continental crust. Throughout this program, particular thought will be given to involvement of a larger scientific community in potential research activities.

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Source-Rock Potential of Evaporitic Environment

Examination of modern saline lakes, solar ponds, and lagoons shows that the evaporitic environment can be very productive of organic matter. Few species survive in the brines, but those that do survive commonly exist in abundance. In a model evaporitic embayment, the flow of surface currents is persistently toward regions of highest salinity, so that there is a continual supply and concentration of those nutrients being brought into the saline environment. Prolific growth of phytoplankton may occur, analogous to phytoplankton blooms in areas of upwelling in modern oceans. Only carbonates precipitate in the "mesosaline" part (4 to 12% salinity) of the marine evaporitic environment and no great dilution of organic matter by clastic or biogenic sediments occurs. Because of stratification of the brine and the chemically reducing conditions associated with brines, much of the organic matter produced is preserved. The result may be a potentially rich carbonate source rock, frequently unrecognized in the geologic column. In the Middle East, mesosaline conditions have occurred many times from Triassic to Cretaceous and may be responsible for the vast reserves of petroleum in the area. Evaporitic conditions may also have played a part in the petroleum productivity of many other basins, including the Michigan, Paradox, Williston, and Devonian of western Canada.

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Patterns of Shallow-Marine Deposition, Upper Cretaceous of Northern Colorado

Economically important sandstone bodies encased in marine shales have been described from the Western Interior region of Utah, Colorado, Wyoming, and New Mexico. Our study of a part of an Upper Cretaceous shelf region in northern Colorado shows that the occurrence and distribution of shelf sands were dependent upon a large dynamic sediment system associated with both major and minor transgressive-regressive phases.

Discrete sandstone members of the Mancos and Pierre Shales represent beach, distributary mouth bar, shoreface, and mid-shelf bar deposits. Texture, sorting, bioturbation, thickness, and bed forms of these units are variable, reflecting the variation in rate of deposition and wave energy. Evidence of transgressive reworking is present locally on the caps of some units. Although some sandstone members (e.g., the Hygiene) have been previously correlated over seaward distances exceeding 50 mi (80 km), our detailed examination of cross-bedding patterns and composition indicates deposition in distinctly different shallow-marine environments. Bed forms (medium-scale tabular cross-beds) and lithology of easternmost exposures of the Hygiene are similar to those in modern sand bars on the United States Atlantic, Bering Sea, and North Sea continental shelves, suggesting deposition at mid-shelf depths. Sources of sands were to the west; dominant direction of transport, however, was to the south.

Key factors in the Upper Cretaceous were the relation between nearshore depositional environments and mechanisms of sediment transport on the shelf. Nearshore sedimentation rates apparently were high but episodic; shelf areas were broad and shallow resulting in discontinuous seaward progradation of delta-front sheet sands; and minor, local transgressive phases, as well as major phases, had impact on the geometry and stratigraphic associations of discrete marine sand bodies during the Late Cretaceous.

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Processes Controlling Characteristics of Surficial Sand Sheet, U.S. Atlantic Outer Continental Shelf

A surficial sand sheet covers almost the entire Atlantic outer continental shelf of the United States. Until recently, the processes controlling the characteristics of this sheet were inferred mainly from the texture and composition of bottom grab samples and from the bathymetry. Studies of these aspects outlined the general nature and age of major processes, but they were necessarily limited in scope.

With the advent of leasing of the outer shelf for petroleum exploration, many process-oriented studies were initiated by the U.S. Geological Survey. These studies included measurements of the velocity of bottom currents, the frequency of bottom-sediment movement, the kinds and amounts of suspended sediments in near-bottom waters, and the acoustic and sedimentary characteristics of the shallow subbottom strata. These new measurements, when used in conjunction with previous data, show that attributes of the surficial sand sheet such as the thickness, volume, composition, texture, and internal structure have been controlled by a variety of ancient and modern processes. Ancient processes include those associated with glaciers, ancestral rivers, nearshore-marine environments, and subaerial solution and erosion. Modern processes include tidal-, wind-, and wave-driven currents, internal waves, movement of water masses, regional circulation patterns, sediment bioturbation, latitudinal changes in biogenic components, and bottom fishing. A knowledge of the various factors effecting the sand sheet is fundamental to (1) an understanding of its general geologic history; (2) the paleoenvironmental interpretation of ancient sand strata; (3) a determination of the distribution and fate of anthropogenic sediments and pollutants; and (4) an evaluation of potential sand resources and geologic hazards.

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Environmental Control of Trace Fossil Morphology

Sandstones, shales, and coal of the Fentress Formation (Lower Pennsylvanian) of north-central Tennessee were deposited in a complex of deltaic and nearshore environments. A geographically restricted unit near the top of the Fentress consists of laminated, fine-grained sandstones with thin interbedded mudstones. It grades laterally into cleaner sandstones lacking mudstone interbeds. Exceptionally well-preserved trace fossils occur on large exposed, bedding-plane surfaces. Commonly, individual traces can be followed for considerable distances allowing direct comparison of behavioral patterns between the fossil organisms and modern counterparts.

Polinices duplicatus produces traces of different morphology in intertidal environments at Barnstable Harbor as a response to both depth of movement beneath the substrate-water interface and sediment grain size. In tidal channels, V-shaped trails result from snails moving several centimeters below the sediment surface. On high tidal flats, the trail is wider and shallower as the snail moves nearer the surface. On compacted sands, the trace has transverse markings resulting from surface probing by the snail's foot. Experimental results indicate that *P. duplicatus* produces more V-shaped and deeper traces in coarse sands than in muddy sands.

Traces in the Fentress Formation also exhibit differing morphology attributable to depth of movement and sediment grain size. Single traces from clay-rich parts of the Fentress sandstones change from V-shaped to bilobed and finally to longitudinal rows of tiny knobs produced, apparently, by movement at decreasing depth below the sediment surface. Traces produced in coarser sands are flat-bottomed and lack transverse markings.

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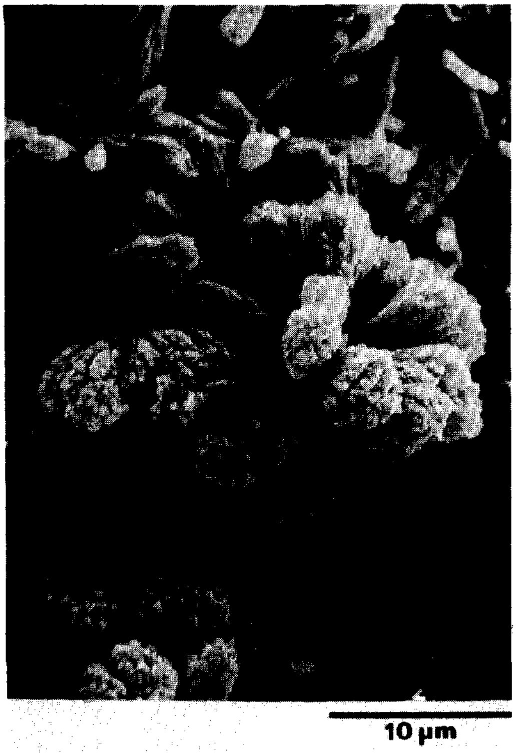
Early Cementation by High-Magnesium Calcite from Gulf Coast of Louisiana

Sandstone pebbles can be found on many of the Gulf Coast beaches of southern Louisiana. Preliminary analyses indicate cement composition to be high-magnesium calcite with 10 to 15 mole % magnesium carbonate. Petrographically, the cement appears in the form of blades and fibers. SEM observations, however, indicate a complex arrangement of stacked euhedral to subhedral crystals.

Field observations have led to the discovery of the lithified sandstone in situ. Cementation occurs along a narrow band between beach dunes and a salt-water marsh on the leeward side of the dunes. Apparently lithification occurs at or near the surface where high temperatures and salinities exist in a supratidal environment. X-ray analyses indicate a cement composition of high-magnesium calcite. The mole percent of magnesium carbonate ranges from 20 to 50%. Although mole percentages are high, X-ray analyses do not indicate the presence of well ordered dolomite. Petrographically, the calcite appears both as a "microspar texture" and fiber-radiate rim cement. As with the reworked sandstone pebbles, SEM observations indicate the presence of stacked euhedral to subhedral crystals that average 0.25 µm in diameter. These aligned or stacked crystals form pseudofiber bundles and blades. Preliminary studies indicate that the in-situ high-magnesium calcite is unstable and probably undergoes molecular leaching when exposed to normal sea water. This is exemplified by the composition of the reworked sandstone pebbles.



KOSTECKI, JOHN A., and VENKATARATHNAM KOLLA, Lamont-Doherty Geol. Observatory of Columbia Univ., Palisades, NY, and PULAK K. RAY, State Univ. College at Buffalo, Buffalo, NY

Lithology and Structures of Quaternary Sediments of Indus Fan

The surface sediments of the Indus fan are primarily chalks, marls, and brown clays. Massive terrigenous sediment dilutions occur only in the areas within 100 km from the Indus River confluence. Throughout most of the fan, underlying the sediments, are gray-green muds and turbidites of Pleistocene age. However, the details of lithology and structures of Pleistocene sediments vary from region to region in the fan. The sediments of the upper fan region are primarily fine-grained muds (with several, small silt beds, T_{d-e}), except on the valley floors where coarse-grained turbidites (T_{a-e}), are commonly present. Two main valley systems, one eastern and the other western, exist on the upper fan. Bioclastic turbidites are common in the eastern valley system, and are derived from the sediment slumps of the Indian margin. Most of the terrigenous, coarse-grained sediments have bypassed the upper fan and reached the