and KRISTIN MCDOUGALL, U.S. Geol. Survey, Menlo Park, CA

Distribution of Benthic Foraminifers Across a Middle Miocene Basin Margin, Central California: Paleoenvironmental, Tectonic, and Biostratigraphic Implications

The quantitative distribution of Miocene benthic foraminifers within the Cuyama basin, central California, demonstrates the relationship between biofacies, key species, and specific environmental factors. During the Miocene, the Cuyama basin occupied an inboard position along an active, convergent to translational, continental margin resembling the modern continental borderland off southern California. Benthic foraminiferal assemblages delineate shelf, slope, and basin plain biofacies. Migration and replacement of these biofacies with time reflect the depositional subsidence history of this Miocene basin. Initially, biofacies are broad and less structured, reflecting the influx of cosmopolitan species during early basin development. Recognizable biofacies are established quickly after the initial marine transgression and basin subsidence. As the basin fills, the number of biofacies decreases and deeper biofacies are excluded, whereas low oxygen and shelf biofacies expand. Bathymetrically displaced species are common, implying downslope transport by turbidity currents, increased sediment input, and/or tectonic activity.

Benthic foraminiferal species diagnostic of the standard California Miocene stages and zones occur commonly throughout the Cuyama basin. Among the key biostratigraphic events commonly cited for the early and middle Miocene are the "*Valv. cal.* flood" zone (middle Luisian) and the evolutionary succession of valvulinerids and siphogenerinids. Although these events are important stratigraphic markers, some difficulty is encountered in recognizing certain zones and chronostratigraphic sequences are boundaries as presently defined. The bathymetric distribution and biofacies associations for certain key species critically impact on the usefulness of these species for biostratigraphy. Siphogenerinids appear only in slope, lower slope, and basin plain assemblages, and individual species are restricted to specific parts of these areas. Stratigraphic and evolutionary events based on these species are therefore limited to deeper water environments. Valvulinerids are present in shelf-edge environments as in-situ members of assemblages and as transported specimens in deeper environments. The *Valv. cal.* flood is obscured in sections dominated by shelf-edge environments where valvulinerids occur in large numbers throughout the middle Miocene, and is confused in lower slope and basin plain assemblages where they are concentrated as transported specimens.

Early and middle Miocene fauna distributions are complex. Sedimentary, tectonic, and oceanographic conditions strongly effect in-situ and transported occurrences of key species. These factors must be evaluated for individual basins if benthic foraminiferal zonations are to have regional applicability.

LARICCIA, MARILYN PLITNIK, and PAUL R. KRUTAK, Univ. Nebraska, Lincoln, NE

Intertidal Variation in Foraminiferal Species Diversity: Mississippi-Louisiana Salt Marshes

Salt marshes are tide-stressed environments where ecologic variables exert strong selective control upon the distribution, type, and abundance of organisms. Ecologic conditions range from marine to terrestrial; hence gradational and/or abrupt environmental changes across marshes produce similar gradients in communities of organisms and their biotopes. Salt marshes are one of the present-day sites of peat accumulation. They represent a potential milieu for lignite and coal formation. Recognition of microenvironments within such marshes will provide coal explorationists and paleontologists with another tool for predicting the location of subsurface peats, lignites, and coals.

Twenty-eight modern bottom samples were collected for analysis for foraminiferal populations (total = live + dead) in the Hancock County, Mississippi, and Pearl River, Louisiana, marshes during May and June 1981. Fourteen stations of the 28 were sampled twice—once at "peak" high tide and once at "peak" low tide. Three microbiotopes occur among the 14 stations: (1) beach (B)—3 localities, (2) lacustrine (L)—3 localities, and (3) bayou-fluvial (BF)—8 stations. Average salinities (parts/mil) at these biotopes were 10.4 (B), 2.3 (L), and 7.7 (BF). Ranges were 0.2 to 13.5. Average dissolved oxygen (ppm) values were 10.4 (B), 7.9 (L), and 5.4 (BF). Ranges were 2.6 to 12. Temperatures (°C) averaged 29.4 (B), 30.4 (L), and 29.3 (BF). Ranges were 20.9 to 32.7. We are currently studying interbiotope and intrabiotope variability.

After extracting a minimum of 300 specimens/sample, foraminiferal species diversity patterns among the 14 doubly sampled stations were studied. We used S (number of species), H(S) (Shannon-Wiener information function), and E (species equitability). The following ranges and average ($\bar{x}$) exist at high tide: S—2 to 13, $\bar{x}$ = 7.4; H(S)—0.311 to 2.046, $\bar{x}$ = 1.25; E—0.306 to 0.720, $\bar{x}$ = 0.522. Low-tide samples have these ranges and averages: S—2 to 12, $\bar{x}$ = 7.0; H(S)—1.721 to 3.750, $\bar{x}$ = 1.08; E—0.326 to 0.727, $\bar{x}$ = 0.488. High-tide samples have much higher species diversity, slightly lower dominance, and are more equable.

LASEMI, ZAKARIA, and PHILIP A. SANDBERG, Univ. Illinois, Urbana, IL

Recognition of Original Mineralogy in Micrites

Detailed SEM study of selected micrites (<4 μm) and microspars (4 to 12 μm) from all Phanerozoic systems and various geographic localities suggest that textural properties of micrites and microspars are mineralogically controlled. Those micrites and microspars with apparent aragonite-dominated lime mud precursors (ADP) have neomorphic calcite crystals which show pitted surfaces or relic aragonite inclusions in polished, etched sections. The presence of relics in all crystal sizes in ADP micrites and microspars indicates an absence of secondary dissolution-precipitation or aggrading neomorphism. That is, formation of all neomorphic crystal sizes occurred in a single diagenetic event. Micritic limestones with apparent calcite-dominated precursors (CDP), however, are characterized by finely crystalline (<4 μm) textures, lack any inclusions, and have unpitted crystal surfaces.

Strontium content of micrites and microspars studied are bimodally distributed. A similar distribution was recognized by Veizer in 1977 and Veizer and Demovic in 1973 and 1974, who suggested it was the result of original mineralogy. Preliminary results on the micrites and microspars studied show Sr distribution generally well correlated with textural properties. ADP and CDP micrites and microspars possess Sr values which fall, with few exceptions, within the high-Sr and low-Sr groups, respectively, of Veizer and others. Several ADP samples which fall within the low-Sr group are molluscan-rich. Thus, likely aragonite contribution to precursor muds was more probably low-Sr. Low-Sr ADP could also be the result of open-system diagenetic alteration. In such cases, low-Sr ADP micrites and microspars are associated with high Mn content. We have found several low-Sr ADP samples that are high in Mn. High-Sr ADP micrites and microspars are, therefore, interpreted as being originally composed of high-Sr aragonite mineralogy. The Sr content of CDP

micrites studied thus far is low and suggestive of high-Mg calcite mud precursors for those micrites.

Oxygen isotopic composition of both CDP and ADP samples are rather broad ranges suggesting varying contributions of original mineralogies for both groups. There is, however, an overall negative trend toward lighter $\delta^{18}O$ isotopic values with increasing age, indicative of either progressively higher temperatures with age or lower $^{18}O/^{16}O$ ratios in ocean water.

LAW, B. E., and J. R. HATCH, U.S. Geol. Survey, Denver, CO, G. C. KUKAL, CER Corp., Las Vegas, NV, and C. W. KEIGHIN, U.S. Geol. Survey, Denver, CO

Geologic Implications of Dewatering of Coal and Other Carbonaceous Lithologies—A Hypothesis

A large amount of water is released from coal and other noncoal carbonaceous lithologies during the coalification process. Calculations of the amount of water released from coal and carbonaceous lithologies in low-permeability Upper Cretaceous rocks in the Green River basin of Wyoming reveal that this source of water is as important as any other sediment-derived water. Based on water resistivity (R_w) calculations and coal compositional changes during coalification, we suggest that this organically derived water is fresh relative to most formation waters. The addition of this water to the pore fluids is of sufficient quantity to create a chemical disequilibrium between the pore fluid and rock constituents, thereby producing a potential for precipitation or dissolution of cements. The addition of fresh water in conjunction with the variable stratigraphic distribution of coal beds and a restricted hydrologic communication between lithologic units implies that variable water resistivities (R_w) could occur that might adversely affect geophysical well-log responses and water-saturation (S_w) calculations. In coal-bearing rocks, the addition of organically derived water into the pore system may, in part, contribute to the development of abnormally high pressures.

The effectiveness of this dewatering process depends on the amount and stratigraphic distribution of coal, stage of coalification, and degree of hydrologic isolation or impermeability of the coal-bearing sequence.

LEDGER, ERNEST B., Stephen F. Austin State Univ., Nacogdoches, TX, and THOMAS T. TIEH, Texas A&M Univ., College Station, TX

Catahoula Formation as a Source of Sedimentary Uranium Deposits in East Texas

Volcanic glass-rich mudstone and siltstone samples from the Oligocene/Miocene Catahoula formation of Jasper County, Texas, and coeval volcaniclastic rock samples from Trans-Pecos, Texas, have been compared as to U, Th, Zr, Ti, K, Rb, and Sr contents. Results are consistent with the 1977 eruption model of Sparks and Walker, in which the east Texas Catahoula samples are their "distal air-fall ash," and the Trans-Pecos samples their near-source units. Uranium is slightly greater in the distal ash (5.85 ppm U) compared to the Trans-Pecos samples (average 5.41 ppm U). Elements which are preferentially incorporated in crystallizing phases are more abundant in the crystal-rich near-source units (310 ppm Sr, 2,163 ppm Ti, 461 ppm Zr, and 22.7 ppm Th) than in the distal ash (48 ppm Sr, 1,050 ppm Ti, 88 ppm Zr, and 18.1 ppm Th). Elements which tend to become enriched in the residual magma are less abundant in the near-source units (206 ppm Rb and 3.09% K) than in the distal ash (291 ppm Rb and 4.94% K). These results emphasize the close chemical affinities of Catahoula and Trans-Pecos volcanic material.

Diagenetic and pedogenetic alteration of Catahoula volcanic glass releases uranium to solution and, under favorable conditions, this uranium may accumulate to form ore bodies. Uranium has been produced from such ore bodies in south Texas, but economic deposits are not known in east Texas. Significant differences between south and east Texas include: (1) a greater amount of volcanic debris delivered to south Texas, both as air-fall ash and stream-transported material, (2) delivery of only air-fill ash to east Texas, (3) the possibility of more petroleum-related reductants such as H_2S in south Texas, and (4) pervasive glass alteration with subsequent uranium release in south Texas due to late calichification. These differences argue against economic deposits of the south Texas type being found in east Texas. If economic deposits occur they are likely to be far downdip making exploration difficult and expensive.

LEONARD, RAY, Amoco Norway Oil Co., Stavanger, Norway

Geology and Hydrocarbon Accumulations, Columbus Basin, Offshore Trinidad

The Columbus basin, on the eastern shelf of Trinidad, lies at the eastern extremity of a belt of severe deformation along the northern boundary of South America that has been affected by compressional and wrench tectonics in the Pliocene-Pleistocene. Two major structural trends are present in the Columbus basin: a series of ENE-trending anticlines and NNW-oriented normal faults. The basin was filled during the late Miocene to Holocene with sediments deposited by an ancestral Orinoco River draining a hinterland to the southwest. The Pliocene-Pleistocene section, which contains the hydrocarbon accumulations in the Columbus basin, was laid down in three coarsening-upward sedimentary sequences followed by a late Pleistocene transgressive sequence.

Traps for hydrocarbon accumulation were formed by an easterly trending Pliocene-Pleistocene wrench system with associated ENE-oriented anticlines combined with NNW-oriented normal faults. Oil was sourced in the late Miocene lower Cruse Formation, whereas gas was derived both from Pliocene-Pleistocene pro-delta shales and as a late high temperature phase of lower Cruse hydrocarbon generation. The NNW faults formed migration conduits from the oil source rock to Pliocene-Pleistocene reservoirs. The temporal relationship of faulting to oil generation is a major factor affecting the distribution of oil and gas. The size of hydrocarbon accumulations is limited to some extent by a lack of an effective hydrocarbon seal, particularly in the western half of the basin.

LEPZELTER, C. G., THOMAS F. ANDERSON, and PHILIP A. SANDBERG, Univ. Illinois, Urbana, IL

Stable Isotope Variations in Modern Articulate Brachiopods

Carbon and oxygen isotopic analyses were performed on several species of Holocene articulate brachiopods from various locations in the Carribbean Sea and in the Atlantic and Pacific Oceans, from salinities ranging between 30 and 38 ‰ and over a temperature range from 4 to 28°C (39 to 82°F). The $\delta^{18}O$ of articulate brachiopods are systematically related to the $\delta^{18}O$ and temperatures of the ambient waters. Lowenstam in 1961 concluded that articulate brachiopods secrete calcium carbonate (low magnesium calcite) in isotopic equilibrium with the surrounding waters. The data compiled in this study, along with that of Lowenstam, closely approximate the equilibrium calcite-water