

ria associated with pectinacids (*Halobia* sp.) of Late Triassic age. In addition, samples of sediments interbedded with pillow lavas at the top of the ophiolite yielded well-preserved Late Cretaceous (Cenomanian to Turonian) Radiolaria.

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Paleoenvironment and Petroleum Potential of Mid-Cretaceous Black Shales in Atlantic Basins

Cores from the Deep Sea Drilling Project in the Atlantic Ocean have permitted recognition of widespread organic-rich black shales in the mid-Cretaceous. However, geochemical studies have proved that the origin and petroleum potential of this organic matter is highly variable. Three main types of organic material can be recognized in these sediments from kerogen studies: (a) marine planktonic, deposited in a reducing environment; (b) terrestrial higher plants, moderately degraded; and (c) residual organic matter, either oxidized in subaerial environments and/or recycled from older sediments.

Vertical and horizontal variations of these three types of organic matter are illustrated by geochemical logs in each main basin of deposition. Paleogeography and environment of deposition of organic deposits are deduced from these data. The petroleum potential of the sediments is therefore a consequence of the paleogeographic setting. Thus, the zones favorable for oil and gas (given adequate maturation), or those devoid of any potential, can be delineated. Complementary studies of wells on the continental shelf of the North American continent tend to show that the organic characters in the deep basins can be correlated with those recognized in nearshore locations.

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Paleoenvironments of Middle Devonian Sandstones of Upper Mississippi Valley

The Dutch Creek, Beauvais, Lupus, and Hoing Sandstones are supermature quartzarenites associated with transgressive carbonate sequences. They generally have gradational upper and lower contacts. Fossils are mostly fragmentary crinoids, brachiopods, and trilobites. Complete fossils are mostly corals that settled during periods of temporary bottom stability and slow sedimentation.

Unidirectional, planar cross-bedding dominates part of the Dutch Creek, Beauvais, and Lupus Sandstones, indicating paleocurrent movement to the northwest. Local herringbone cross-stratification with associated reactivation surfaces indicates tidal action. Lenticular bodies of Hoing and Lupus sandstone enclosed in calcilutite contain graded sequences and basal conglomerates, suggesting tidal-channeling of banks and shoals.

Parallel lamination and cylindrical structures in the Hoing Sandstone indicate high intertidal environments.

These sandstones all consist of bimodally distributed fine- and medium-sized quartz grains. Medium-sized grains are well rounded to rounded, contrasting with angular fine-grained quartz. Cementation is mostly by sparite and microcrystalline calcite. Locally, secondary silica replaces carbonate. Near faults, quartzitic texture probably results from pressure solution. Interlocking secondary overgrowth locally provides cementation.

Bimodal grain-size distribution, seaward thickening of the sandstone, and an apparently inadequate source suggest eolian transport to the sea across a carbonate terrane prior to marine deposition. This does not require a sabkha, but depends on aridity and sparse plant cover. Subsequent tidal, wave, and current action is believed responsible for ultimate transport and deposition of the sand.

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Shallow-Submarine Seismic Stratigraphy, Mississippi River Delta Front

High-resolution seismic, and engineering borehole data were integrated to interpret the shallow seismic stratigraphy of the Mississippi River delta front. Three seismic stratigraphic units have revealed the transgressive-regressive depositional sequences associated with late Pleistocene glacio-eustatic changes in sea level. Each of the stratigraphic groups was found to consist of a lower clayey unit and an upper fine-sand and shell unit. Paleotopographic maps of the stratigraphic units reveal the morphology of the former continental shelves. Structural features observed within the delta front area include shelf-edge growth faults, a salt diapir, and an extensive erosional unconformity which is believed to be the result of a large slide mass of early Holocene age.

The modern, prodeltaic sedimentary wedge includes up to 100 m of soft, underconsolidated, gas-bearing silty clays, deposited during the past 500 years. The thickness of this unit within the delta-front area has been mapped.

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Computer Applications of Petroleum Data System

The Petroleum Data System, a collection of general field and reservoir information, has been available for public use for approximately 3 years. Data have been used in a variety of studies by oil companies, consultants, and government agencies. In particular, many studies have been done in an effort to determine the potential of specific basins for future exploration and drilling, the feasibility of certain types of enhanced recovery techniques, and future reserves from existing fields. The different types of output are histograms, scatterplots, bargraphs, correlations, simple listings, and summary reports obtained by manipulation of the data in the file. These examples illustrate problems that have to be faced in working with large data bases, such as

missing data, conflicting data, and fuzzy or nonstandard data definitions.

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Analytic and Interpretive Procedures for Geologic Applications

The extraction of geologic information from remotely sensed data, which consist of encoded radiometric signals detected above the terrain, is procedurally governed by the same logical sequence and argument employed by a geologist when the data are typical ground-based observations and measurements. Each respective data set relates physical and compositional conditions of the geologic environment. In either situation, the sequence of problem definition, data collection, data reduction, interpretation, and testing is followed and, commonly, dictates the geologist's success or failure in arriving at an adequate geologic interpretation.

The most useful data format for geologic analysis and interpretation is an image display in which both radiometric and geometric relations in the data can be correlated with conditions on the earth's surface. The objectives of applying a systematic approach in obtaining geologic information from images are: (1) to provide a framework in which geologic interpretations are logically derived from the imaged data; (2) to separate the more objective aspects of image analysis from the subjective considerations imposed on a geologic interpretation; and (3) to facilitate the efficient reduction of imaged data by separating tasks, concentrating attention, and thereby minimizing omissions.

In geologic investigations, imaged data are analyzed and their geologic significance is interpreted; consequently, both spectral and spatial aspects of the data are considered in deriving geologic information. Preceding the interpretation of geologic relations, the data must be grouped according to their spectral characteristics. Subsequently they are reduced into landscape elements based on their spatial distribution and association. These two actions, the spectral classification and spatial reduction, constitute the two phases of image analysis. The interpretation of geologic information from the analyzed data must be made by a person trained in geology. Beyond this, the individual must be able to correlate and interpret the geologic significance of the landform, drainage, and cover patterns that are products of image analysis.

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Geologic Significance of Sedimentary Reflectors in Deep Western North Atlantic

Several major seismic reflectors in the deep western North Atlantic have been calibrated according to age and physical and lithologic nature by JOIDES drilling. These reflectors result from geologically abrupt changes in depositional conditions and lithofacies. Within the limits of biostratigraphic resolution, the reflectors are approximately but not strictly synchronous, and sedi-

ment accumulation, although commonly changing in rate, was continuous across the seismic boundaries. Major reflectors include horizon B, which ranges between Hauterivian and Barremian in age and correlates with an upward change from limestone to black clays coincident with a rise in the calcite compensation depth (CCD). In middle to late Maestrichtian time, a brief, sharp depression of the CCD caused widespread deposition of chalks that correlate with horizon A. This reflector commonly conforms to preexisting topography, a fact which suggests its pelagic origin. Widespread deposition of sediments enriched in biogenic silica occurred during the Eocene, and diagenesis formed chert beds in the upper lower to lower middle Eocene section. The top of these cherts matches horizon A^C, which is one of the most laterally extensive reflectors in the western North Atlantic. Across the western Bermuda Rise, an overlying reflector, horizon A^T, correlates with the top of a sequence of turbidites deposited prior to and during uplift of the rise in the latter half of the Eocene. Limited biostratigraphic data at JOIDES boreholes suggest that the reflector is diachronous; this probably results from gradual westward offlap of the turbidites as the Bermuda Rise was uplifted. One major reflector, horizon A^U, is not within a continuously deposited sedimentary section, but corresponds to a major unconformity eroded between late Eocene and early Miocene time by abyssal currents along the lower continental rise. Sedimentation patterns mapped from the distribution and spacing of these reflectors are used to interpret the paleo-oceanographic conditions in the basin.

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Models for Evolution of Interior Basins

The structure of many interior basins is dominated by lithospheric flexure. A wide range of observations has confirmed that the outer shell of the earth, which has a temperature of less than about 600°C, behaves elastically on geologic time scales. This behavior is consistent with theoretical and laboratory studies of rock rheology. The linear structure of the Appalachian basin and the near circular structure of the Michigan basin can be attributed to lithospheric flexure under loading. In general, the structure of sedimentary basins with horizontal scales of a few hundred kilometers can be attributed to lithospheric flexure. The time evolution of many sedimentary basins appears to be governed by the thermal time constant of the lithosphere (i.e., about 100 m.y.). A simple model for the subsidence of sedimentary basins assumes that the lithosphere is initially hot; as the lithosphere cools its density increases and it subsides. This simple model explains the subsidence record of parts of the Los Angeles basin. This mechanism does not appear to be sufficient, in itself, to explain the subsidence of interior basins such as the Michigan basin. An additional mechanism such as a thermally activated phase change is required.

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