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Oil Source Beds and Oil Prospect Definition in Upper Tertiary of Gulf Coast

Data on the origin and migration of oil in the highly productive Gulf Coast Tertiary are sparse. What is known with some certainty is that crude oil (1) is most commonly found in old salt-related structures, (2) probably migrated vertically a considerable distance through fault-associated fracture systems, and (3) most likely originated in deeply buried high-pressure marine-slope shales. All other conclusions are highly speculative. Oil compositions suggest multiple sources with mixed type II and type III kerogens. Although many migration modes have been suggested, most oil movement probably took place as a continuous oil phase or as a solute in a supercritical gas phase. Accumulation occurred most readily in structural closures within or just above the "soft" geopressure zone where pressure gradients are high and seals are effective.

Because of their location in the "hard" geopressure zone, oil source beds are rarely penetrated, and the lack of adequate samples has made practical application of geochemical data in the Gulf Coast difficult if not impossible. Nearly all published information defines only thermally immature, organic lean, gas-only source beds. Consequently, until appropriate samples can be collected and analyzed, it is important to develop conceptual models based on geologic history and seismic-stratigraphic methods to predict distribution of oil source beds.

A model for oil source bed deposition in anoxic, salt-controlled intraslope basins has been developed. Most modern, silled basin analogs, however, are oxic and do not contain oil-generating kerogens. Reduced bottom circulation and resulting anoxia could have existed better during periods of global warmup and high sea level stands that occurred during the Pliocene and middle Miocene. Definition of these oil source bed sites, either directly by geochemical analysis or indirectly through seismic investigations, can greatly enhance our ability to predict oil occurrences and to separate oil from gas prospects. It should also stimulate collaboration among Gulf Coast geologists, geophysicists, geochemists, biostratigraphers, and petroleum engineers, which will result in improved geologic models and exploration successes, quite possibly including the discovery of oil in obscure and subtle traps.

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Exploration and Development of Gulf Coast Tertiary, 1983

Total well completions in the Texas Gulf Coast portion of the Tertiary trend registered a marked decline during 1983, with gas completions experiencing the largest drop. The overall success rate, however, remained almost unchanged at 62%. Wildcat drilling declined by about 14%, but the success rate increased to 23%. The Wilcox, particularly the deep Wilcox and Lobo trends of south Texas, was the most popular exploration target and resulted in 40 new field discoveries. The Frio provided the largest number of new discoveries in 1983 with 55 recorded, as well as most of the new pays and extensions. Drilling for Yegua pay was also brisk and resulted in 18 new fields.

In south Louisiana, a similar decline occurred in overall completions and wildcats drilled, with the respective success rates of 46% and 8% being markedly lower than for the Texas Gulf Coast. Here the most significant new trend was the downdip Wilcox, centered in Lockhard Crossing and Livingston fields in Livingston Parish, and originated by Callon Petroleum in 1982. The Miocene, however, attracted the greatest amount of wildcat drilling in 1983 and constituted the pay in most of the new fields discovered with 12 listed.

Several prolific extensions to existing Miocene fields were also reported. The Wilcox play in the central Louisiana parishes resulted in four new field discoveries, and its extension into southwestern Mississippi opened nine new fields there. The shallow Miocene play continued in Baldwin and Mobile Counties, Alabama.

Offshore Texas and Louisiana, the bulk of exploration was directed at Miocene targets—including several tests drilled in water depths up to 3,450 ft (1,050 m)—and resulted in 19 new Miocene field discoveries.

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Thermal and Diagenetic History of Pleasant Bayou-Chocolate Bayou Area, Brazoria County, Texas

Studies of the Pleasant Bayou 1 and 2 test wells and of data from the Chocolate Bayou oil and gas field have yielded the most complete picture of a geopressured geothermal aquifer system yet obtained from the Texas Gulf Coast. The principal geothermal reservoir, the "C" (Andrau) sandstone, has outstanding porosity and permeability owing to (1) initially high porosity resulting from deposition in a winnowed distributary-mouth bar complex, (2) enhancement of porosity by secondary leaching by acid waters, and (3) isolation from late carbonate cementation. The maturity profile obtained for the test well is anomalous, but can be modeled using various time-paleotemperature and burial-history configurations. These models fall into two groups. The first assumes the present geothermal gradient, modified by cooling of the lower Frio section by water flow. In the second, anomalously cool paleogeothermal gradients must be enhanced by the passage of warm waters through the middle Frio section. Both models indicate a fairly late origin of secondary porosity.

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Microfacies and Porosity in Vivian Field, Caddo Parish, Louisiana

Approximately 1 million bbl of oil and 2 bcf (5.7×10^7 m^3) of gas have been produced from the Vivian field since its discovery in June 1981. Ultimate recoverable reserves after water flooding are estimated to be 5.1 million bbl of oil and 8.3 bcf (2.4×10^8 m^3) of gas. The field is a stratigraphic trap resulting from porous, permeable grainstones pinching out into muddy limestones and shale. It is located on the northwestern flank of the Caddo-Pine Island structure in Caddo Parish, Louisiana, and has 56 productive wells, 52 of which produce from one or more reservoirs in the Pettet "B" interval. (The Pettet "B" is a term used by the operator of the field to denote the second of four limestone units encountered when drilling through the Lower Cretaceous Sligo Formation in the vicinity of Vivian field.) The reservoir rock is primarily skeletal-rich grainstone (rarely oolitic). The occurrence of these high-energy deposits at this location indicates that the broad Sligo platform was divided by an oolite-shoal complex into a platform lagoon on the landward side of the grainstones and an outer platform on the basinward side. A similar situation was described for the Sligo of south Texas.

The Pettet "B" interval contains eight microfacies: oolitic grainstone, skeletal grainstone, skeletal-oolitic grainstone, skeletal packstone, oolitic packstone, skeletal-oolitic packstone, skeletal wackestone, and shale. Three depositional environments (high, moderate, and low energy) are represented by these microfacies.

Reservoir grade permeability of 0.5 md or greater is restricted to the grainstone microfacies in the Pettet "B." Normally, this occurs in the skeletal and skeletal-oolitic grainstone microfacies where permeabilities can be as high as 80 md. A portion of the lower B2, however, does have lower limit reservoir permeability in a medium-grained oolitic grainstone. Porosities associated with reservoir-grade permeabilities range from 9 to 21%.

The Pettet "B" represents an oolite-shoal complex which built up on the broad Sligo platform. An apron of skeletal grains, primarily aragonite mollusc shells, accumulated in a narrow belt on the seaward flank of the oolite-shoal complex. Porosity and permeability are highest in this skeletal grainstone, which has both primary and skeletal-moldic porosity.

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Transmission Electron Microscope Study of Illite/Smectite, at GCO/DOE 1 Pleasant Bayou Geopressured Geothermal Test Well, Brazoria County, Texas

Six shale samples, two from core and four from hand-picked cuttings, were examined by transmission electron microscopy (TEM) techniques to study the effects of burial metamorphism on mixed-phase illite/smectite (I/S). TEM lattice fringe images from shallower samples show mixed-phase I/S layers in subparallel orientations relative to each other, commonly with branching and interfingering relationships. Electron diffraction patterns of these shallower samples show very diffuse basal reflections, prominent turbostratic structure, pronounced streaking along z*, and multiple z* orientations in the same diffraction pattern. All of these features indicate a poorly defined interstratification of the mixed-phase I/S: the diffuse basal reflections are probably due to the presence of only a few layers in a diffraction position; the turbostratic structure is due to misalignment of individual layers relative to each other; the z* streaking is due to stacking disorders of the layers in a direction perpendicular to the layers; and the multiple z* orientations are due to rotational disorder of the layers about an axis parallel with the layers.

TEM lattice fringe images from deeper samples show mixed-phase I/S layers arranged in a more parallel fashion, with less branching and interfingering. Electron diffraction patterns for these deeper samples show well-defined basal reflections, and both turbostratic structure and z* streaking are less pronounced. These relationships indicate a more regular interstratification for deeper layers: more layers are in diffraction position, the misalignment of individual layers is less evident, and the stacking disorder perpendicular to the layers is less pronounced.

X-ray powder diffractograms have been interpreted to indicate ordering of illite and smectite layers within the mixed-phase I/S. This order is first observed below the "soft" geopressure boundary (0.465 psi/ft) and is prominent below the "hard" geopressure boundary (0.7 psi/ft). However, neither the TEM lattice fringe images nor the electron diffraction patterns show ordering of illite and smectite layers within mixed-phase I/S.

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Surface Exposures of Late Cretaceous Strata at Rayburns Salt Dome, Bienville Parish, Louisiana

Surface exposures of Cretaceous strata in Louisiana are restricted to isolated occurrences associated with salt domes in the northwestern part of the state. The best known Cretaceous exposures are associated with the Rayburns salt dome in Bienville Parish. Strata exposed at this structure previously have been correlated with formations exposed in southwestern Arkansas, in particular, the Marlbrook Formation and the Saratoga Chalk.

Several distinct Upper Cretaceous lithologic units can be identified at the Rayburns locality. Detailed stratigraphic relationships of these units are obscured by the incomplete nature of the exposures and by dense vegetation. Strata on the west side of the outcrop area include a basal olive-gray marl that is locally glauconitic. This unit is thought to correlate with the Brownstown Marl in Arkansas. The basal marl is overlain in part by a massive glauconitic sandstone at the western end of the outcrop area and by a gray chalky marl at the eastern end. These lithologies are thought to correlate with the Buckrange Sand Lentil or basal Ozan Formation exposed in Arkansas. The sandstone and gray chalky marl units are directly overlain by a hard white chalk. This chalk lithology correlates faunally and lithologically with the upper Ozan and the Annona Chalk in Arkansas.

Exposures along the east side of the outcrop area, adjacent to an abandoned quarry, are blue-gray marl and chalk whose fauna and lithology correlate with the Saratoga Chalk in southwest Arkansas. The concretionary clays of the Midway Group, of Paleocene age, lie unconformably on the truncated surface of this Saratoga equivalent. The unconformity is marked by a thin layer of bored, calcareous nodules. The uppermost portions of the Navarro Group, which occur elsewhere between Cretaceous and Paleocene strata, have apparently been eroded at this locality.

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Depositional Controls on Porosity and Permeability Evolution in Upper Smackover Formation at Tubal Field, South Arkansas

Hydrocarbon production at Tubal field is from secondarily enhanced, preserved primary porosity in an interval of carbonate grainstones at the top of the Upper Jurassic Smackover Formation. These grainstones were deposited as an ooid shoal over a topographic high on the south Arkansas shelf. The degree of porosity and permeability preservation in these sediments ranges greatly and is controlled by both depositional and diagenetic processes.

Porosity and permeability are reduced mostly by pressure solution and the precipitation of late sparry cements. The chemical stability of a grain type determines its resistance to pressure solution, whereas pore size is critical to retaining porosity and permeability after cementation. Therefore, the ability of particular facies types to preserve permeability is controlled chiefly by the types, sizes, and sorting of the constituent grains. Using these parameters, pay facies (facies in which porosity and permeability are commonly preserved) can be defined and identified. Pay facies at Tubal field include the poorly sorted coarse ooid facies, the ooid-composite grain facies, and the pellet-grainstone facies. By studying the distribution of analogous modern facies, the ability to predict the distributions of upper Smackover pay facies, and thus production, can be improved.

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Oil and Gas Prospects in Arkansas Ouachitas

The Arkansas Ouachitas is a frontier area for exploration for oil and gas. To date, drilling has been so limited as to prove meaningless as far as subsurface exploration is concerned. This area provides a rare opportunity to examine various techniques, criteria, indicators, and even hunches using only foresight without the benefit of hindsight in assuming that it will be productive of oil and gas. Time will tell if these predictions are true.

Criteria that one would look for in exploration in a new province include the following in the Ouchitas: (1) sedimentary column that in its entirety exceeds 50,000 ft (15,240 m); (2) numerous oil seeps, gas shows, and residual asphaltic deposits; (3) numerous source beds, reservoir beds, and seals in the stratigraphic column; (4) potential for various entrapping mechanisms in the form of structure, faulting, stratigraphic traps, and reefing in ordovician carbonates under the overthrust; (5) a north-south seismic line that shows definite stratification of beds across the entire thrust area; and (6) Landsat interpretation which indicates areas of structural and tonal anomalies.

The next 5-10 years will witness an extensive and expensive exploration effort in this area. Only after drilling has probed the area will this story be concluded.

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Computerized Particle Size Analyzer—An Exploration Technique, Saint Mary Field, Lafayette County, Arkansas

Grain size frequency and cumulative weight percentages, mean grain size, standard deviation, and skewness provide the geologist with information necessary for studies assessing rock complexity and heterogeneity, and in some cases, depositional environment. Although grain size distribution data are important to the exploration geologist, they are not normally available in sufficient quantity or on a timely basis.

The new computerized Particle Size Analyzer (PSA) enables the explorationist to obtain grain size distribution information rapidly and economically on sidewall and conventional cores. The porosity and the measured grain size distribution, which includes silt and clay sizes, are used to "index" the quality of the reservoir rock. This quality grading or "indexing" is then used to evaluate changes in formation water saturation and/or electric log resistivity, thereby better identifying hydrocarbon productive intervals and oil-water contacts.

Data generated from conventional core samples in the Mitchell sand of the Rodessa Formation in Saint Mary field, Lafayette County, Arkansas, illustrate the use of particle size data for improved well evaluation.

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Variation in Chemical Composition of Oil Field Brines with Depth in Northern Louisiana and Southern Arkansas: Implications for Mechanisms and Rates of Mass Transport and Diagenetic Reaction