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Oil Source Bed Distribution in Upper Tertiary of Gulf Coast

Effective oil source beds have not been reported in Miocene and younger Gulf Coast sediments and the organic matter present is invariably immature and oxidized. Crude oil composition, however, indicates origin from mature source beds containing reduced kerogen. Oil distribution suggests extensive vertical migration through fracture systems from localized sources in deeply buried, geopressured shales.

A model is proposed in which oil source beds were deposited in intraslope basins that formed behind salt ridges. The combination of silled basin topography, rapid sedimentation, and enhanced oxygen-minimum zones during global warmups resulted in periodic anoxic environments and preservation of oil-generating organic matter. Anoxia was most widespread during the middle Miocene and Pliocene transgressions and rare during regressive cycles when anoxia occurred primarily in hypersaline conditions such as exist today in the Orca basin.

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Stratigraphic Applications of Geologic Analysis System

The Geologic Analysis System is a multipurpose data-management and applications software package designed to graphically integrate massive amounts of data to help solve oil and gas exploration and research problems. The Geologic Analysis System includes: (1) TECH/SYS, a technical file-management system that can accommodate multiple files, (2) PICS, a user-friendly geologic mapping and contouring system, and (3) applications programs, which retrieve, manipulate, list, and display a wide variety of rock sample analytical data.

Benefits to the stratigrapher include: (1) publication- or report-ready graphic displays, (2) database edit routines, and (3) both graphically and statistically displayed outcrop sections and cores that objectively define the stratigraphic character of a rock sequence.

The utility of the Geologic Analysis System is demonstrated by a case study involving the Lower Cretaceous (Albian) Blackleaf Formation in southwestern Montana. A TECH/SYS database was created for a composite stratigraphic section of the Blackleaf Formation near Lima. Analysis of the database reveals 4 Blackleaf lithofacies units: (1) lower transitional clastic unit, (2) lower shale unit, (3) upper clastic unit, and (4) upper volcaniclastic unit. To define lithofacies variation objectively, stratigraphically variant data items are graphically displayed and analyzed. These data items include textural elements, porosity, mineralogy, lithology, paleontology, paleocurrent direction, and diagenetic features. Where applicable, bivariate plots, ternary diagrams, and multivariate statistical routines, such as discriminant function analysis and cluster analysis, are used to define the lithofacies variation.

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Role of Geologic Studies in Reservoir Modeling and Enhanced Oil Recovery

Detailed geologic studies have become increasingly important especially for secondary- and tertiary-recovery projects. Success or failure of such projects is strongly dependent on a proper understanding of reservoir heterogeneity. In virtually every case, the reservoir has been found to be more complex than originally envisaged. In some reservoirs, complexity has cast serious doubts on viability of the project as initially formulated.

With development of modern computers capable of handling much larger numbers of grid blocks, different scales of heterogeneity can be simulated realistically. It is possible to simulate complex fluvial channel architecture over an interval of several hundred feet, as well as the effect on reservoir performance of crossbedding of meter scale or less.

Today's reservoir geologist is faced with the challenge of quantifying his conceptual sedimentologic models more precisely. At higher levels of reservoir heterogeneity, probabilistic techniques to predict reservoir configuration between available wells appear promising. Reservoir modeling of individual sandstone bodies is dependent on modern analogs or outcrop-derived prototypes. Textural criteria should be taken into account in the selection of prototypes, as grain size ultimately controls shale barrier distribution and sedimentary structures. Cementation is an important form of reservoir heterogeneity commonly neglected in reservoir modeling. In the case of small-scale reservoir heterogeneity as manifested in cores, carefully planned core analysis programs are required to measure the potential anisotropy caused by sedimentary structures and to determine accurately in-situ properties resulting from clay-mineral diagenesis or overburden stress.

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Geomorphic Features off Southern California as Seen by GLORIA Side-Scan Sonar System

Approximately 165,000 km^2 of the sea floor off southern California was mapped during May 1984, as part of a USGS/IOS cooperative program to study the newly proclaimed Exclusive Economic Zone (EEZ) of the United States Pacific margin. The area was insonified using the Geological Long-Range Inclined Asdic (GLORIA), a long-range side-scan sonar system. Images were corrected for water-column velocity anomalies, for along-track distortions caused by variations in ship speed, and for slant-range distortions caused by acoustic ray travel paths. A photomosaic of the overlapping sonographs has been compiled at a scale of 1:375,000.

The basins of the inner California continental borderland are characterized by both sinuous channel and fan complexes and by feathery acoustic patterns indicating active sediment transport. In contrast, outer borderland basins appear to be more sediment starved, exhibit large areas of sediment failure, and show significant structural influence.

West of Patton Escarpment, the sonographs are dominated by acoustic patterns showing volcanic ridges and seamounts and by deposits of the Monterey and Arguello Fans. Arguello Fan, for example, exhibits multiple sinuous channels that have transported sediment 60 km south from the canyon mouth. These channels coalesce into a single 100-km long, westward-meandering channel that terminates in a 600-m deep box canyon. A zone of sediment failure is identifiable on the north levee of an upper fan channel. Tectonic trends associated with oceanic basement are highlighted by the terminus of the west-trending Murray Fracture Zone and by the prevailing northeast trend of volcanic ridge and seamount chains.

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Effect of Differential Subsidence in Growth-Faulted Regions on E-Log Patterns and Preservation Potential

Detailed electric log correlation, supplemented by cores, in the Eocene Wilcox Group and the Oligocene Frio Formation of the Texas Gulf basin contradicts a commonly held notion that changes in log character across growth faults exclusively reflect changes in environment. An invariable consequence of growth faulting is thickening of a depositional unit in the downthrown block, reflecting a greater subsidence rate. The growth ratio (downthrown or upthrown) varies from just over 1:1 to as much as 10:1.

Analysis and mapping of log character indicate that the basic unit of both deposition and physical correlation is regressive coarsening-upward sequences. In Wilcox deltas, prodelta shales pass up into delta-front sandstones while in Frio barrier-bar or standplains, shelf and lower-shoreface deposits pass up into upper-shoreface sandstones. Regressive packages grade downdip in environment from delta plain and bay or lagoon to offshore marine. Growth faults had no significant surface expression and did not separate contrasting environments.

A marked change in log character (e.g., from smooth to serrated) across a growth fault in a regressive shoreface sequence appears to indicate that the subsidence rate of the downthrown block exceeded a threshold value, enabling preservation of low-energy muddy layers and possibly episodic waning-flow storm deposits that were largely destroyed by fair-weather wave reworking on the upthrown block.

This concept has implications both to regional stratigraphy and reservoir properties. Correlative units can abruptly change log character across growth faults, impeding correlation. Sandstones in the down-

thrown block may contain shale barriers to vertical fluid flow if the threshold subsidence rate was exceeded.

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Distinction of Glacial and Interglacial Cycles in Feni and Gardar Drifts, North Atlantic

The Feni and Gardar drifts of the North Atlantic are thought to represent large accumulations of current-deposited material and should record changes through time in direction and intensity of overflows in the Norwegian Sea and Iceland-Faereo Ridge, respectively. Both drifts were drilled by DSDP Leg 94. Initial shipboard examination revealed no visual differences between these sediments and typical pelagic North Atlantic sediments. Fourier shape analysis on quartz silts, augmented by SEM, showed that each sample consists of a mixture of 3 grain populations. One grain type is covered with surface fractures unmodified by subsequent abrasion. Lack of such abrasion and the fact that the abundance of these grains varies independently of other shape types suggest a glacial-ice rafted origin. A second shape family is covered with irregular, platy silica overgrowths, typical of diagenesis in a poorly sorted, clay-rich environment and is likely the product of erosion of submarine lutites. A third grain type, plastered with fine-grained silica, is characterized by protuberences and indentations typical of primary continental source terranes. These last 2 grain types vary inversely with one another, implying that at glacial maxima, bottom currents deposited first-generation continental material, but at glacial minima, they eroded material from the sea bottom and redeposited it as drift sediments.

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Exploration Potential of Paleozoic Rocks of Morocco

Paleozoic rocks of Morocco have some similarities with the producing Paleozoic sequences in Algeria. In Morocco, there is a basic division between the cratonal sequences of the Tidouf basin and continguous areas and the Paleozoic megabasin to the north and possibly to the west under the present continental shelf areas. The Paleozoic of the northern megabasin has the following positive exploration elements. (1) Both wrench and normal extensional tectonics have produced significant structures that may have been reactivated during 2 later orogenic events. (2) Reservoir quality, although poor in outcrop, can be significantly improved in the subsurface. Wells from the Bojad region of the Tadla basin encountered porosities up to 30% in Devonian clastic sequences. (3) No area can be condemned on the basis of present published geochemical evidence. Burial depths are sufficient for mature hydrocarbons, and rocks with organic material are present in sediments ranging in age from Cambrian to Carboniferous. Paleozoic oil shows have been encountered and may actually serve as the source of hydrocarbon in the Essouira basin in a downfaulted Triassic red-bed sequence. (4) Quality of seismic data is good, even where Paleozoic rocks are onlapped by Mesozoic and Cenozoic sediments.

Drilling for Paleozoic targets has been sparse, hence, few data are available to test both source and reservoir potential. Paleozoic rocks still need to be tested by industry and must be considered a frontier area.

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Eocene Tidal Deposits, Northern San Diego County, California

A transgressive-regressive sedimentation sequence is recorded in a band of middle Eocene strata a few miles wide. An abundance of primary sedimentary structures, along with interfingering relationships and paleontology, define 12 lithofacies representing depositional environments including nearshore shelf, outer and inner barrier island, tidal flats and channels, lagoon and lagoonal delta. Tide-influenced sedimentary features are well defined and include meandering and abandoned tidal channels, oppositely inclined superimposed cross-strata, interlaminated mud and sand along the basal and lateral accretion surfaces of migrating tidal channels, flaser and wavy bedding, and storm-deposited strata.

The first sedimentary half cycle was transgressive and documents the compression of dominantly tidal-flat and lagoonal environments against a steep, hilly coastline by the overall rising sea level of early and medial middle Eocene time. The inboard tidal-flat and lagoonal mudstones (Delmar and Friars Formations) and outboard tidal flat, channel and bar sandstones (Torrey Sandstone and Scripps Formation) interfinger in a landward-climbing, 3-dimensional sedimentary mass that parallels and meets the basement with a pronounced unconformity.

The second half cycle was regressive and occurred in the medial and late middle Eocene. It formed due to the influx of coarser, more angular sediment from the adjacent basement into the narrowed paralic zone. This westward (seaward) progradation of lagoonal delta and inner tidal-flat sandy sediments occurred despite the still-rising sea level.

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Multiple Parallel Microstylolites and Early Diagenetic Pressure Solution in Chalk

Pressure-solution phenomena, including both early-stage microstylolites and late-stage macrostylolites, are locally common in chalk. It is now well known that Upper Cretaceous chalks of northwestern Europe exhibit a wide range of stylolitic development in association with nodular fabrics and hardgrounds, generally in *Thalassinoides*-rich facies. It is not widely recognized, however, that virtually uncemented chalk commonly exhibits extensive microstylolitization of remarkably unique character. Multiple parallel horizontal microstylolites are well-developed in homogeneously white non-nodular pure-calcitic chalks of Denmark and elsewhere. They can be seen, however, only when samples are treated with contrast-enhancing methods, such as the application of light oil, to increase the visibility of small-scale primary and secondary structures in the sediment.

The microstylolites are nearly planar and some are slightly wavy, but almost none are zigzag or sharply spiked. They occur in fairly evenly spaced sets that render a finely laminated appearance to the rock upon close inspection. Typically, each dark lamina is only about 10-50 μm thick, and they are spaced approximately 100-500 μm apart. The lamination planes obviously are diagenetic and not primary, because they are imprinted on top of a totally bioturbated ichnofabric; the tiny dissolution seams cut straight through some burrows and are diverted around others. The relationship of these planar microstylolites to healed hairline microfractures and to various trace fossils, especially *Zoophycos*, suggests that the microstylolites are very early diagenetic in origin, postdating the burrows but predating or coinciding with the microfractures.

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Initial Process of Rifting

The generally accepted model of rifting (the McKenzie model) has certain geometric and spatial constraints that seem to preclude its operation in the earliest stage of rifting. It may be a more advanced stage of the rifting process, if it is correctly described.

An aborted rift system can be studied in the subsurface of the Permian basin. The Delaware, Val Verde, and Marfa basins formed a rift-rift-rift triple junction in mid-Pennsylvanian time, but it never progressed far enough to cause permanent extension. It apparently rose thermally, and then settled back down in place during the cooling cycle. The details of earliest rifting are preserved.

Several geometric factors need to be considered in the rift model. The first is that the earth is a sphere. On a sphere, uplift causes extension, and downwarping causes compression. The dominant fracture system in the brittle crust tends to be vertical, and on a sphere, vertical planes converge at the center.

The rheology of the basement and the overlying sedimentary rocks is different. The basement can be extended areally by dilating the fracture system during uplift and extension, but the sedimentary rocks will be stretched plastically. During the cooling cycles, vertical fractures can close, but there will be sediment to spare. The rocks will be buckled, crinkled, and overturned during the cooling cycle as they are lowered from