

blocks may occur at other Devonian bank margins in both the surface and subsurface. Recognition of such deposits can assist in determining bank proximity; in better interpretation of bank and bank-margin genesis; in determining time of diagenesis, particularly cementation and dolomitization; and in correlation.

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PERMEABILITY-POROSITY PATTERNS OF SOME RECENT SEDIMENTS

Permeability, porosity, and textural analyses were conducted on 1,016 sand samples collected from river point bars, beaches, and dune fields undergoing active sedimentation. A total of 326 samples are from point bars on the Whitewater River in southwestern Ohio and the Wabash River in western Indiana; 531 samples are from beaches on the Bolivar Peninsula in Texas, Ship Island in Mississippi, and Santa Rosa Island in Florida; and 159 samples are from dunes on Santa Rosa Island and St. Andrew's Beach in Florida.

River point-bar sand samples have permeability values ranging from 160 md to more than 500 d and average 93 d. Porosity values range from 17 to more than 50 percent, and average 38. Permeability-porosity values for point bars are highly variable and show a systematic pattern related to positions on the bars.

Beach and dune sand samples have very similar permeability values, which range from 3,600 md to 166 d and average 60 d. Porosity values range from 30 to more than 65 percent, and average 45. Permeability-porosity values for beaches and dunes show a low variability and a poorly developed pattern related to positions within the environments.

Permeability and porosity values in all three depositional environments have low correlations with textural parameters. In some point-bar sands, high percentages of silt and clay account for low permeability values. However, high permeability and porosity in river-bar, beach, and dune sands are not well correlated with large grain sizes and good sorting; instead, packing seems to be the primary controlling factor.

Comparison of permeability-porosity values of these Recent sediments with available values from comparable ancient sediments shows that the Recent sediment values are several orders of magnitude higher; however, Recent sediments do show the same degrees of variability and distribution patterns as those in the ancient sediments.

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SOLE MARKS IN SILTSTONE OF NONTURBIDITE ORIGIN

Sole marks and other directional structures generally assumed to be of turbidite origin have been found as common features in shallow marine siltstone and shale of Ordovician to Mississippian age in Ohio, Kentucky, and Indiana. The sole marks include: flute casts, load casts, groove casts, current crescents, prod marks, bounce marks, brush marks, and channel casts. Other directional features include: micro-ripple marks, micro-cross lamination, oriented fossils, ripple marks, and cross-bedding.

Comparison of sole-mark orientations with associated cross-bedding directions, shows a high degree of directional similarity. In those fine-grained sequences, where cross-bedding is rare to absent, the ubiquitous

sole marks are the only reliable and available indicators of paleocurrent pattern.

This study suggests that paleocurrent investigations of shallow marine sequences need not be restricted to the coarse-grained sediments, since the fine-grained siltstone and silty shale also may have abundant directional features in the form of sole marks.

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X-RAY DIFFRACTION ANALYSIS OF HEAVY MINERALS

Suites of heavy-mineral samples from the Upper Cretaceous sediments and Recent littoral sediments of the eastern Gulf coastal plain have been analyzed by X-ray diffraction techniques and conventional optical methods. Initial results indicate that X-ray diffraction can be used as a routine, rapid, and supplementary method of analysis for large numbers of heavy-mineral samples. Distinctive patterns for specific mineral suites are produced and meaningful associations are thereby determined, from which smaller numbers of samples are selected for detailed, conventional, optical analysis. Detailed identification and quantification of individual mineral elements in each of the irradiated samples are not the immediate purposes, but are possible.

Techniques have been developed to yield reproducible results and to overcome some of the problems inherent to the X-ray diffraction analysis of small, highly cleavable, and high iron content mineral samples. This technique requires uniform grinding of samples to less than 4 microns and the randomly oriented mounting of the particles in an X-ray transparent medium. Variables important to reproducibility and interpretation of data produced by this technique have been studied and their effects determined. These variables include mineral composition, texture of original sample, superimposition of peak positions, size of sample, grinding, orientation of mounted grains, mounting media, and irradiation variables.

Heavy-mineral samples from the Upper Cretaceous sediments in the eastern Gulf coastal region can be separated readily into several distinctive X-ray diffraction-pattern associations that are identical with associations determined by detailed and time-consuming optical analysis.

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MINERALOGY, STRATIGRAPHY, AND ORIGIN OF LOWER TERTIARY CLAYS AND CLAYSTONES OF ALABAMA

The Alabama Tertiary rock units studied include, in ascending order, the Clayton, Porters Creek, and Nabeola Formations of the Paleocene, and the Nanafalia Formation, Tuscahoma Sand, and the Hatchetigbee and Tallahatta Formations of the lower Eocene.

Throughout the area the lower and middle part of the Clayton Formation and the upper part of the Nanafalia Formation contain the zeolites clinoptilolite, heulandite, and a "mixed form" with structural characteristics of both clinoptilolite and heulandite. These occur with cristobalite and montmorillonite. Heulandite and montmorillonite occur in the thicker clays of the Porters Creek Formation in western Alabama. Clinoptilolite is the predominant constituent of a lower Tallahatta clay in western and central Alabama. A cristobalitic claystone makes up the upper

two thirds of the Tallahatta in western Alabama, whereas it is interlaminated with clinoptilolitic clays in central Alabama. In the eastern part of the state the upper Tallahatta claystone consists of cristobalite and montmorillonite.

No evidence indicates that montmorillonite is other than a detrital constituent in the clay and coarser grained sediments of the Naheola and Hatchetigbee Formations and the Tuscahoma Sand. However, montmorillonite could be considered a diagenetic mineral where it occurs as a part of a mineralogic suite that includes cristobalite and/or the diagenetic sedimentary zeolites clinoptilolite and heulandite.

Considering these mineral suites, it is suggested that clinoptilolite was formed from volcanic ash of a rhyolitic composition in a nearly closed hydrated system. Paragenetically, heulandite and then montmorillonite would develop from clinoptilolite through a desilicification process whereby cristobalite would have evolved as a byproduct. Conversely, it is plausible that, except for clinoptilolite, each zeolite species and montmorillonite were formed individually from volcanic ash in an open hydrated system. In the case of heulandite some silica would need to be deleted from the reacting system. However, montmorillonite development would entail not only a deletion of some silica but also an addition of magnesium. Therefore, similar mineral suites could evolve in either of two reacting systems, open or closed.

Cristobalite, where it occurs as distinct but lens-like strata and not associated necessarily with the sedimentary zeolites or montmorillonite, is believed to be a primary mineral precipitated locally on a broad marine-shelf area according to Oswald's step rule.

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MEASUREMENT OF SHEAR STRENGTH, BULK DENSITY, AND PORE PRESSURE IN RECENT MARINE SEDIMENTS BY *in-situ* PROBES: RESULTS OF 1967 SHALLOW-WATER TESTS

Three telemetering probes designed to rest on or in fine-grained sediments of the sea floor and to make in-place measurements were used successfully at sea from the USC&GS ship *Davidson* during the summer of 1967. The test and evaluation site was a pocket of clay in the Wilkinson basin, Gulf of Maine; water depths ranged from 240 to 290 m. A tower about 4 m high and 2.4 m wide at the base was lowered to the sea floor. Within the tower was contained a motor-driven shaft to which was attached either a torque assembly and a vane for measuring shear strength, or a two-legged probe containing a Cs-137 isotope source in one leg and a scintillation detector in the other for measuring bulk density by gamma-ray transmission. The motor was operated remotely by command from the ship. Vane rotation measurement made by strain gauges was telemetered through 3.6 km of electrical cable to the surface and recorded on an x-y plotter aboard the vessel. Pulses from the gamma-ray apparatus were transmitted directly over the electrical cable to the ship, where they were counted.

Shear strength was measured at eight localities in successive 30-cm intervals to a depth of 2.5 m below the bottom. Bulk density was measured at five localities in successive 2.5-cm intervals to a depth of 1.5 m below the bottom. The in-place results have been

compared with laboratory measurements of shear strength and bulk density made on sediment cores collected in 1966 from the same localities. In-place vane shear strength distinctly is higher than laboratory vane shear strength and lower than laboratory Swedish fall-cone shear strength. All bulk density values determined by in-place and laboratory gamma-ray transmission methods and by the weight/volume laboratory method are nearly identical.

Pore pressure was measured successfully in place at one location by a differential piezometer probe that telemetered results over the electrical cable to a ship-board computer. The results obtained from this probe are not conclusive because of problems with the cable.

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AMAL FIELD, LIBYA

Oil was discovered in November 1959 at Amal field, Libya, located in the eastern part of the Sirte basin, in well B1-Concession 12. The exploration technique utilized was reflection seismic because there is no surface topographic expression in this area. The field now includes more than 100,000 acres and extends north-south for 30 mi and east-west for approximately 10 mi. To date 81 wells have been drilled in the field, 76 of these being producers. The outer configuration of the gross reservoir has been defined on the north and on the southeast. The gross oil column is as thick as 600 ft in the most favorable areas.

The Amal field accumulation is on a plunging horst block extending northwest from the old ancestral basement knob, the Rakk high. The field is interpreted from seismic and gravity data to be bounded on the west and east flanks by large fault systems.

The principal reserves in the field are contained in the Amal Formation, a fractured, quartzose sandstone of Cambro-Ordovician age and the Early Cretaceous Maragh Formation, a sandstone interbedded with siltstone and shale. The Amal Formation in most of the field is unconformable below the Cretaceous Rakk Formation, and is at a depth of 10,000 ft. The Maragh Formation is on the north and east flanks of the main horst block; it is a transgressive marine Lower Cretaceous unit.

Several prolific oil fields have been discovered in association with the ancestral Rakk high. These are the Amal field (1959), the Nafoora field (1965), and the Augila field (1966). Several hundred million barrels of reserves have been established by the operating companies in this geological province since Mobil's first discovery. Additional exploration within this general area will discover new and additional petroleum accumulations.

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MIRROR IMAGE OF CLIMATE-CAUSED FORAM EXTINCTION: PACIFIC AND GULF COASTS

Pacific Coast foraminiferal correlations combined with those of Lamb (1964) show that there are synchronous mirror-image biostratigraphic trends in the Oligo-Miocene of the Pacific and Gulf coasts of North America. Correlation has been established by using restricted but phylogenetically overlapping, rapidly evolving uvigerinid lineages, planktonic forami-