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Geopressured Geothermal Resource in Texas and Louisiana -- Geological Constraints

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ABSTRACT

Geopressured geothermal aquifers of the Texas and Louisiana Gulf Coast must comprise thick, extensive sandstone units with high temperature, high porosity and permeability, and low salinity. Geological studies have demonstrated that sandstones decrease in abundance and thickness with depth; however, exceptions do occur and some are now being drilled and tested. Porosity and permeability also decrease with depth, but variations in composition, burial history, and diagenesis result in variations in preserved porosity. Salinity within the geopressured zone is highly variable and probably related to aquifer porosity and permeability, thickness, and lateral extent and to the nature of the bounding growth faults.

Locating ideal aquifers for testing the geopressured geothermal resource requires a thorough knowledge of the regional geology in order to identify prospects which meet the maximum number of requirements. It is doubtful that any prospect will meet all requirements of the ideal model.

INTRODUCTION

The success of the U.S. Department of Energy-sponsored project to produce thermal energy and methane from aquifers in the geopressured zone of the Texas and Louisiana Gulf Coast (fig.1) is dependent upon identifying thick sandstone reservoirs with large areal extent, high temperature, high porosity and permeability, and low salinity. Regional and detailed geological and engineering studies at the Bureau of Economic Geology, University of Texas at Austin, and Louisiana State University/Louisiana Geological Survey have indicated that reservoirs containing the optimum conditions in all catagories are not common or perhaps do not exist.

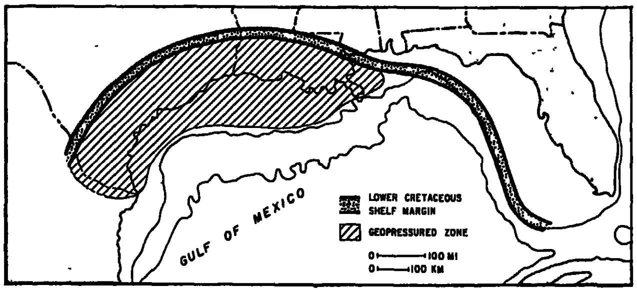
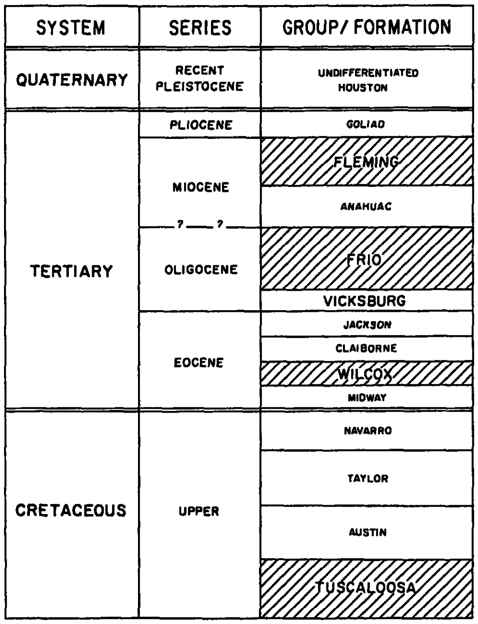


Figure 1. Geopressured zone along the Texas and Louisiana Gulf Coast.

The location of major sandstone accumulations in the various Tertiary formations (fig.2) is dependent upon the climate and the location of major river systems which were responsible for delivering the sand and mud to the ancient coastline to be deposited in river deltas or barrier-bar systems. Through geologic time, these river systems, as well as the sites of accumulations, shifted. The first sediments to be deposited Gulfward of the older, buried Lower Cretaceous margin (fig.1) became the oldest growth-faulted and geopressured sandstones and shales in that area. The stability of the Lower Cretaceous carbonate shelf landward of the shelf edge prevented growth faulting there. In Texas, the oldest known geopressured section consists of Tertiary Wilcox sandstones and



SYSTEM	SERIES	GROUP/ FORMATION
QUATERNARY	RECENT PLEISTOCENE	UNDIFFERENTIATED HOUSTON
TERTIARY	PLIOCENE	GOLIAD
	MIOCENE	▨ FLEMING
	?——?	ANAHUAC
	OLIGOCENE	▨ FRIO
		VICKSBURG
	EOCENE	JACKSON
		CLAIBORNE
		▨ WILCOX
		MIDWAY
CRETACEOUS	UPPER	NAVARRO
		TAYLOR
		AUSTIN
		▨ TUSCALOOSA

Figure 2. Upper Cretaceous and Tertiary formations of the northern Gulf Coast. Formations with the hatchured symbol occur in the geopressured zone.

shales; in Louisiana, the Upper Cretaceous Tuscaloosa section is geopressured Gulfward of the Lower Cretaceous shelf edge. Here, prograding deltaic and shoreline sands and shales were deposited on soft, unstable basinal mud (fig.3) and growth faulting was initiated. The formations to reach this position onshore are the Tuscaloosa, Wilcox, Vicksburg/Frio, and Fleming (fig.2).

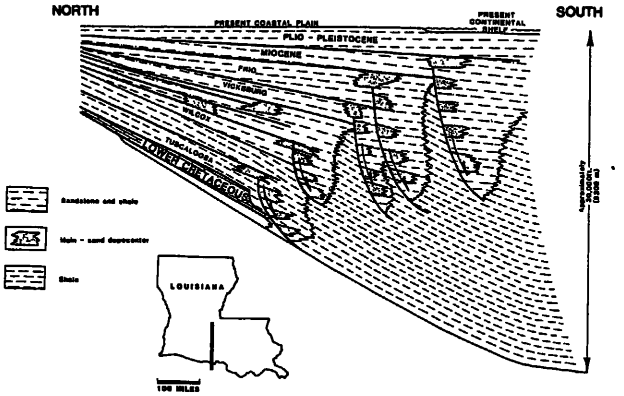


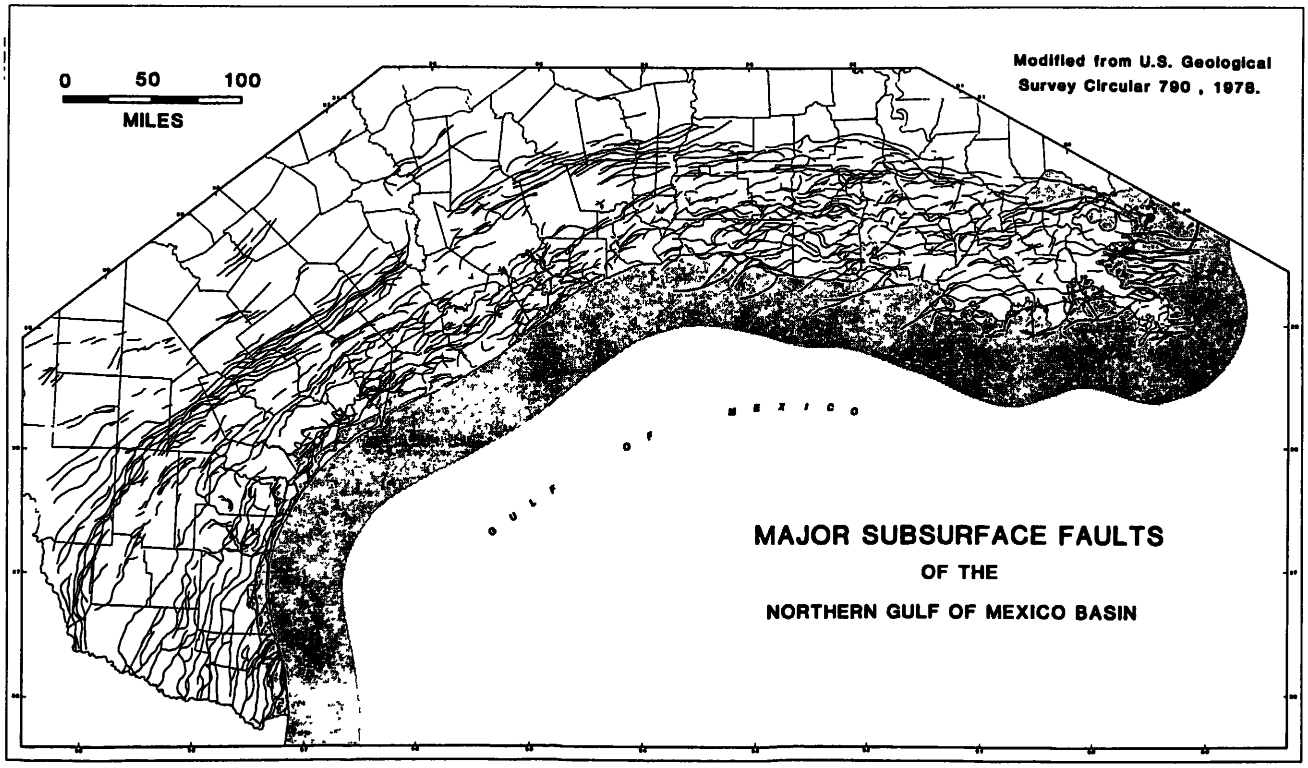
Figure 3. Diagrammatic cross section across the geopressured zone of south Louisiana.

LATERAL EXTENT OF GEOPRESSURED SANDSTONES

The initial constraint on reservoir size is imposed by the various depositional models as understood from the study of modern areas. Superimposed upon the depositional models are the numerous contemporaneous faults (growth faults) which should be assumed to be barriers to fluid flow. The major growth-fault systems in the Gulf Coast (fig.4) are complex and result in the subdivision of sandstone-prone areas into units averaging 30 to 50 square miles in area. Detailed study in smaller areas invariably results in the location of many additional faults and further reduction in the size of the area of lateral continuity (Bebout et al., 1979; McCulloh and Pino, 1981; Snyder, 1981; and Flournoy and Ferrell, 1980). There may be fluid flow if sandstones not genetically related are juxtaposed across a fault.

SANDSTONE RESERVOIR THICKNESS

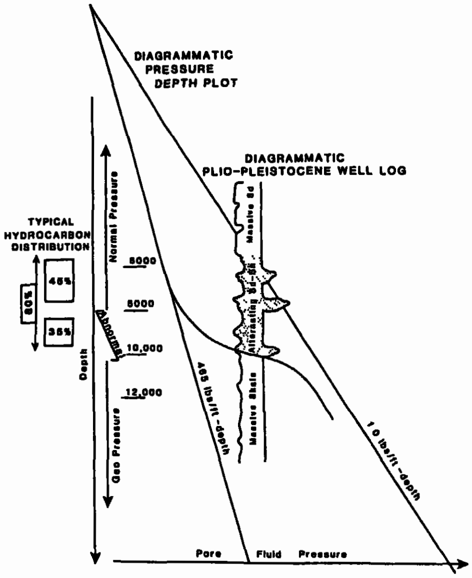
In general, sandstone units become thinner and less abundant with depth. Norwood and Holland (1974) illustrate the general changes in sandstone thickness and occurrence for the offshore Pleistocene (fig.5). Norwood and Holland show thick sandstones in the hydropressured zone, interbedded sandstone and shale in the transition zone, and thick shale and thin sandstones in the geopressured zone.



Modified from U.S. Geological Survey Circular 790 , 1978.

Figure 4. Major subsurface faults along the Texas and Louisiana Gulf Coast.

Exceptions to this overall trend occur with variations in sediment supply, climate, and subsidence rates during specific geologic times, resulting in differences in the amount of progradation of sand units into the Gulf. Therefore, thick sandstone units deep in the geopressured zone in Louisiana are not at all rare, but it is important to emphasize that thick geopressured sandstones are the exception to the regional geological model and do not occur everywhere.



Norwood and Holland 1974

Figure 5. Relationship of sandstone thickness and geopressure in the Pleistocene of offshore Louisiana.

TEMPERATURE

Plots of bottom-hole temperature recorded on well logs provide ample data to permit the prediction of subsurface temperature at any depth in Texas and Louisiana. For example, in Louisiana the 200°F isotherm occurs near the top of geopressure and generally ranges in depth from -10,000 to -12,000 feet. However, the 200°F isotherm occurs as shallow as -8,000 feet in the Frio and Wilcox Formations. The 300°F isotherm occurs between -13,000 and -18,000 feet.

The geothermal gradient in the geopressured zone of the Miocene and Frio decreases from greater than 2.5°F/100 feet along the Lower Texas Gulf Coast, to 1.8 to 2.1°F/100 feet along the Upper Texas Gulf Coast and west Louisiana, to 1.2 to 1.3°F/100 feet in east Louisiana; consequently, the 300°F isotherm occurs at -13,000 to -15,000 feet in Texas and west Louisiana but at -15,000 to -18,000 feet in east Louisiana.

POROSITY-PERMEABILITY

Porosity decreases with depth uniformly and, in general, predictably. Loucks, Dodge, and Galloway (1979) showed this trend very clearly in the lower Tertiary by using a large number of diamond-core analyses from the Texas Gulf Coast (fig.6). A similar trend is displayed from Louisiana using diamond-core analyses from Core Laboratories data (fig.7). However, it is important to note that there are wide variations in porosity at any depth.

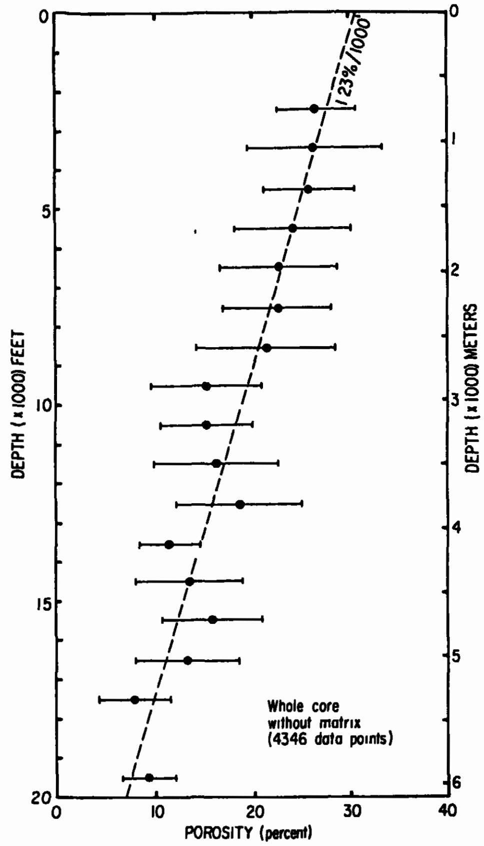


Figure 6. Relationship of porosity and depth from whole-core analyses from lower Tertiary formations along the Texas Gulf Coast. From Loucks, Dodge, and Galloway, 1979.

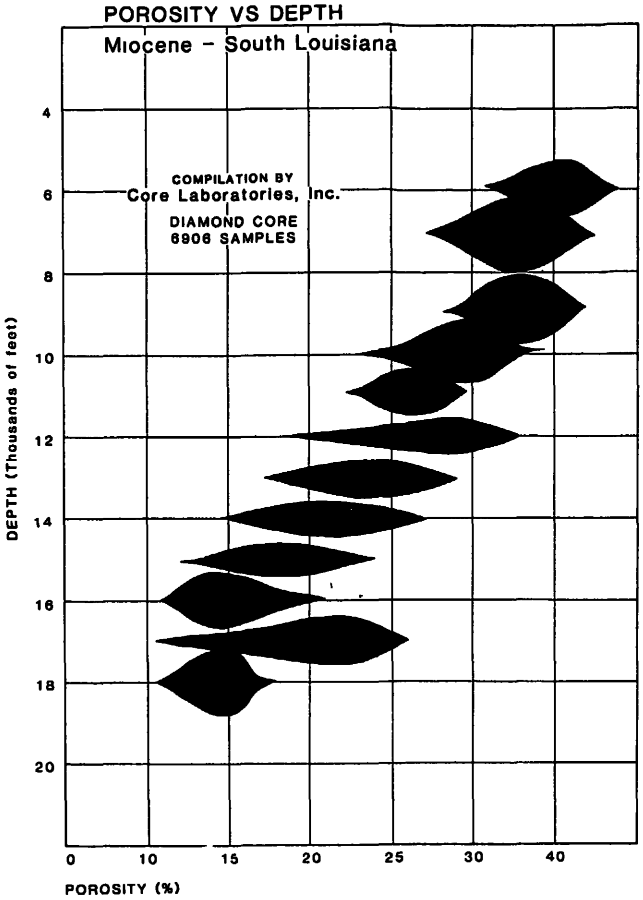


Figure 7. Relationship of porosity and depth from whole-core analyses from the Oligocene and Miocene formations along the Louisiana Gulf Coast.

SALINITY

In general, salinity increases with depth and is highest in the hydropressured zone just above the geopressured zone. Here in the hydropressured zone, salinity is generally 100,000 ppm. or greater. In the geopressured zone, the salinities are highly variable and range from more than 100,000 ppm. to less than 20,000 ppm. Controls on the formation fluid salinity are poorly known, but reservoir porosity and permeability, aquifer size, nature and spacing of bounding growth faults, and fluid movement along the faults and out of overlying and underlying shale units during burial are probably important.

CONCLUSIONS

In spite of the large amount of data available from oil and gas wells, the nature of the aquifers in the geopressured zone is poorly understood. It is now necessary to test aquifers which have widely varying reservoir parameters in order to identify the most efficient reservoir type within practical limits. The DOE Well-of-Opportunity and Designed Test-Well Programs have been ongoing for several years with the objective of testing a variety of reservoir situations in the geopressured zone of Texas and Louisiana. For example, in the Designed Test-Well Program, the Austin Bayou and Sweet Lake Prospects have thin sandstones with wide lateral distribution and fluids with high salinity; the Parcperdue Prospect is specially designed to investigate the drawdown characteristics of a thin and areally limited sandstone reservoir; the Rockefeller Refuge Prospect has an extremely thick sandstone possibly with limited areal extent and high-salinity fluids; and the LaFourche Prospect will encounter thin sandstones in a complexely faulted area with low-salinity fluids. Geological studies continue in Texas and Louisiana to identify additional favorable test-well sites.

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