voirs has stimulated detailed analysis of the generation and occlusion of porosity in these rocks. Porosities, which may exceed 45%, reflect conditions of sedimentation and subsequent diagenesis. Sedimentation rate, a function of skeletal productivity and dissolution within the water column, influences cementation at the seafloor. Intraparticle porosity is relatively rare and is found primarily within foraminiferal tests. The more abundant primary interparticle porosity is imprinted during deposition, and reflects calcareous nannofossil preservation. Highest porosities are characteristic of zones containing relatively well-preserved nannofossils. Porosity in chalk may be secondarily enhanced by fracturing.

Initial porosity is reduced by mechanical compaction (dewatering), by solution-transfer of calcite, by growth of authigenic clays, and by precipitation of silica on skeletal elements. These siliceous coatings and locally abundant chert nodules are interpreted as products of remobilization of biogenic opal. Although these observations and interpretations are based on North Sea chalk reservoirs, exploration in frontier areas should reveal chalks with similar features and comparable reservoir potential.

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Sedimentation in Mississippi Trough, Gulf of Mexico

Interpretation of high-resolution seismic data indicates that the Mississippi Trough was eroded, and then partially filled, by submarine gravity flows. These flows occurred primarily during late Quaternary stages of lowered sea level. Present-day mass transport appears to be a combination of seafloor creep and low-velocity turbid-layer flow.

An acoustically chaotic seismic facies characterizes the deeper parts of the trough fill. Visible reflectors are discontinuous, wavy, and subparallel; they commonly disappear into almost reflectorless, seismically homogeneous units. Sediments deposited lateral to the chaotic facies are commonly composed of continuous, parallel reflectors. These strong reflecting units were deposited as onlapping fill and ponded sediments, and many are confined to semienclosed depressions within the trough walls. These various seismic-facies units represent the "freezing-in" stage of submarine-canyon sedimentation, and may result from separate submarine debris flows. The deposits of the Mississippi Trough debris flows are fine-grained sediments generated by mass failures of oversteepened deposits which occurred at the mouth of the ancestral Mississippi River. High-energy gravity flows thoroughly mixed the depositional material, leaving little bedding to produce coherent seismic-reflector patterns. Debris flows generated lower velocity gravity flows, which moved independently and lateral to the main flows. The onlapping fill deposits and sediment ponding were deposited by lower velocity flows.

Recent sediments, which were sampled by piston coring along the axis of the trough, are rapidly deposited, hemipelagic, olive-gray silty clays. Sedimentary structures are limited to scattered, very thin laminae and thin beds. Clay sedimentation has been continuous during the late Quaternary, as is revealed by the clays containing mixtures of indigenous planktonic Foraminifera, displaced shallow-water microfauna, and terrigenous mineral grains.

Large diapirs controlled the position and flow direction of the main erosional channel. Small feeder channels were eroded into the walls of the trough. Trough-wall sediments cover a steep erosional escarpment; they have moved downslope by slump and creep failure. An isopach map of the canyon fill, above erosional surfaces, outlines a linear channel-fill deposit.

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Gamma-Ray Spectral Logging Data Assist in Geologic Studies

Natural gamma-ray spectral logging in open and in older, already cased wellbores has a broad problem-solving capability in evaluation of clastics, carbonate rocks, evaporites, and igneous formations.

Geologic application of such gamma-ray spectral data on a qualitative basis includes detailed stratigraphic correlation, identification of rock types, presence of secondary porosity and natural fracture systems, recognition of the depositional environment and source-rock potential of shales, location of watered-out intervals in reservoirs under enhanced recovery, etc; and on a qualitative basis, the determination of reservoir shaliness, in-situ potash concentration, etc.

Basically, natural gamma-ray spectral logging techniques yield a calibrated, continuous record of the total natural gamma-ray radioactivity and the individual potassium, uranium, and thorium content of subsurface formation as illustrated by field studies from the United States, the North Sea area, South America, and the Middle East.

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Videotapes of Active Primary Physical and Biogenic Sedimentary Structures of Epicontinental Shelf, Northern Bering Sea

Videotapes from 23 camera stations in the northern Bering Sea provide a unique view of the formation and modification of primary sedimentary structures in the marine environment. The study area is a shallow-water (<35 m) ridge and swale terrane located west of Seward Peninsula and south of Bering Strait, Alaska. Strong, north-flowing, unidirectional currents of Alaskan coastal water dominate the region. Ancillary information collected at each station includes bottom samples, surface-to-bottom current-meter and light-transmission data, and high-resolution seismic reflection and side-scan sonar records.

Ridges exhibit 5 to 10 m of relief and are mantled by fine to medium, moderately well-sorted detrital sand. Bed forms observed on ridge crests and flanks include wave and current ripples and two populations of sand waves ($\lambda \cong 15$ m and $\lambda \cong 200$ m). Videotapes recorded atop sand ridges show modification of ripples in response to oscillatory bottom currents. Observations of

small bottom-dwelling fish escaping from bottom ripples provide evidence of penecontemporaneous bioturbation of sedimentary structures. Ripple migration and bottom transport of many starfish occur as a result of strong (>25 cm/sec) bottom currents. Swales between sand ridges are covered predominantly with mud, generally devoid of bed forms, and contain local patches of shell accumulations. Current speeds are reduced (<15 cm/sec) and strongly asymmetric in the swale areas. The videotapes show the transport of fine-grained sediment and organic material in suspension and the formation of burrows, trackways, and trails by benthic organisms (crabs, worms, and shrimp).

The information conveyed by these videotapes is useful for interpreting primary sedimentary structures in adjacent lithofacies of ancient epicontinental-shelf deposits.

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Variations of Morphology and Sediment Transport Within Crenulate-Bay Beaches

Crenulate-bay beaches, common geomorphologic features associated with rocky headlands, were studied on Kodiak Island, Alaska. Grain size, sediment-transport direction, and slope variability were analyzed at four mixed sand, granule, and pebble crenulate-bay beaches ranging from 600 to 2,000 m in length. Nine stations were set up along each beach with a profile measured at every other station. At each station, two replicate samples were similarly collected at three sites normal to the beach. Sampling involved collection of 960 cc of beach material, measurement of the volume of each pebble over 2 cc as well as intermediate axis, shape, and analysis of composition. Individual grains <2 cc were labeled as "fines," cumulatively measured volumetrically, and a small sample was brought back to the laboratory for standard size analysis. A computer-generated wave-refraction diagram was used to determine wave-refraction, diffraction, and reflection patterns which helped to determine transport directions.

Results indicate: (1) Grain size coarsens toward the center of each crenulate-bay beach. Within the four beaches, an average of 80 to 90% coarse material (>2 cc) is present in the center, and 30 to 65% coarse material is found at the tangential and "shadow zone" ends. (2) Grain size and sorting decrease seaward. An average of 23% more coarse material is present at the landward than at the most seaward sample site. (3) There is a constant increase in beach slope from the "shadow zone" end to the tangential end of each crenulate bay. (4) Grain-size data do not support the tangential end sediment transport for crenulate-bay beach morphology that has frequently been reported in the literature.

Because equilibrium-beach development due to construction of an artificial headland by coastal engineers takes on a crenulate-bay morphology, understanding of natural crenulated-bay beaches is especially important.

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Synthesis of Protodolomite, High-Magnesian Calcite, Hydromagnesite, and Nesquehonite from Calcium-Magnesium Bicarbonate Solutions by Freeze Drying

The synthesis of true cation-ordered dolomite at low temperature has been tried many times in the past without success. However, the natural formation of early diagenetic dolomite in various marine and nonmarine sedimentary environments is frequently observed when magnesium-calcium solutions of molar ratio greater than seven react with preexisting calcium carbonate. We have been able to synthesize protodolomite via an intermediate, amorphous Ca-Mg-carbonate phase from $CaCO_3$ and $MgCO_3$ solutions with a ratio of Mg/Ca = 1. Our experiments were as follows.

Reagent grade $CaCO_3$ and $MgCO_3$ were dissolved (0.01 molar) in distilled water with the following Mg/Ca ratios: 0.2, 0.5, 0.8, 1.0, 1.7, 3.0, 5.3, 25. Freeze drying these solutions produced X-ray amorphous Ca-Mg-carbonate phases (gels). These substances were then moistened with distilled water and maintained in sealed tubes at 55°C for a week.

A definite relation was observed between the final crystalline product and the Mg/Ca ratio of the initial solution. Solutions with a Mg/Ca ratio up to 0.8 formed only low-magnesian calcites with varying magnesium content. At a ratio Mg/Ca = 1, protodolomite was obtained within the composition range of $Ca_{0.65}$ $Mg_{0.35}$ to $Ca_{0.54}$ $Mg_{0.46}$. At a ratio Mg/Ca >1.7, high-magnesian calcite with a maximum of 19 mole $MgCO_3$, as well as hydromagnesite and nesquehonite, developed.

The synthesized protodolomite consisted of spherules (diameter 1 and 5 μm) and spherular aggregates. The X-ray patterns, differential-thermal-analysis curves, and the congruent solubility of the material clearly distinguish it from other low-temperature magnesian calcite and prove that protodolomite (according to its original meaning) was synthesized.

There is some evidence of protodolomite formation resulting from this mechanism in nature. We have found protodolomite with a radiocarbon age of only a few decades in speleothems of the Eibengrotte (a small cave in West Germany), and C. C. von der Borch and J. B. Jones have described modern spherular dolomite from sediments of the Coorong area in South Australia.

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Structural Evolution of Michigan Basin and Its Petroleum Potential

Well data suggest that the Precambrian basement of the Michigan basin is highly faulted with vertical tectonics exerting a dominant control over basin structures. A single deep test on the mid-Michigan gravity high penetrated at least 5,000 ft (1,500 m) of Precambrian(?) red beds, suggesting the presence of a rift or graben.

An embryonic form of the Michigan basin was present in Cambrian time. The basin, in approximately its present dimensions, was created during the Middle Ordovician. Two phases of maximum subsidence occurred during the Paleozoic: 4,000 ft (1,200 m) of Silurian sediment, topped by several major unconformities, is followed by 3,800 ft (1,140 m) of Devonian strata. Variations in thickness and sedimentary facies in the Silurian