REIMNITZ, ERK, and P. W. BARNES, U.S. Geol. Survey, Menlo Park, CA

Depositional Complexities in Sea-Ice Environment of Arctic Shelves: Example from Harrison Bay, Alaska

Harrison Bay, a gently sloping, shallow embayment on the continental shelf of northern Alaska near the Colville delta, is ice covered 9 months of the year. The 3 to 5-m Holocene marine sediment blanketing the shelf commonly is gouged into jagged relief forms by ice, and periodically winnowed or shaped into 1-m high sand waves by waves and currents. Yearly fathometer and sidescan sonar surveys, many diving observations, and numerous cores collected along a 14-km long test line show a complex sedimentation pattern, apparently typical for much of the shallow circum-Arctic shelves.

Ice-plowed sediments piled 20 to 80 cm above the shelf surface form a rough topography composed of soft cohesive mud. Locally the excavation products border gouges as continuous ridges; elsewhere they form isolated massive extrusion mounds with fissured crests. In some years a transient layer, as thick as 50 cm of flocculated silt and clay, blankets the surface, and only the crests of excavation products protrude. This transient layer remains trapped only in narrow gouges, where as much as 60 cm of mud may accumulate yearly. Original gouge floors commonly consist of smoothly striated compacted mud, as distinguished from the soft fill. The sea floor between recent gouges has subdued relief, is very firm, and is characterized by sediment-texture variations from clean sand to silty clay over distances of 10 m or less; pebbles are rare. Cores typically contain clean cross-bedded sand interbedded with mottled mud in 10 to 20-cm thick lenses, as well as ice-disruption structures. Distinct layers in closely spaced cores cannot be correlated. The addition of gouge fill—sinuous, crisscrossing shoestring-like deposits of mud—appears to be the primary accretional process on shallow arctic shelves.

RICE, DUDLEY D., and GEORGE E. CLAYPOOL, U.S. Geol. Survey, Denver, CO

Significance of Shallow Gas in Ancient Marine Sequences

Shallow, methane-rich gas is generated at low temperatures by decomposition of organic matter by anaerobic microorganisms in accumulating marine sediments, and is referred to as biogenic gas. The most efficient biologic mechanism of methane generation is anaerobic respiration and CO_2 reduction. The factors that control methane production after sediment burial are: anoxic and sulfate-deficient environments, low temperature, availability of organic matter, and sufficient pore space. The timing of these factors is such that most biogenic gas is generated prior to burial depths of 1,000 m. Biogenic gas is characterized by enrichment of the light isotope ^{12}C in the methane ($\delta^{13}C_1$ lighter than -55 ppt) and by large proportions of methane ($C_1/C_{1\text{-}5} > 0.98$).

In marine sediments most of the biogenic gas formed is retained in solution in the interstitial (pore) waters. This can be attributed to higher methane solubility at the higher hydrostatic pressures and lower temperatures due to the weight of the overlying column of cool seawater. This dissolution capacity permits accumulation of gas in nonindurated sediments while they are being compacted, and while traps and seals are being formed. Free gas occurs either when the solubility minimum is exceeded, or by exsolution brought about by a reduction in hydrostatic pressure or an increase in temperature. Possible trapping and sealing mechanisms are as follows: early carbonate cementation in zones of high CO_3^{2-} activity resulting from reduction of CO_2, low-permeability reservoirs, bentonites, gas hydrates, and subnormal pressures.

More than 20% of the world's discovered gas reserves are of biogenic origin and commonly are associated with marine sequences. Accumulations of ancient biogenic gas have been discovered in Canada, Germany, Italy, Japan, Trinidad, U.S.A., and U.S.S.R. The accumulations occur in Cretaceous and younger rocks and at depths of burial less than 3,350 m.

RICHMOND, BRUCE M., and RALPH E. HUNTER, U.S. Geol. Survey, Menlo Park, CA

Oblique Dunes of Oregon Coast

The oblique dunes of the Oregon coast are the largest (as high as 55 m) on the west coast of the United States. Where best developed, these perennial ridges have been migrating northeastward at an average rate of 4.4 m/year, as measured from aerial photographs dating from 1939 to 1975. The wind regime of the area can be characterized as obtuse bimodal, with sand-transporting winds from the north and northwest throughout the dry summers and between storms at other seasons, and from the south and southwest during fall, winter, and spring storms. Although the sand-transporting capacity of the southerly winds is reduced by accompanying rainfall, these winds are nevertheless strong enough to do more work than the northerly winds.

Dune processes during the winter season of southerly storms include: (a) erosional smoothing of the south (stoss) slope; (b) erosion and formation of sawtooth remnants (yardangs) on the dune crest; (c) deposition by adhesion on the wet, low-angle north slope between the dune crest and the slip-face brink; (d) grainfall deposition on the west slip face, causing steepening to angles of 44° or more, followed by slumping; (e) local deposition by adhesion in wet interdune troughs; and (f) local subaqueous deposition in ephemeral interdune ponds and streams. Dune processes during the summer season of northerly winds include: (a) growth of small southeast-facing transverse dunes at the crests and on the south slopes of the oblique dunes, and in troughs between the oblique dunes; (b) plastering of wind-rippled sand sheets against the base of the winter slip face, leading to the formation of a gently north-sloping apron; and (c) erosion of the upper part of the winter slip face, reducing the slope angle to 25° or less.

RICHMOND, WILLIAM C., DEBORAH J. BURDICK, and DONALD J. KROTSER, U.S. Geol. Survey, Los Angeles, CA

Geologic Hazards and Constraints, Federal Oil and Gas Lease Sale 53 Area, Offshore Central and Northern California

Studies have been completed to assess potential geologic hazards and constraints which could adversely affect safe petroleum resource development in offshore areas of central and northern California. The study includes 243 tracts tentatively selected for the proposed federal Outer Continental Shelf (OCS) Oil and Gas Lease Sale 53. Geologic hazards and constraints are identified in five offshore areas of central and northern California: Santa Maria, Santa Cruz, Bodega, Point Arena, and Eel River. A total of 10,500 line-km of high-resolution data was collected on a 1.0 × 2.0-km grid over the five areas.

Geologic hazards are defined for this study as any geologic feature or process that would inhibit the safe development of petroleum resources. Geologic hazards present on the central and northern California continental margins are: (1) mass movement of unconsolidated to semiconsolidated sediments due to earthquakes, overloading, oversteepening, or other causes; (2) steep slopes ($>10°$), especially those covered by sediment, and steep-walled submarine channels; (3) faults that intersect or offset the seafloor or Holocene sediments; and (4) areas of high seismic activity. Geologic features considered hazardous in their present state but whose effects can be economically lessened through existing technology and design are referred to as constraints. Constraints identified in offshore central and northern California are: (1) filled or shallow buried channels where load-bearing capacity differs from surrounding sediments; (2) gas seeps, mounds, and craters; (3) zones of unconsolidated to semiconsolidated sediments (3 to 50 m beneath the sea floor) saturated with interstitial gas under normal to near-normal pressures; and (4) possible pressurized shallow gas identified as bright spots or amplitude anomalies.

These geologic hazards and constraints were evaluated for each of the 243 tracts as a basis for recommendation of withdrawal or stipulation prior to the formal announcement of the sale. Further data acquisition and analysis on a more detailed grid will be required of lessees or operators before drilling will be permitted on leases resulting from the sale.

RIGGS, STANLEY R., and DON W. LEWIS, East Carolina Univ. Greenville, NC, ALBERT C. HINE, et al, Univ. South Florida, St. Petersburg, FL

Miocene Phosphorite Sedimentation on Atlantic Continental Shelf, Onslow Bay, North Carolina

An extensive sequence of phosphorites outcropping on the Atlantic continental shelf of Onslow Bay, North Carolina, has been delineated by utilizing a series of vibracores and high resolution subbottom profiles (3.5 kHz, uniboom, and sparker). This broad outcrop belt extends 100 km from western Bogue Banks, southwestward across the shelf toward the outer part of Frying Pan Shoals off Cape Fear, North Carolina. Along the outcrop zone the Tertiary phosphorites have been and are presently being eroded, supplying reworked phosphate grains in diluted concentrations to the associated thin Pleistocene to recent sediment and rock blanket. The Tertiary phosphorites are primarily an interbedded sequence of muddy, quartzose phosphorite sands; phosphatic dolosilts; and fossiliferous, dolomitic, phosphatic, quartz sands. The sediment sequence closely resembles that found in the Aurora area of the North Carolina Pungo River basin, a major mining district, and is presently considered to be the Pungo River Formation of middle Miocene age. These phosphorites unconformably overlie the slightly glauconitic, calcareous, fine quartz sands, calcarenites, and sandy, moldic limestones of lower Miocene and/or Oligocene age. Small parts of the updip outcrop belt of the Tertiary phosphorites, as well as the downdip section to the southeast, are covered by a thickening sequence of fossiliferous, clayey, quartz sands of the Yorktown Formation (Pliocene). The distribution of the Tertiary phosphorites is primarily related to the Cape Fear arch, a major coastal plain structural element, and is locally controlled within Onslow Bay by several second order structural features and associated entrapment basins.

RIGGS, STANLEY R., DON W. LEWIS, A. KELLY SCARBOROUGH, et al, East Carolina Univ., Greenville, NC

Cyclic Deposition of Upper Tertiary Phosphorites of North Carolina Coastal Plain and Their Relation to Global Sea Level Curves

The upper Tertiary phosphorites in the Aurora area occur within the Miocene Pungo River Formation (units A, B, C, and D) and the Pliocene Yorktown Formation (lower and upper units). These units are characterized by the following features of sedimentation. (1) Three major erosional unconformities and five diastemic surfaces mark the boundaries between consecutive units. (2) Indurated carbonate sediments, which usually contain either a weathered fossil assemblage or are completely moldic, cap each unit. The carbonate surfaces locally contain a rock-boring infauna and are commonly phosphatized. (3) Phosphate sedimentation began in unit A and increased to a maximum through unit C, was negligible in unit D, was reinitiated in the lower Yorktown, and was nonexistent in the upper Yorktown. (4) Phosphate concentration generally increases upward within each unit until carbonate sediments become important, then the phosphate decreases. (5) The dominant carbonate within each unit is as follows: unit A and B, dolosilt; unit C, calcitic micrite; unit D, dolosilt with abundant calcite shell material; and both Yorktown units, calcitic micrite with abundant calcite shells.

This sequence of upper Tertiary sediment units suggests a cyclical pattern controlled by global eustatic sea level fluctuations. Each depositional unit, its carbonate cap, and the associated diastemic surfaces correlate with established third order sea level cycles. Units A, B, and C appear to represent the maximum transgressive part of the second order Miocene supercycle. Phosphate sedimentation was coincident with the transgression; the maximum deposition occurred during the highest level of the sea. Unit D was deposited only over the eastern area as a regressive facies of the supercycle. The Pliocene Yorktown sediments were deposited during the next supercycle. The lower Yorktown phosphorites coincided with the maximum transgression while the nonphosphatic upper Yorktown was deposited during the subsequent regressive phase.

RINDSBERG, ANDREW K., Colorado School Mines, Golden, CO, and ROBERT W. FREY, Univ. Georgia, Athens, GA

Ichnology of Neritic Turbidite: Silurian Red Mountain Formation, Georgia and Tennessee

It has recently been shown by others that two thousand units in the Red Mountain Formation are relatively shallow-water turbidites, water depth roughly 100 to 300 ft (30 to 91 m). The turbidites, probably storm-generated, consist of alternating sandstones and shales in fining-upward sequences with scoured bases; the lower turbidite grades upward into hummocky bedded alternating sandstones and shales. Biogenic structures are dominated by *Chondrites gracilis, C. flexuosus,* and *Trichophycus striatus,* which occur through most of the units. Others include *Dictyodora, Asterosoma, Planolites* spp., *?Megagrapton,* as yet unnamed radiating grazing trails, and rare *Fraena, Aulichnites, Monocraterion, Halopoa,* and *?Bifungites.* The traces are preserved largely as sandstone hypichnia, hence most were the work of mud-dwellers. Deposit-feeding evidently predominated over suspension-feeding; *?Megagrapton* is an example of a bacteria-farming network. The ethology of *Trichophycus* is uncertain; the burrow was partly a dwelling structure but may have been the work of a deposit-feeder, suspension-feeder, or carnivore. Stellate forms of *Trichophycus* are perhaps analogous to circular patterns of burrow apertures seen in deep-sea photographs. The assemblage is a mixture of genera from *Cruziana* (shelf) and *Zoophycos* (slope) ichnofacies, as might be expected in a neritic turbidite. Without recently published stratigraphic evidence, the units could be misinterpreted as bathyal turbidites.