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Complex-Mixing Dolomitization of Supratidal Deposits, Ambergris Cay, Belize, Central America

Extensive dolomitization of Holocene sediments is occurring on humid supratidal flats adjoining lagoons in the interior of Ambergris Cay. One such flat (Tomas Savannah) caps 3 discrete emergent beach-ridge and washover-swale sand and mud systems that prograded over an irregular, karstic surface of Pleistocene limestone. The *Scytonema*-covered sediments of the flats are dominantly Mg-calcitic peneroplid (foram) sands and micrites, with subordinate amounts of aragonite from cerithids and bivalves. The relict beach ridges stand as much as 30 cm above mean sea level, whereas adjoining swales are nearly perennially bathed in waters of varying salinity. The most-landward swale occupies a bowl on the Pleistocene surface and is the locus of dolomitization on the flats. The sediments of the swale are a 0.7 m thick section of graded sandy muds in which 3 superposed dolomitic crusts (each 10-15 cm thick) are present; the middle and upper crust are dated at 1,700 and 905 yr B.P. (± 130), respectively. The volume of dolomite on this one flat alone is 17,000 m^3, which formed at a startling rate of 14 cm/1,000 yr. Each crust grades downward to an equal thickness of unconsolidated deposits. The upper crust contains 64-68% protodolomite, the remainder is Mg-calcite micrite and altered peneroplids; most of the skeletal aragonite has been removed by dissolution. The dolomite is microcrystalline and has selectively replaced the host micrite of the sediments. Average porosities and permeabilities of the crusts are 45-52% and 5.9-7.2 darcys, respectively.

The hydrology of the flats is complex, and involves first-order, seasonal cycles of (minor) hypersaline to normal-marine through fresh interstitial and standing waters on the flats. Superimposed on these cycles, meteoric input results not only in lagoonward flood recharge through the flats, but also upward-charging from the subjacent karst aquifer. In addition, the semidiurnal tidal flux appears effective in introducing variable-salinity lagoon waters to the ambient pore fluids on the flat. The significant amount of dolomite found here compares with or exceeds that in the Coorong, both areas containing more dolomite than other Holocene supratidal occurrences. Such complex hydrologic regimes in humid areas may be requisite for the formation of regionally extensive, penecontemporaneous peritidal dolomites.

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Evolution and Stratigraphy of a Sandy Tidal-Flat Complex Within a Mesotidal Embayment

Sand-dominated intertidal environments in St. Helena Sound, South Carolina, a mesotidal estuarine system, can be divided into a continuum of barlike deposits dominated by tidal flows and sheetlike deposits of sandy tidal flats that are influenced by both waves and currents. A large sand flat attached to a marsh-island complex in the central interior of St. Helena Sound resembles a large flood-tidal delta and has been reworked by waves and migrating ebb-dominated tidal channels. The lower tidal flat (flood ramp) is composed of coarse to medium sand mixed with shell material. Large-scale planar cross-beds are formed by flood-oriented sand waves. Middle tidal-flat deposits consist of fine to very fine sand where burrowing by intertidal fauna disrupts structures of intermediate to small-scale bed forms generated by both waves and tidal currents. The muddy, fine-grained sands of the upper tidal flat are reworked by wave-generated small-scale ripples and are partially bioturbated. A salt marsh–chenier complex, landward of the upper tidal flat, has prograded over older portions of the sand flat during earlier regressive phases.

Evolution of the St. Helena Sound sand flats began with a transgressive phase marked by a transgressive lag deposit dated at 4,200 yr B.P., overlying Pleistocene estuarine, mud-flat, and salt-marsh deposits. Sediment for buildup of the sand flats was derived from reworking of surrounding barrier-island sands by migrating tidal channels. Sand was introduced into the lower tidal flat by swash-bar accumulation or strong flood-tidal currents. Building of the sand-flat sequence and development of the overlying salt marsh–chenier complex occurred episodically due to minor fluctuations in sea level. At present, the sand-flat sequence is in a transgressive phase and is being reworked by migrating tidal channels and the seawardmost chenier is subject to frequent overwashing.

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Seismic Prediction of Pore Fluid and Gas Thickness

This study documents reservoir delineation and gas thickness prediction for a thin, poorly consolidated, porous deltaic sand in a Miocene basin. A grid of 4 seismic lines over the field was calibrated with 4 wells. Nine seismic attributes (amplitudes, areas, and thicknesses) were measured for statistical analysis. The choice of measurements was guided by a simple physical model of the seismic response of a thin, bright reservoir of fixed acoustic impedance embedded in thick shales. A learning set, composed of 420 seismic traces where the pore fluid was assumed known, was chosen based on information from predevelopment wells. A multivariate discriminant function, based on the 9 attributes, correctly differentiated gas from brine for 98% of the learning set. Application of this function to the seismic grid produced a map of the gas-water contact consistent with the contact located by development drilling.

Multivariate regression analysis was used to relate gas thickness to seismic attributes for 14 traces adjacent to wells. A 5-variable prediction equation was the most accurate model at well locations, but the predictions were overly sensitive to noise away from the wells. Use of a single amplitude measurement reduced this sensitivity. The single-variable model, in conjunction with the multivariate gas or brine discriminator, resulted in a gas reserve estimate close to the post-development estimate. This study provides a rapid method for pore-fluid discrimination and net-pay prediction in the production setting. The empirical nature of the resulting statistical functions limits their application to the specific field for which they are derived. However, given a few wells and a reasonable geologic model, predictors for new fields can be developed easily.

MCCULLOH, THANE H., and J. J. FAN, Mobil Research and Development Corp., Dallas, TX

Burial Thermal Histories, Vitrinite Reflectance, and Laumontite Isograd

The optical reflectance of vitrinite has become the standard basis for quantitative judgments of integrated temperature-time (burial) histories. Inferences about the crystallization temperature of the calcium zeolite laumontite also have been used repeatedly for such purposes. In a few cases, these 2 approaches have been combined or their results compared. As generally employed, neither approach has quantitative validity.

Factors other than temperature and time play roles in the way that burial history affects vitrinite reflectance (R_o). In particular, the organic geochemical environment exerts a strong and variable local-to-regional influence on the rate of increase of R_o versus temperature. Hydrocarbon-rich environments retard the rate of R_o increase; hydrocarbon-deficient environments accelerate it. Local (interbed) R_o divergencies up to 0.5% result, and regional (interbasin) divergencies are equal or possibly greater. Much of the scatter in compilation plots of R_o versus TTI may result from such divergencies.

Laumontite, where it can crystallize at all, precipitates according to specific stringent requirements of fluid pressure and temperature. The crystallization temperature at the laumontite isograd ranges from 32°C (1 atm) to 193°C (P_f = 1,325 atm). The crystallization rate is geologically instantaneous, completely unlike the time-dependent organic reactions responsible for the progressive aromatization of coal macerals during kerogen maturation, providing an instantaneous pressure-sensitive maximum-recording "thermometer." Paleotemperatures to constrain interpretations of R_o data may be one of the greatest values to be gained from studies of diagenetic laumontite.

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Recent Armored Mudballs Associated with a Mudflow, Egan Range, Eastern Nevada

Armored mudballs and boulders (AMBs) were observed in direct association with a mudflow produced by heavy snowmelt and rainfall in the spring of 1983. The mudflow was 0.8 km wide, about 2 km in length, and up to 23 cm in depth. The mudflow followed an ephemeral stream channel and moved downstream with force sufficient to bend over evergreen trees up to 90 cm tall.

AMBs ranged from 5 to 90 cm in diameter and were spherical to ovoid with alternating internal layers of clay and limestone clasts (lithologically identical to stream gravels). AMBs were most commonly found lodged in the upper 1-3 cm of the mudflow; a few lay in the stream bed adjacent to or downslope from the flow. The majority of AMBs were concentrated near the toe of the mudflow. AMBs appeared to have been produced by a combination of rolling along the stream channel and "rafting" by the mudflow.

Observation of the mudflow and AMBs after 10 hr of steady rainfall revealed the mudflow to be intact, but all except the largest AMBs were reduced to piles of limestone clasts lying on top of the mudflow.

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Hydrodynamic Systems of Orthoconic Nautiloid Cephalopods: Independent Check on Phylogeny

Seldom is it possible to use direct evidence of the physiology of extinct marine organisms as a means of investigating the phylogenetic relationships at any taxonomic level. Hydrodynamic mechanisms of orthoconic cephalopods are an exception because the form and structure of aragonite deposits used as hydrodynamic devices reflect the genetically controlled physiology of the animal. Data on cameral and siphuncular deposits (hydrodynamic devices) of Pennsylvanian (Desmoinesian/Westphalian C) orthocones from the Boggy Formation (=Buckhorn asphalt) of southern Oklahoma provide a test of existing phylogenetic relationships established by standard paleontological methods. The analysis reveals that early growth stages of many taxa considered to be related at the family level have similar to identical morphologies of cameral deposits, while some do not. In all cases, the form of the cameral deposits changes among taxa during later growth stages. In one case, congeneric taxa are shown to belong to different genera on the basis of gross differences in deposits designed to function hydrodynamically.

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Depositional Facies, Diagenesis, and Reservoir Quality of Ivishak Sandstone (Sadlerochit Group), Prudhoe Bay Field

The Sadlerochit Group is a large fan-delta system comparable in size to the modern Kosi River wet alluvial fan of Nepal and India. Braided-stream processes distributed chert gravel and quartz and chert sand in radial fashion to construct the subaerial part of the fan delta. Fluvial energy, slope of the fan surface, and grain size decrease in a north to south basinward direction. There is also a decrease in scale of sedimentation units from source area seaward. Facies of the subaerial fan delta can be broadly categorized as midfan delta (alternating conglomerate and sandstone), distal fan-delta (chiefly sandstone), and abandoned channel-fill, overbank, and pond facies (mudstone, siltstone, fine-grained sandstone). Seaward of the subaerial fan delta are the delta-front and prodelta facies. Subaerial fan-delta and delta-front facies compose the Ivishak sandstone, which grades basinward into the Kavik shale, a prodelta facies. Diagenetic effects were gradually superimposed on the sediments deposited in the Sadlerochit fan-delta system. The sedimentary facies, and in particular their textural characteristics, seem to control the side and degree of diagenesis, including enhancement of porosity and permeability. Comparison of permeability trends among the facies of the Ivishak sandstone with permeability patterns displayed by unconsolidated sands with analogous grain size and texture, indicates that the general trends that existed in the Ivishak sediments are still recognizable in spite of the diagenetic overprint.

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Continental Slope Morphology in Northern Gulf of Mexico Mapped with Long-Range (GLORIA) Side-Scan Data

GLORIA II long-range side-scan data provide a mosaic of the continental slope in the northern Gulf of Mexico, seaward of the Texas-Louisiana coast. A swath as wide as 30 km and a 10% overlap of the data between parallel track lines provide a continuous picture of the complex slope morphology, which is largely controlled by salt deformation. Morphologic features range from piercement structures approximately 2 km in diameter to basins as much as 30 km across. The GLORIA data delineate the East Breaks submarine slide, where surface lineations are suggestive of deformation features. High-resolution 10 kHz seismic-reflection profiles indicate that the very irregular surface on the slide has a relief of 10 m. The 3 types of intraslope basins (blocked canyon, interdomal, and collapse) described by A. H. Bouma can be identified on the GLORIA data. The walls of Gyre basin, an example of a blocked canyon, have what are interpreted to be gullies, which are commonly associated with submarine canyons. Another basin downslope has similar gully-like features on the walls, which suggest that it may have been part of the original canyon system. Although many canyonlike features direct the movement of sediment downslope, the present data show that all conduits end in closed basins. No system of basins can be shown to transport sediment across the entire slope between the Mississippi Canyon and the East Breaks slide. Small-scale slumps, which can be identified on the flanks of some of the diapiric structures, also contribute sediments to basins such as Gyre basin.

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Near-Surface Methane Anomaly over Shallow Foley Gas Field, Baldwin County, Alabama

The shallow Miocene stratigraphic gas field discovered near Foley, Alabama, in late 1979, afforded an excellent opportunity to test whether gas from an accumulation seeps upward through overlying "impermeable" beds in adequate concentrations for detection in the near surface. In mid-1980, when this survey was done, several confirmation wells had been drilled, but the field was not yet producing.

Samples were collected from the bottom of 10-ft holes drilled on a rough 0.5 mi grid and were quickly sealed in gas-tight containers for later analysis. At several sites, sampling was done from grass roots down to 15-20 ft. At sites where the deeper samples had anomalous concentrations of gas, there was virtually no gas from the surface down to 6-8 ft. Below this, where anomalous gas concentrations were encountered, they tended to increase gradually downward. This confirmed previous conclusions that sampling for near-surface surveys should generally be done at 10 ft.

Gas contents of survey samples ranged from 3 to 87 parts per million by volume, and it was virtually all methane (i.e., identical with the gas at Foley). Probability plots revealed a background population with a mean of 10 parts per million, with values above 20 ppm being anomalous. The mapped and contoured anomaly has a striking correspondence to the outline of the field determined by later drilling. These results show that near-surface hydrocarbon surveys can sometimes detect microseepage from petroleum reservoirs and that such surveys can be valuable in exploration.

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Migration and Maturation of Hydrocarbons—Evidence from Fluid Inclusions

Oil-filled fluid inclusions occur in cements in petroleum reservoirs and are evidence for the generation and migration of hydrocarbons in a basin. Generally, oil-filled inclusions occur together with aqueous inclusions in the same cement crystal. Geothermetric studies of the aqueous inclusions provide thermal and compositional data pertinent to interpreting the time of cementation and hydrocarbon migration relative to source rock maturation.

Oil-filled inclusions occur both in random locations and in alignment with crystal cleavages or fractures. Random distributions of fluid inclusions suggest oil entrapment during growth of the cement crystal into primary porosity whereas the occurrence of fluid inclusions along sealed fractures suggests migration through secondary porosity. Generally, the oil-filled inclusions consist of liquid hydrocarbon and a gas phase, but inclusions containing oil, water, and gas also occur. Those different compositions suggest differences in the migration and mechanism of petroleum.