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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.

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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.

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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