, & Rutter #1 Volpe
25S-7E-8	9	Gulf #1 Pena
25S-7E-8	10	Alaska Steamship, Texita, and Gil #1 Cuellar
25S-7E-8	11	Osage #1 Uribe
25S-7E-8	12	MacDonald #1 Uribe
25S-7E-8	14	Rio Grande Valley #1 Dodier
25S-7E-8	15	Miller and Fox #1 Dodier
25S-7E-8	16	Coastal States #4 Dodier
25S-7E-5	17	KRM #1 Volpe
25S-7E-5	18	McAll #3 Singer
25S-7E-5	19	McDaniel #1 Singer
25S-7E-5	20	Bateman #1 Gutierrez

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Township
RangeWell No.Well Name

25S-7E-5	21	Miles #1 Ramirez
25S-7E-5	22	McAll #1 Gutierrez
25S-7E-5	23	Rowe #1 Flores
25S-7E-9	24	Alaska Steamship #1 Vasquez
25S-7E-9	25	Solo #1N. Singer
25S-7E-9	26	Solo #1 I. M. Singer
25S-8E-1	1	Halbouty #1-E Garza
25S-8E-1	2	Blanco and Dougherty #1 Benavides
25S-8E-4/5	4	Pennzoil #4 Haynes
25S-8E-4/5	5	Pennzoil & Patrick #2 Haynes Est.
25S-8E-5	6	Pennzoil #1 Haynes
25S-8E-5	8	Humble #1 Haynes Est.
25S-8E-6	9	Gulf #1 Security Nat. Bank of L.A., Calif.
25S-8E-7	10	Gulf #1 Trevino
25S-8E-8	11	Crescent #1 Haynes
25S-8E-9	12	Pennzoil #1 Vela
25S-8E-9	13	Gulf #1 Volpe
25S-8E-8	15	Bright & Schiff #1 Vela
25S-8E-8	16	Pennzoil #1 Vela
25S-9E-9	2	Hamon #1 Campbell
26S-7E-8	1	Texas #1-M Guerra
26S-7E-8	2	Stanolind #1 Serafic Nela
26S-7E-8	3	Texas #1 Guerra
26S-7E-8	4	Hamon #1 Alexander
26S-8E-1/6	1	Suburban #1 Sanchez
26S-8E-2	5	Katz #1 Vela
26S-8E-3	6	Standard of Texas #1 Garcia
26S-8E-5	8	Traman #1 Garcia
26S-8E-5	9	Crescent, et al. #1 Morales
26S-8E-5	10	Tenneco #1 Garcia
26S-8E-8	11	Crescent #1Foss
26S-8E-8	12	Gulf #1 Benavides
26S-8E-8	13	Crescent #2 Benavides
26S-8E-8	14	Jonnell #3 Benavides
26S-8E-9	15	Frankfort #1 Benavides
26S-8E-8	17	Clinton #1 Benavides
26S-8E-5	18	Irahan #1 Whittier
26S-8E-5	19	Crescent #1 Vela
26S-8E-8	20	Jonnell #1 Zamora
27S-7E-7	1	Standard of Texas #1 Ramirez
27S-7E-1	2	Fullerton #1 Vela
27S-7E-3	4	National #1 Barberio
27S-8E-3	1	Hudson #1 Zamora
27S-8E-3	2	Frankfort #1 Sanchez
27S-8E-3	3	Frankfort #1 Garcia
27S-8E-3	4	Jonnell #1 Lopez Heirs
27S-8E-4	6	Gosden #1 Ramirez
27S-8E-8	7	Union #1 McDermit
27S-8E-9	8	Jonnell #1 Yzaguirre
27S-8E-9	9	Jonnell #1 Ranos

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Township
Range

Well No.

Well Name

27S-8E-9	10	Jonnell #1-A Guerra
27S-8E-9	11	Jonnell #2 Ranos
27S-8E-4	13	Ashland #1 Munoz
27S-8E-9	14	Standard of Texas #2 Ramirez
27S-8E-4	17	Katz #1 Ramirez
27S-8E-4	18	Jonnell & Sohio #2 Ramirez
27S-8E-4	19	Delhi #2 Ramirez
27S-8E-9	20	Jonnell #2 M. Ramirez
27S-8E-9	21	Jonnell #2 B. Ramirez
27S-8E-9	22	Jonnell #1 Guerra
27S-8E-2	24	Frankfort #2 Sanchez
27S-9E-4	1	Sun #1 Guerra Gas Unit
28S-7E-1	1	Hamon & Colorado #1 Guerra
28S-7E-1	2	Hamon #1 Yzaguirre
28S-7E-1	3	Hamon #1-A Ramirez
28S-8E-1/2	2	Humble #1 Humble-Martinez
28S-9E-4	1	Austral #1 Sanchez