grainstone buildups. South of the basin center, only a single shoaling-upward sequence is present, with dolomitized, mostly restricted-marine skeletal wackestone to pelletal wackestone or packstone reservoir facies. Nesson anticline, between these 2 areas, contains a single shoaling-upward sequence without an anhydrite cap. In northern Nesson anticline, Mission Canyon reservoir facies are oolitic-pisolitic, intraclastic wackestone or grainstone buildups or open-marine skeletal packstone or grainstone. Both limestones and dolostones are productive in southern Nesson anticline. Limestone reservoir facies are transitional, open to restricted-marine slightly intraclastic, skeletal wackestone or packstone facies. Dolostone reservoir facies are restricted-marine mudstone to skeletal mudstone and pelletal wackestone or packstone.

Northeast of the Nesson anticline, production is from oolitic to pisolitic packstone or grainstone buildups in the Rival (or Nesson) subinterval and from restricted-marine, dolomitized spiculitic mudstone in the Midale subinterval (base of Charles Formation). In the northern Nesson anticline, Rival (Nesson) reservoir facies are offshore open to restricted-marine, skeletal, intraclastic, pelletal wackestone and/or packstones.

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Reservoir Geology of Portion of Sailor Springs Consolidated Field and Its Impact on Primary and Secondary Production

The pool under study is part of the Sailor Springs Consolidated field, Clay County, Illinois. The 23 wells within the pool have produced more than 350,000 bbl of oil from the McClosky limestone (Mississippian-upper Valmayeran) since 1981. The average depth of the wells and the pay zone is 3,000 ft.

The trap is predominantly stratigraphic in nature. Examination of core, thin sections, and geophysical logs indicates that the producing zone is composed of a complex series of oolitic bars. The individual bars are laterally discontinuous, flat bottomed, convex upward, and composed of oolitic skeletal grainstones that grade into dense skeletal wackestones and mudstones that act as reservoir seals. The bars are commonly subtle and easily overlooked. Several wells produce more than 100 BOPD from a zone less than 3 ft thick.

Detailed mapping of total pore volume, total permeability, and facies cementation patterns is essential for successful field development and secondary waterflooding. These parameters have had a direct impact on primary and secondary production performance within the pool. Detailed reservoir mapping also reveals that the pool is subdivided into several reservoirs separated by reentrants that cut across the oolitic bars.

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Beach-Swash Zone: Primary Ooid Factory?

The shore of Long Bay along the southeastern coast of Providenciales Island in the Turks and Caicos Islands, British West Indies, represents a bankward-accreting beach and dune complex of Holocene oolitic grainstone. Offshore, en echelon bars of very low relief consist of skeletal-pelletal grainstones with thin oolitic coatings. Nearshore, the oolitic coatings become more numerous and thicker with the largest and most completely developed ooids found in the beach and swash-zone environments. Adjacent beach and storm-berm sands serve as the source for oolitic particles that have constructed dunes as much as 40 ft high.

This observed relationship between ooids forming in the beach and swash zones, and their subsequent deposition in adjacent beach dunes may provide the most reasonable explanation for the topographically high oolitic dunes of Pleistocene age (some as high as 150 ft) that rim many of the narrow shelf margins of the Bahama Banks. In these settings, little evidence appears for extensive offshore bar development. It is possible, though difficult to prove, that production of oolitic coatings in Bahaman submarine tidal bars and banks (Cat Cay, Schooner Cays, south end of the Tongue of the Ocean) primarily occurs during periods of low tide in a beachlike environment rather than during periods of movement associated with strong tidal currents.

This swash-zone method of oolite formation provides an alternative model to the traditional bar mechanism for the formation of elongate oolite sand accumulations. Such a mechanism might also explain extensive ancient oolitic sand sheets that may have grown through lateral accretion of the oolite-forming beach facies, or as a basal transgressive beach facies deposited during a relative sea level rise.

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Carbonate Structural and Stratigraphic Trap with a Diagenetic Twist: West Purt Field, East Texas

The Rodessa Limestone (Aptian) produces from structural and combination traps in the East Texas basin. West Purt field, in northeastern Anderson County, is a Rodessa combination trap where porosity and permeability have been affected by hydrocarbon alteration, adding an additional complexity to the reservoir.

In West Purt field, porous skeletal grainstones successively pinch out obliquely across the crest of a northwest-plunging structural nose. The structure is cut by a eastward-dipping fault that forms the eastern boundary of the field. The reservoir grainstones have been subdivided into 3 facies. Two of these facies are fine-grained to cobble-size, poorly sorted coral-skeletal rudstone, cyclicly interbedded with fine-grained, well-sorted mollusk-echinoid grainstone and packstone. The third facies is the overlying fine to coarse-grained mollusk-peloid grainstone, commonly laminated or graded. The overall sequence is interpreted as a prograding shoreface and foreshore deposit.

Among the more significant aspects of diagenesis are the early formation of moldic porosity that is partially filled with phreatic isopachous and equant calcite spar cements. Later compaction and minor cementation by saddle dolomite and anhydrite had a minimal effect on porosity. The final stage of cementation was the precipitation of solid bitumen. This bitumen causes a moderate decrease in core-measured porosity, but a significant decrease in permeability by plugging pore throats. The presence and distribution of solid bitumen are not discernible on logs owing to the lack of significant density contrast between crude oil and bitumen. Solid bitumen occurs only in wells adjacent to the eastern boundary fault, regardless of structural elevation. Geochemical analyses of bitumen samples suggest that secondary gas from an underlying source (migrating up the eastern boundary fault) caused the precipitation of solid bitumen by deasphalting the in-place oil.

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Oil-Productive Miocene Algal and Sea Grass Carbonate Mudbanks, South Sumatra, Indonesia

Ramba and Tanjung Laban oil fields, located about 70 km northwest of Palembang in southern Sumatra, produce from wackestones and packstones in the lower Miocene Batu Raja Formation. Reservoir rocks are part of relatively small, undolomitized, low-relief carbonate buildups that accumulated on a widespread platform facies. Rocks in the platform facies are dominantly shaly nodular wackestones, whereas rocks in the buildup are dominantly nonshaly wackestones and packstones. The regional setting, the abundance of micrite in the buildups, the absence of both coralline algae and marine cements, and the geometry of the buildups suggest that noncalcareous algae and/or sea grasses were the dominant organisms responsible for forming these mudbanks.

The absence of shale in the mudbanks has been important in forming the secondary porosity that yields most of the oil. Vugs and molds form as much as 30% of the rock in the best reservoir zones. Fractures formed by dissolution and collapse greatly enhance reservoir quality in many places. Another type of porosity, microintercrystalline, occurs within "chalky" micrites scattered through the upper part of the buildups. Porosity in these micrites reaches 25%, but permeability is very low.

The recent discovery of oil in these low-energy carbonate mudbanks of the Batu Raja Formation has opened a new exploration play in the South Sumatra basin. Many similar buildups will likely be found as exploration continues and the basin's paleogeography becomes better understood.

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Southern Appalachian Thrust Model

Synthesis of seismic data, geologic mapping, and satellite imagery suggests a general 3-stage model of thrust and fold development in the Southern Appalachian belt. Essential to the model is the contrast in gross physical properties of the 2 basic rock packages present: (1) lower Paleozoic carbonates and chert, which behave competently, and (2) upper Paleozoic sandstones and shales, which behave incompetently. The individual structural development of each of the 2 rock packages differs but both are directly related to the development of a thrust structure.

Stage 1.—Initial displacement (0-3 mi) creates a large hanging-wall anticline (drag fold) in the lower Paleozoic.

Stage 2.—With greater displacement (2-5 mi), a J. L. Rich model anticline develops in the lower Paleozoic hanging wall. In the process, the upper Paleozoic was bulldozed by the lower Paleozoic, creating more internal folding and faulting.

Stage 3.—With further displacement (> 5 mi), the thrust will probably become a major overthrust. It develops by ramping of the lower Paleozoic through the highly deformed upper Paleozoic with intense penetrative deformation developing in areas of significant overthrusting.

From this 3-stage model, it may be possible to infer source rock and reservoir juxtapositions, relative timing of hydrocarbon generation, and fracture development. The regional distribution of structural types suggests that initiation of thrusting progressed westward with time. The model may have application in other orogenic belts (e.g., the Idaho and Wyoming Overthrust belt.

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Morphologic Variations of Calcite Crystals in Waterfall Travertine Deposits, Arbuckle Mountains, Oklahoma

A motley assortment of low-magnesian calcite morphologies occurs in travertine deposits in Oklahoma. These morphologic variations result from (1) precipitation, (2) dissolution, and/or (3) neomorphism in this nonmarine environment; analogous morphologic variations in both marine and nonmarine strata may likewise indicate nonmarine processes.

Commonly precipitated crystals include hexagonal prisms and rhombohedrons (2-150 μm long), and bladed to fibrous forms (0.02-2 mm long, many revealing triangular cross sections). Many of these crystals contain inclusion-defined growth layers that dissolve preferentially, leaving abundant intracrystalline porosity. This porosity parallels crystal outlines, imparting a nested appearance to the crystals. Partial dissolution also creates parallel "spikes" (4-30 μm long, 1-10 μm wide), and parallel "ribbon" crystals (30-150 μm long, 3-12 μm wide) that repeatedly narrow and widen, and occasionally twist. In addition to precipitational and dissolutional forms, aggradational neomorphism produces columnar crystals, commonly exceeding 8 mm in length. These crystals originated as elongate spar around filamentous cyanophyte tufts and were transformed subsequently into ragged-edged columnar crystals at the expense of overlying micritic crystals.

Morphologic variations in calcite crystals often have been attributed to ionic concentrations (particularly Mg and SO_4) of ambient waters. In this study, however, the low concentrations of both Mg (averaging 12 ppm) and SO_4 (approximately 16 ppm) may be interpreted as supporting theories relating precipitational morphologies to growth rates rather than to "poisoning" ions. In any case, recognition of similar morphologic suites resulting from precipitation, dissolution, and/or neomorphism may aid in the identification of nonmarine processes in marine and nonmarine strata.

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Sedimentation Dynamics About Salt Features

Detailed side-scan sonar and gridded bathymetric surveys on continental margins reveal the existence of numerous submarine canyons. Recently published compilations of current velocities in submarine canyons indicate that alternating and undirectional flows often exceed 20-30 cm/sec with peak velocities ranging from 70 to 100 cm/sec. Current meters attached to the ocean floor have been lost at current velocities of 190 cm/sec. Such velocities are ample to transport sand-size sediments. The results of DSDP Leg 96 show the existence of massive sands and gravels on the Louisiana slope, deposited during the last glacial advance. Thus, present physical oceanographic data may be an analog to conditions during glacially induced lowered sea levels. Salt ridges and domes underlie much of the Louisiana slope, determining morphology. Submarine canyons lace the slope. Given a prograding shelf, the net sediment transport routes will be down the submarine canyons. Sediment deposition patterns around the salt ridges and domes include parallel-bedded foredrifts on the upslope side, lee drifts on the downslope side, and moats along the lateral flanks of the salt features. Major differences exist between the sedimentation patterns around a ridge and a dome. The size and shape of the flow pattern will determine whether there can be a flow over the salt feature with a resulting turbulent wave that may influence sedimentation. Sedimentation patterns about salt features on the present slope should be applicable to similar paleoenvironments.

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Seismic Stratigraphy, Pleistocene Climate, and Tertiary Sea Level Changes

The Quaternary is characterized by 2 climatic signatures: that of the last 800,000 yr, the upper Pleistocene climatic signature (UPCS), and that of the period from 900,000 to 1,800,000 yr ago, the middle Pleistocene climatic signature (MPCS). Glacial cycles within the UPSC are about 100,000 yr long with interglacials of 10,000-12,000 yr duration and a "full" glacial period of 20,000-30,000 yr. The cycles of the MPSC range from 20,000 to 40,000 yr duration. Interaction between the 3 planetary orbital parameters of eccentricity, tilt, and precession are believed to cause the observed climatic signatures.

From DSDP cores, 8 major Miocene hiatuses have been described. There is a roughly equal duration of hiatuses and deposition, with periods ranging from 0.5 to 2 m.y. $\pm$0.5 m.y. The deep-ocean hiatuses correlate well with the seismically determined lowered sea levels of P. Vail. The hiatuses are interpreted to be caused by increased activity of ocean-bottom currents, in turn initiated by increased glacial activity. Thus, it is geologically reasonable that within each period of increased glacial activity there are 100,000-yr long UPSC-type cycles. The UPCS cycles have been tentatively identified in seismic data on the Louisiana, east Greenland, and Caribbean shelves and on the Indus Cone. Miocene glacial cycles should be sought in seismic data using innovative data processing techniques.

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Effect of Biological Markers and Kerogens in Geochemical Exploration for Oil and Gas

The aliphatic hydrocarbons of 29 Tertiary argillaceous rock samples from eastern China have been examined by computerized gas chromatography-mass spectrometry. The steroid and triterpenoid components provide new information for the characterization of depositional environments, organic matter, and maturation of the source rocks. These samples contain gamaceranes, 8,14-open-hopanes, diterpenoid hydrocarbons, and diasteranes. The abundant gamaceranes correspond to the preference of even carbon atoms. The highest gamacerane occurs in the strongly reducing environment. The abundant diterpenoid hydrocarbons relate with the type III kerogen. These diterpenoid hydrocarbons are derived from higher plant forms. The threshold of oil formation can be correlated with the ratio of 20S (22S) and 20R (22R).

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Distribution of Dolomite in Deep Marine Sediments as Function of Time

The distribution of dolomite in deep marine sediments as a function of time was determined for the Cretaceous and Cenozoic, 150 Ma to present, using data from 1,142 DSDP samples. The general distribution patterns for the Atlantic and Indo-Pacific are similar. Their curves show a maximum in the Miocene, minimum in Paleogene, and 2 maxima in the Cretaceous separated by a Cenomanian low. The less time-extensive data of the Gulf-Caribbean and Mediterranean have a Miocene maximum. Red Sea data peak in late Miocene to early Pliocene. The general similar-