southeast progradational trend and a tendency for the sub-Millerella units to thicken updip to the line of post-Carboniferous erosional truncation. An isopach map of the Tuscumbia-Millerella interval shows thickening toward the north, away from the Ouachita orogenic source area.

Limited petrographic evidence from Lewis and Carter sandstone bodies associated with the principal subsurface deltaic facies tract indicates a dominance of monocrystalline quartz and chert rock fragments, as well as an absence of lithologic indicators for an orogenic provenance. By way of contrast, outcrop studies of the Hartselle and Parkwood units in Alabama by W. A. Thomas et al describe an abundance of polycrystalline quartz in the Hartselle and both metamorphic quartz and phyllite rock fragments in the Parkwood. The Parkwood samples containing the orogenic indicators are restricted to the folded Appalachians.

The Pottsville Group can be broken down into a maximum of 10 regionally mappable subsurface intervals. Widespread delta destructional coal seams and marine reworked sandstone bodies serve as marker units. Pottsville gas production derives from barrier bar facies in the lowest two genetic intervals and from the mixed barrier-bar and deltaic sandstone units of interval 3 (Nason). This Lower Pennsylvanian clastic wedge has its predominant source area to the south in the Ouachita orogenic belt. An isopach map of the total Pottsville documents significant thickening to an excess of 10,000 ft (3,000 m) in central Mississippi. All of the previously mentioned orogenic indicators are noted in the outcropping deltaic Pottsville facies.

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Vicksburg Group Carbonates—A Look at Gulf Coast Paleogene Carbonate Banks

Throughout the Paleogene of the northern Gulf coastal plain large deltaic systems dumped thick sequences of lithoclastic sediments onto the shelf of the Gulf of Mexico. In between major deltaic pulses, thick carbonate banks or reefs developed in the vicinity of the broad Wiggins uplift of southern Mississippi and Alabama. Because the present-day outcrop of the Oligocene Vicksburg Group in Mississippi and Alabama cuts across sedimentary strike, all of the component lithofacies of a typical Paleogene carbonate bank complex of the northern Gulf coastal plain are exposed. By relating outcrop lithology to electric log character, the various lithofacies of the Vicksburg Group can be mapped throughout its subsurface extent. Similar inferences and maps can be made for the other Paleogene carbonate complexes.

Outcrop sediments of the Vicksburg Group comprise five lithofacies, all of which show variations: (1) molluscan, glauconitic, foraminiferal, quartz silty sand/wackestone; (2) foraminiferal, algal mudstone; (3) (quartzose) bryozoan, foraminiferal silty sand; (4) glauconitic, *Lepidocyclina,* algal(?), silty sand; (5) skeletal grainstone/coarse sand.

These lithofacies suggest a set of depositional environments (corresponding lithofacies number in parentheses): (A) destructional delta (1); (B) algal muddy shelf bottom (2); (C) regressive carbonate shelf (1); (D) carbonate bank (back-bank primarily) (3,4); (E) regressive carbonate shoal/shoreline (5).

All of these environments, with their slightly different faunal constituents, can be found in the other carbonate units of the Gulf Coast Paleogene. The Tatum and the Salt Mountain Limestones have coral-algal community shelf margins, whereas the Cook Mountain, Ocala, and Vicksburg have a slightly deeper water foraminiferal-algal community at the margin. Time-equivalent lithoclastic deposition to the west prevented westward expansion much beyond central Louisiana. During the Miocene, bank complex communities were displaced farther to the east by continued Rocky Mountain-derived sediments coupled with a major epeirogenic uplift of the southern Appalachians.

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Depositional Framework and Reservoir Potential of an Upper Cotton Valley (Knowles Limestone) Patch Reef, Milam County, Texas

The Knowles Limestone is an upper unit of the Cotton Valley Group, and in Milam County, Texas, it is approximately 350 ft (100 m) thick, consisting of shales, terrigenous dolomitic limestones, grainy limestones, and algal boundstones with stromatoporoids and corals. The boundstones represent an elongate, wave resistant, encrusted skeletal patch reef which probably developed on a subtle salt-generated topographic high. The reef appears to be slightly more than 1 mi (2 km) across in its narrowest lateral dimension as determined by facies correlations of three cored wells in the study area.

Principal reef framebuilders included massive and columnar stromatoporoids, solitary or dendroid corals, and encrusting *Tubiphytes* and *Lithocodium* algae. Dendroid stromatoporoids, digitate corals, *Tubiphytes* oncoids, echinoids, and various mollusks were the principal contributors to the detrital infill of the reef.

Increased dip and dip reversal of draping beds suggest the Knowles reef achieved relief above the sea floor. Evaluation of dipmeter logs indicates the beds dip 5°NW on the updip reef flank and 10°SE on the downdip reef flank.

Reef core boundstones and reef talus were consistently present downdip, and lagoonal to tidal-flat facies were common updip throughout Knowles deposition. The reef organisms eventually became overwhelmed with terrigenous sediment transported downdip as the tidal-flat environment prograded over the lagoonal, reef talus and reef core facies at the end of Knowles deposition.

Early dolomitization of tidal flat and lagoonal facies has created local porous zones in some of these rocks. However, the reef, per se, is cemented by sparry calcite and is not a potential reservoir facies.

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Delineation of Delta Types: Norias Delta System, Frio Formation, South Texas

The Norias delta system was the major depositional component of the Frio Formation, South Texas. The Norias was an expansive, predominantly sandy, progradational complex fed by the updip Gueydan fluvial system. This progradational complex effectively filled the Rio Grande embayment of South Texas by the end of Frio deposition. Initiation of Norias deltaic progradation was probably associated with the early rise in sea level following a lowstand. As sea level rose following the lowstand, topographic expression of the preexisting Vicksburg progradational wedge caused a northward deflection of the Gueydan fluvial system within the Rio Grande embayment. Subsequently, the Norias delta complex was established as a stable progradational system in a position lateral to the north flanking margin of the main Vicksburg deltaic platform. The Norias delta system was flanked laterally with time-equivalent depositional systems, including a northerly strand-plain/barrier-bar system and to the south there are indications of a possible deltaic complex in northern Mexico. Entrenchment of the Vicksburg shelf during sea level lowstand probably led to development of a submarine canyon adjacent to the south flank of the Norias delta system. Incorporated within the complex body of the progradational sequence a well-defined evolution of Norias delta styles can be documented through the time of Frio deposition. Early Frio high-constructive, fluvially dominated, lobate geometries were characterized by meandering distributary systems as well as thick delta-front and delta-margin sands.

Middle Norias deltaic deposits continued to be generally high-constructive lobate in style, but evidence for significant reworking of deltaic sediments can be inferred based on the strand-plain/barrier system developed to the north. Late Norias deltas were high-destructive wave dominated in nature. Essentially the Norias depositional complex had become a broad alluvial plain feeding a strand-plain/barrier-bar system with little physiographic expression of a delta lobe.

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Geology of Sweet Lake Geopressured-Geothermal Prospect, Cameron Parish, Louisiana—Drilling and Testing Results

The Sweet Lake geopressured-geothermal well is located in a basin on the north flank of an east-west trending salt ridge that includes the Hackberry, Big Lake, and Sweet Lake structures. The south side of the basin is bounded by a fault downthrown to the north. This fault converges eastward with a major east-west trending fault downthrown to the south. The two faults form a graben which terminates to the east by the convergence of the faults and is open to the west. Within the basin the primary geopressured-geothermal aquifer is the *Miogypsinoides* sand of the *Camerina* zone (upper Frio Formation of Oligocene-Miocene age). Within the graben, sediments dip northwest into the basin with dip angles as high as 20°. The first *Miogypsinoides* microfossil was picked at 14,970 ft (4,563 m) and the first good sand occurred at 15,065 ft (4,592 m). The sequence is 640 ft (195 m) thick (15,000 to 15,640 ft, 4,572 to 4,767 m), with 250 ft (75 m) of net sand. There are seven potentially productive sands within the sequence. Four diamond cores were taken. Data from Core 3, 15,389 to 15,405 ft (4,690 to 4,695 m) indicated the sands are medium to fine-grained, with 1 to 2% silt-sized material. Median grain size is 0.26 mm. Thin sections parallel and perpendicular to the core axis show the grains to be angular to subangular. X-ray analysis showed 75% quartz, 19% feldspar, 4% illite, 2% mixed-layer clay (illite/smectite), and a trace of kaolinite. SEM photographs showed cement as quartz overgrowths and clay as very fine hairs in the pore spaces. Porosity is 24% and permeability 3,600 md in Core 3, the fifth sand in sequence. Initial reservoir pressure in this perforated zone (15,387 to 15,414 ft, 4,690 to 4,698 m) was 12,060 psi (83,154 kPa). Temperature at the middle point in the sand was 299°F (148°C). The calculated SP salinity for the well was 50,000 to 70,000 ppm. If Rw/2 is used instead of Rw, the calculated salinities increase to 125,000 to 140,000 ppm.

Reservoir testing included drawdown and buildup tests. The well flowed a total of 240 days. Flow rates varied from 1,000 bbl/day to 34,000 bbl/day. Average surface pressure during the testing is 2,500 psi (17,238 kPa). The gas to water ratio is 25 to 28 SCF/B, of which 20 SCF/B are recovered. Additional testing of the reservoir is planned.

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Growth Faults and Salt Tectonics in Houston Diapir Province—Relative Timing and Exploration Significance

Oil and gas accumulation in Gulf Coast Tertiary strata is controlled mainly by regional growth faults and by salt-related structures. Salt forms the most prominent set of structures in the Houston diapir province of southeast Texas. Recent work in three study areas shows that the Tertiary growth-fault trends, so well displayed along strike to the southwest, continue through this salt basin as well, but they have been deformed by later salt movement.

In the Katy area, seismic data disclose early (pre-Wilcox) salt pillows downdip of the Cretaceous reef trend. Progradation of the lower Wilcox Rockdale delta system created a linear growth-fault trend above and seaward of the pillows. Salt stocks were injected upward from the pillows during Claiborne deposition, and were flanked by deep withdrawal basins and turtle structures. Major oil accumulations occur over an inferred turtle structure and over deep-seated salt domes. The lower Wilcox growth-fault trend deformed by the later salt flowage, is virtually unexplored, although geopressured gas production from these low-permeability deltaic reservoirs exists in adjacent areas.

In Brazoria County, a major lower Frio growth-fault trend, affecting the Houston delta system, was deformed by later salt domes, by a salt-withdrawal basin, and by a possible turtle structure at Chocolate Bayou. A productive geopressured aquifer exists in the salt-withdrawal basin bounded by the previously formed growth faults. In Jefferson County, in contrast, salt-tectonic activity and growth faulting appear to have been coeval. Early salt-cored ridges continued to rise throughout Frio deposition; growth faults occur both updip and downdip. Salt diapirism may have occurred throughout Frio deposition at Orange and Port Neches salt domes, but other domes such as Spindletop formed in post-Frio time. Hydrocarbons accumulated over the salt domes in growth-fault anticlines and in stratigraphic traps. Contemporaneous, low-intensity growth faulting and salt movement may be ascribed to the minimal loading imposed by the sand-poor lower and middle Frio section.

Recognition that shelf-margin growth faulting preceded the development of the present pattern of domes and basins has important implications for hydrocarbon exploration. Growth faults may be migration paths for hydrocarbons; furthermore, early formed traps, distorted by salt movement, may still be found to contain hydrocarbons.

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Cretaceous and Tertiary Samples Dredged from Florida Escarpment, Eastern Gulf of Mexico

Cretaceous and Tertiary rocks were dredged along the Florida Escarpment at five areas south of 27°05′N in late 1982 during cruise LY-82A of USNS *Lynch*. The escarpment was sampled from near the base (as deep as 3,300 m, 10,800 ft) to near the top (as shallow as 1,500 m, 4,900 ft) of the slope. The majority of samples recovered are middle Cretaceous peritidal and lagoonal limestones and dolomites deposited under restricted, low-energy conditions. Presumed middle Cretaceous dolomites deposited in hypersaline bank-interior environments were taken primarily from the walls of canyons incised from 10 to 50 km (6 to 30 mi) into the escarpment, and also from the escarpment proper at several dredge stations. Limestone lithologic characteristics are generally bioturbated miliolid and mollusk wackestone/packstone (lagoonal) and fenestral and algal-laminated mudstone/wackestone (peritidal). Some dolomites retain primary sedimentary structures (e.g., mottling and algal lamination), whereas others appear structureless, perhaps due to recrystallization. Few of the middle Cretaceous samples were deposited under high-energy conditions. Those that are high-energy deposits are bioclastic rudstones and coral boundstones. Late Cretaceous and Tertiary deep-water limestones and chalks unconformably overlie and drape the older shallow-water carbonates. The limestones are Late Cretaceous in age, while the chalks range from Late Cretaceous through Pleistocene. The limited occurrence of high-energy facies rocks indicates that the escarpment has been eroded bankward over its entire length south of 27°05′N, and not just at canyon reentrants. The younger deep-water rocks reflect the drowning of the middle Cretaceous platform in Late Cretaceous time. The facies change from limestone to dolomite is attributed to higher salinities in the bank interior during the middle Cretaceous.

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Exploration and Development of Lobate Back-Barrier Facies Sandstones

Lobate back-barrier sandstones deposited as washover fans and flood-tidal deltas are major reservoirs for stratigraphically trapped hydrocarbons on the Gulf Coast. Understanding back-barrier facies relationships can improve the efficiency of exploration and development in three ways: (1) recognition of their irregular to lobate geometry (rather than simply linear parallel to depositional strike) allows more accurate predictive reservoir mapping, (2) detailed correlation and mapping of each individual wedge of reservoir provides more precise determination of the updip pinch-out, and (3) resistive zones on electric logs, representing coals or tight sandstones, can be used as "adjacent clues" to the nearby presence of a back-barrier reservoir. Application of these concepts in south Texas led to extension of the previously abandoned Draper field.

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Multiple Zone Coal Degasification Potential in Warrior Coal Field of Alabama

The upper Pottsville Formation in the Warrior coal field of Alabama has seven recognized groups of bituminous coal seams. Three of these groups, the Pratt, Mary Lee, and Black Creek, consist of seams containing commercially significant quantities of methane. Each group has several seams within a vertical interval that, in many areas, can be stimulated collectively. In parts of the Warrior coal field, where all three groups can be penetrated in one vertical borehole, the potential production from multiple zone completion wells can result in commercially profitable wells. Various open-hole and through-the-casing completion procedures are being applied, resulting in successful methane production from these multiple zone coal gas wells.