fossil counts applied to subsurface deltaic interpretation. The major hydrocarbon reserves at the Hollywood and Houma fields are attributed to thick prodelta shale (low nannofossil counts) prior to sand deposition. This thick shale triggered faults and diapiric structures that were timed perfectly for receiving the early-migrating hydrocarbons.

The Hollywood and Krumbhaar deltas prograded over the thick shale depositing distributary-mouth bar sands. Accumulation in the Krumbhaar sand at the Hollywood and Houma fields was controlled by the lenticular nature of the distributary-mouth bar sand. Distributary-mouth bar sand "E" contains most of the reserves discovered to date in the Krumbhaar sand. Perfectly timed structure, faulting, and lenticular deltaic sand are responsible for this geographic concentration of hydrocarbons in a sand covering an area of 50 by 100 m (80 by 160 km).

The Krumbhaar sand was deposited by two distinct and separate deltas. The deltaic environmental setting for hydrocarbon accumulation in the Houma embayment area compares favorably with a similar Oligocene Vicksburg-Frio delta in Jefferson County, Texas. Deltaic information obtained from this study may serve as a subsurface model for discovering large reserves hidden by subtle deltaic traps.

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Late Cretaceous Volcanism in South and Central Texas—Stratigraphic, Structural, and Seismic Models

Since their discovery in 1915, hydrocarbon traps in and around "serpentine plugs" have produced about 47 million bbl of oil, and have significant potential for additional small discoveries. Production is from isolated reservoirs within mounds of altered volcanic tuff and associated shoal-water carbonates. A review of the more than 200 volcanic centers and intrusive bodies of south and central Texas has led to development of stratigraphic, structural, and seismic models useful in exploration and production.

The so-called serpentine plugs are largely tuff mounds formed by accumulation of volcanic ash (altered to palagonite) on the sea floor around a submarine volcanic vent. Volcanic activity peaked during deposition of the upper Austin Chalk and lower Taylor Marl (about 80 m.y. ago). After their eruption, the tuff mounds localized the deposition of shoal-water carbonates with good porosity and permeability. Low-permeability, organic-rich marine shale and marl of the Taylor Group capped the carbonates, serving as both a hydrocarbon source and a stratigraphic seal. Compactional draping of overlying San Miguel and Olmos sands, with minor offset faulting, created important additional traps in south Texas.

Central Texas volcanic centers are highly aligned along strike-oriented regional faults and fractures of the Balcones and Luling systems. The magmas in both central and south Texas were ultramafic and alkaline, suggesting that partial melting occurred at depths of about 37 mi (60 km). The magma rose rapidly to the surface, probably in an extensional stress regime controlled by pre-Tertiary Balcones-Luling faults.

The palagonite tuff of a typical, productive volcanic center has low seismic velocity and is encased in high-velocity carbonates. The strong velocity contrast, coupled with the distinctive shape of the tuff mass, yields a characteristic seismic pattern. Modern acoustical techniques, coupled with stratigraphic data, allow accurate delineation of buried tuff mounds and prediction of productive carbonate facies.

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Upper Jurassic–Lower Cretaceous Fan-Delta Complex—La Casita Formation of Saltillo Area, Coahuila, Mexico

The La Casita Formation represents a major influx of terrigenous sediment on the epicontinental shelf of northeastern Mexico during the Late Jurassic and earliest Cretaceous. Near Saltillo, the La Casita can be divided into three major units: (1) a basal unit of carbonaceous siltstone and mudstone, (2) a middle unit which is predominantly sandstone and pebble conglomerate, and (3) an upper unit of siltstone and fine-grained sandstone with thin limestone and dolomite layers becoming more abundant upward, and grading into the overlying Taraises Formation. The La Casita-Taraises terrigenous sequence is underlain and overlain by shallow-marine limestones.

In the Saltillo area, the La Casita crops out in narrow canyons in breached anticlines of the Sierra Madre Oriental. Consequently, interpretations concerning the depositional framework of the La Casita must be made from vertical sequences exposed in widely spaced canyons. A first-order, single-dependence Markov analysis aids in identifying preferred vertical transitions in lithologically variable parts of the section.

Important aspects of the La Casita in the Saltillo area include: (1) the large-scale depositional sequence of basal shallow-marine mudstones overlain by shallow-marine and alluvial sandstone, conglomerate, and mudstone, which are in turn, overlain by shallow-marine, fine-grained sandstone, mudstone, and carbonate rocks; (2) conglomeratic shallow-marine sediment; (3) textural and mineralogical immaturity; (4) the nonrandom nature of upward lithofacies transitions; and (5) a predominance of coarsening-upward sequences in the middle unit. These characteristics suggest that the La Casita in the Saltillo area records the progradation of a complex of fan deltas.

The lower, fine-grained unit represents Late Jurassic "prodelta" deposits that accumulated on the submarine shelf prior to the influx of coarse sediment. The middle, coarse-grained unit was deposited during the period of maximum seaward advance of the fan-delta complex during latest Jurassic time. This unit contains predominantly coastal and shallow-shelf conglomerate, sandstone, and mudstone, with some distal alluvial-fan conglomerate and sandstone. The upper La Casita records the waning input of coarse sediment as the fan-delta system retreated in earliest Cretaceous time.

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Paleocene-Eocene Boundary in Eastern Gulf Coast

The Paleocene-Eocene boundary in Alabama has been placed at various levels within the Tuscahoma Formation and the overlying Bashi Formation. The location of this boundary is important because both lignite- and petroleum-bearing deposits occur within this sequence in the Gulf Coast, and the region appears to be a good locality to test the local coastal-onlap models.

The middle beds of the Tuscahoma Formation are upper Paleocene (calcareous nannofossil Zone NP9 and *Morozovella*

velascoensis Interval zone). The entire overlying Bashi Formation is lower Eocene (Zone NP10 and lower part of the *Morozovella subbotinae* Interval zone). No calcareous fossils are known from the upper part of the Tuscahoma. Therefore, the boundary problem was investigated, using abundant sporomorphs in cores of the Tuscahoma and the Bashi at Ozark, Alabama, and other cores and outcrops in Alabama and western Georgia.

The sporomorph assemblages of the Tuscahoma and the Bashi differ considerably, but the assemblages within each formation are generally quite uniform from base to top. According to sporomorph data, a small hiatus appears to exist between the Tuscahoma and the Bashi.

In the Oak Grove core hole in Virginia, the shallow-marine Aquia Formation contains Tuscahoma-like sporomorphs in beds within Zone NP9. The overlying lagoonal Marlboro Clay is either entirely upper Paleocene or may span the Paleocene-Eocene boundary. Above the Marlboro is the marine-transgressive Nanjemoy Formation (Zone NP10), containing Bashi-like sporomorphs. Thus, sporomorphs from the top of the Tuscahoma in Alabama are most probably of late Paleocene age, as are the similar sporomorphs from the upper Paleocene middle part of the Tuscahoma and upper Paleocene Aquia Formations.

The uppermost beds of the Tuscahoma in eastern Alabama and western Georgia are marginal-marine to nonmarine deposits. The overlying Bashi Formation is of inner neritic origin. Therefore, in the Atlantic and Gulf coastal plains, a regression marked the end of the Paleocene, and a fairly rapid, sea-level rise occurred at or just after the beginning of the Eocene; this agrees with published global sea-level curves.

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Clay Mineralogy and Depositional History of Frio Formation in Two Geopressured Wells, Brazoria County, Texas

Twenty-three shale samples, ranging in depth from 5,194 to 13,246 ft (1,583 to 4,037 m), from Gulf Oil Corp. 2 Texas State Lease 53034 well, and 33 shale samples, ranging in depth from 2,185 to 15,592 ft (666 to 4,752 m), from General Crude Oil Co./Department of Energy 1 Pleasant Bayou well were examined by X-ray techniques to determine the mineralogy of the geopressured zone in the Brazoria fairway. Both wells have similar weight-percent trends with depth for a portion of the mineralogy. Calcite decreases, whereas plagioclase, quartz, and total clay increase slightly. Within the clays, illite in mixed-layer illite-smectite increases and smectite in mixed-layer illite-smectite decreases.

Four minerals have distinctly different trends with depth for each well. In the 2 Texas State Lease 53034 well, potassium feldspar and mixed-layer illite-smectite decrease, kaolinite increases, and discrete illite is constant. In the 1 Pleasant Bayou well, potassium feldspar and kaolinite are constant, mixed-layer illite-smectite increases, and discrete illite decreases.

The most important diagenetic change in each well is the transformation of smectite to illite within the mixed-layer phase which occurs according to the reaction suggested by J. R. Boles and S. G. Franks with Al^{3+} acting as an immobile component. This change begins at calculated equilibrium temperatures of 89 to 92°C. The decrease in calcite and the lack of chlorite in the shales suggest that carbonate, iron, and magnesium migrate out of the shale in each well.

In the 2 Texas State Lease 53034 well, the Boles and Franks reaction is consistent with a steady supply of original mixed-layer illite-smectite during deposition. Potassium feldspar provides K^+ for the smectite to illite transformation. The breakdown of potassium feldspar also results in the formation of kaolinite and the increase of plagioclase feldspar, which is due to the reaction with Na^+ and Ca^{2+}, provided by the smectite to illite change.

In the 1 Pleasant Bayou well, the Boles and Franks reaction is consistent with an unusually high mixed-layer illite-smectite content in the early depositional stages. The source of K^+ for the smectite to illite reaction is discrete illite. The breakdown of discrete illite results in both the formation of kaolinite and the increase in plagioclase feldspar.

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Paleocene to Middle Eocene Stratigraphy of Alabama

Each of the eight Paleocene to middle Eocene formations that crop out across Alabama contains similar lithofacies. Each of the formations is characterized by east to west thickening, representing one or more transgressive cycles. An integrated biostratigraphic framework of calcareous nannofossils and planktonic foraminifers demonstrates that individual formations are generally the same age throughout Alabama, although the base of some cycles may be older in southwestern Alabama. The lower Eocene strata were deposited in a more open-marine environment in eastern Alabama than the rapidly prograding sequence in western Alabama.

The early Paleocene Clayton Formation contains calcareous nannofossils characteristic of Martini's Zones NP1, NP2, and NP3, and planktonic foraminifers typical of Stainforth's *Subbotina pseudobulloides* and *S. trinidadensis* Interval zones. The lower and middle parts of the Porters Creek Formation are of late early Paleocene age (Zone NP3 and *S. trinidadensis* and *Morozovella uncinata* Interval zones); the upper Matthews Landing Marl Member of the Porters Creek is of early late Paleocene age (Zone NP4 and *M. angulata* Interval zone). The Coal Bluff Marl Member of the Naheola Formation is also of early late Paleocene age (Zone NP5). The lower Gravel Creek Sand Member of the Nanafalia Formation is assigned to Zone NP5 and is separated by a significant unconformity from the middle and upper members of the Nanafalia; the middle "*Ustrea thirsae* beds" and the upper Grampian Hills Member are late Paleocene in age (Zone NP7 and NP8 and *Planorotalites pseudomenardii* Range Zone). The lowermost marl beds of the Tuscahoma Sand in western Alabama are assignable to Zone NP9 and the *P. pseudomenardii* Range Zone, and the remainder of the Tuscahoma is assigned to Zone NP9 and the *Morozovella velascoensis* Interval zone (late Paleocene). The Hatchetigbee and Bashi Formations are of earliest Eocene age (Zone NP10 and lower part of *Morozovella subbotinae* Interval zone). A major unconformity separates these formations from the overlying Tallahatta Formation, which is assignable to Zones NP12, NP13, and NP14, resulting in a late early Eocene age for the lowermost part of the Claiborne Group.

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Modern Thecamoebinids (Arcellinida) from Balize Delta, Louisiana

Distribution patterns exhibited by both living and dead thecamoebinids are discussed in relation to four physiographic subenvironments to the Balize delta, Louisiana. The subenvironments are the channels, submerged levees, interdistribu-