occurs as both grain coats and pore bridgings, kaolinite forms scattered pore fills, and Fe-chlorite coats a few grains.

The channel-fill deposits are well to poorly sorted, very fine to medium-grained sandstones, commonly conglomeratic, and contain calcite-cemented zones. These deposits are mineralogically similar to the bar-finger deposits but contain abundant shale and fossil fragments at the base. Noncalcareous channel sandstones are characterized by scattered Fe-chlorite grain coatings and pore-filling illite.

Intergranular porosity is well developed and has not been severely reduced by the pervasive quartz overgrowth cementation. The eastern part of the project area contains a higher quality reservoir section because of the sparsity of clay zones in the bar-finger sandstone and the thicker channel-fill deposits in this area. Secondary porosity, produced by the dissolution of feldspar grains, has slightly enhanced the overall quality of the Benoist Sandstone.

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Holocene Infilling of Coastal Lagoons by Mixed Terrigenous Siliciclastic and Marine Carbonate Sediments, Vieques, Puerto Rico

Infilling of coastal lagoons along the southern coast of Vieques, Puerto Rico, during the Holocene transgression is the result of contributions from both terrigenous siliciclastic and marine carbonate sources. Four lagoons displaying varying infilling and interaction with open marine waters were chosen for detailed stratigraphic study. Cores taken perpendicular to modern lithotope trends show a well-defined sequence that is similar throughout the lagoons. The stratigraphy also defines two distinct origins of the lagoonal basins: those resulting from sheltering provided by Oligocene-Miocene limestones and those developed by accretion of beach ridges seaward of shallow embayments.

Sedimentation in both types of lagoons began with deposition of terrigenous colluvium. Rising sea level was accompanied by storm-generated marine derived gravels that accumulated above the colluvium. Intertidal mud-flat facies and subsequent *Diplanthera* peat deposits denote the existence of restricted intertidal and subtidal environments respectively. These facies were overlain by molluscan gravel and *Halimeda* sand indicating increased water depth and improved circulation with the open marine environment. Mangrove peats are prominent in cores from the lagoonal margins. They show seaward migration of this environment as terrigenous sediment continued to prograde into the lagoons.

Lagoonal margins display a terrigenous, siliciclastic-dominated progradational sequence, whereas the central and seaward portions display a mixed siliciclastic and carbonate transgressive sequence. These sequences occur in close geographic proximity and could provide problems of interpretation for the geologist concerned with the ancient record if detailed stratigraphic data were not available.

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Effects of Clays on Well Economics, Wire-Line Log Interpretation, and Completions

Composition and distribution of clays (both as clay minerals and true shales) can have a direct impact on the day-to-day and long-term economic performance of a well. Clays affect the following:

(1) Distribution and quantity of interstitial fluids (i.e., value of reserves in place). The specific composition of dispersed (authigenic) clays controls the surface area of the pore system. Water bound in micropores created by these dispersed clays can comprise ±70% of fluid volume, but the well may produce water-free hydrocarbons. In such shaly sands, calculation of S_w by itself often may not identify either the amount or type of fluid production. It can predict the presence of hydrocarbons, but is not an optimum indicator of fluid production.

(2) Rate of production (i.e., time value of reserves). The distribution of clays affects rate of production. Laminar clays will not reduce flow rates as significantly as dispersed clays. For example, a sand containing 20% clay distributed as laminae will have its net pay reduced by 20%. Production from the sand laminae is not affected by the clay. However, a sand with 20% clay dispersed in 30% pore space may not produce economic quantities of hydrocarbons. Furthermore certain clay minerals, such as fibrous illite, can significantly increase flow tortuosity and reduce daily flow rates.

(3) Wire-line log response (i.e., bypassed production). Calculated values of S_w, porosity, and V_{shale} must be interpreted considering clay type and shale distribution. High values of log derived S_w can indicate (a) highly productive laminated sand-shale sequences, (b) low permeability dispersed clay production, or (c) water production. Calculated porosities depend upon assumptions of rock density, which can be significantly altered by the presence of shales. V_{shale} is calculated from the gamma ray response, yet three of the four major families of clay minerals are nonradioactive and do not have any effect upon gamma response. Much production is bypassed due to inadequate knowledge of clay composition in potential horizons.

(4) Completion. The role of clay minerals on completion procedures is well documented. Clay minerals dispersed in pores can interact with common well-bore fluids and irreparably damage potentially productive sands. A knowledge of detailed clay compositions is vital to successful stimulation effects. Individual wells or whole zones can be written off as nonproductive if inappropriately designed stimulation efforts prove unsuccessful.

Identification of bypassed production and incorrectly stimulated zones are particularly important during field development because of the heavy front-end investment necessitated by development. Once this investment is made, then hydrocarbon-productive zones that were not obvious or considered uneconomic during exploratory evaluation, become important targets. Experience suggests that much bypassed production contains unusual clay content or clay distribution.

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Fluid Movement and Diagenesis in Fine-Grained Geopressured Sediments of Frio Formation (Oligocene), Kaplan Field, Southwestern Louisiana

Investigation of structure, temperature, pressure, salinity, and core samples at Kaplan field yields information on diagenesis of fine-grained sandstones deposited in an outer shelf/upper slope depositional environment. Cross sections and structural maps reveal a domal structure at 15,000 ft (4,572 m) of depth and a northeast-striking growth fault. Post depositional faults occur at shallower depths (11,500 ft; 3,505 m). A large growth fault forms the northern border of the study area. The shallow occurrence of geopressure is related to structure and a high shale/sand ratio. Low isothermal surfaces in the down fault blocks accompanied by anomalous high temperatures in the upthrown blocks indicate vertical leakage of fluids along growth faults from underlying geopressured aquifers. The association of low salinity fluids (less than 60,000 ppm) with leakage zones affirms structural control of fluid movement through the Anahuac and Frio formations (Oligocene) at Kaplan field.

The Frio Formation core samples from 16,700 to 19,600 ft (5,090 to 5,974 m) of depth, representing channel and channel-edge turbidite sandstones, were examined petrographically and by SEM. The arkosic composition of late stage diagenesis sandstones at Kaplan field suggests an original arkose or lithic arkose composition (classification of McBride). Nonferroan calcite cementation, chlorite rims and cement, and quartz overgrowths characterize early diagenesis. At a middle stage of diagenesis secondary porosity is developed by dissolution of unstable grains and calcite cement. Samples flushed by geopressured waters from greater depth show kaolinite pore-fill and quartz overgrowths, chlorite (polytype IIb) and illite cement, and feldspar overgrowths in the late diagenetic stage. Premetamorphic textures are apparent in the deepest section at 338°F (170°C).

The low permeability of sandstones with extensive early chlorite cement (channel-edge sandstones) precludes development of extensive secondary porosity. In contrast, sandstones with little early chlorite cement develop and maintain secondary porosity through the late diagenetic stage. Restriction of fluid movement by early chlorite cement has ramifications for migration of hydrocarbons or geothermal waters, and for gas production at Kaplan field.

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Catalytic Effect of Smectitic Clays in Hydrocarbon Generation

Smectites or three-layer expanding clays promote the thermal decomposition of long-chain aliphatic hydrocarbons to produce hydrocarbons of lower molecular weight. Smectites are believed to act as acid catalysts through the dissociation of water, thus promoting carbonium ion reactions. When sedimentary organic matter, isolated as kerogen from suspected petroleum source rocks, is pyrolyzed in the laboratory, long-chain aliphatic hydrocarbons are in the pyrolyzate, commonly in abundance. When the source rock contains smectite and is pyrolyzed, the pyrolyzate has significantly less high molecular weight aliphatic hydrocarbons and more lower molecular weight hydrocarbons.

Mixtures of kerogens with quartz, silica, alumina, calcium carbonate, kaoline, or illites not containing smectite-illite mixed layer clay, yield pyrolyzates more similar to those of the kerogen alone, i.e., the range of hydrocarbons in the pyrolyzates is broad including those of high molecular weight. This is interpreted to be due to a lack of catalytic activity of these minerals as compared with the catalytically active smectite. The catalytic effect of smectite is observed particularly when the concentration of sedimentary organic matter in the source rock is relatively low, amounting to less than about 2% total organic carbon. Smectites in sediments with a modest or low amount of organic matter are critical regarding the type petroleum generated, exemplified by the gas condensates of the northern Gulf of Mexico basin and Indonesia. Consequently, it is concluded that smectitic argillaceous sediments containing less than approximately 2% organic carbon are poor sources of oil, although they may be productive of gas and gas condensate.

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Sediment Gravity Flow Deposition on a Modern Carbonate Slope Apron: Northern Little Bahama Bank

Carbonate sediment gravity flow sedimentation north of Little Bahama Bank is initiated along a "line source" consisting of numerous small slope gullies on the upper slope and results in deposition of a wedge-shaped lower slope apron of coarse sediment. This broad (over 100 km; 62 mi) smooth apron (30 km, 19 mi, wide) parallels the adjacent carbonate bank margin and lies between 20 and 50 km (13 and 31 mi) seaward of the platform. The apron is marked by a relatively abrupt decrease in slope and ranges from 2° to $^1/_2$° between depths of 850 and 1,400 m (2,789 and 4,593 ft). This apron is composed of a variety of medium to coarse-grained sediment gravity flow deposits of variable thicknesses, interbedded with an equal proportion of fine-grained pelagic ooze. Based on texture alone, ancient slope aprons could easily be misinterpreted as lower slope or inner fan/braided suprafan environments of a submarine fan, which operates as a "point source."

A detailed piston core study utilizing X-radiography, grain-size analyses, and standard petrographic techniques revealed 36 sediment gravity flow deposits displaying a spectrum of depositional characteristics. Single-layer deposits are either: (1) muddy, poorly sorted (debris flows); (2) clean, massive to inversely graded (grain flows); or (3) normally graded (turbidites). Double-layer deposits are composites of single-layer types resulting from flows that occur in two phases. They consist of either: (1) normally graded overlying muddy, poorly sorted, or (2) normally graded overlying clean, massive to inversely graded deposits. A ratio of 3:2:1 exists among debris flow, turbidity current, and grain flow deposits respectively.

Debris flow deposits, up to 5.6 m (18 ft) thick, display a downslope transition from mud to grain-supported fabrics. This transition is interpreted as a progressive downslope loss of muddy matrix due to turbulence. Grain flow deposits, up to 5.2 m (17 ft) thick, occur close to the slope break and represent deposition from flows of high concentration. Turbidites, up to 1.4 m (5 ft) thick, are ubiquitous on the apron. Typically they are simple graded "basal turbidites", lacking upper Bouma-sequence laminated intervals. Some exhibit multiple-graded sequences suggesting pulsating flows.

The sediment gravity flow deposits lack shallow-water sediment, but contain resedimented intraclasts derived from submarine cemented upper slope deposits (nodules) along with lithified layers and deep-water corals from the lower slope. Although textures and structures appear similar in both terrigenous submarine fan and carbonate slope apron environments, sedimentation models differ radically. Knowledge of those differences should aid in the recognition of ancient carbonate slope apron deposits.

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Hardground Petrography and Carbonate Microfacies: Paola Limestone (Upper Pennsylvanian), Southeastern Kansas

The Paola Limestone (Missourian) of the Mid-Continent region is the basal carbonate member of the Iola Formation (Kansas City Group). The Paola is a thin (1 to 3 ft; .3 to .9 m) massive layer of bioturbated, fossiliferous (algae, crinoids, and foraminifers) calcilutite containing abundant phosphatic nodules. This distinctive limestone is, according to previous investigators, correlative from Nebraska, southward, into northeastern Oklahoma. The Paola Limestone is overlain (in ascending order)