

*nolites*, *Chondrites* and *Thalassinoides*, (2) glauconitic wackestones, (3) rudist-*Orbitolina* wackestones, and (4) oolitic-bioclastic grainstones. These carbonate facies are associated with cross-bedded coastal marine and platform quartzarenites and silty carbonaceous lagoonal facies. Facies 1, which overlies the basal transgressive clastic wedge, is interbedded with thin rudist-bearing wackestones and algal grainstones. This algal wackestone facies represents deposition in restricted marine back-bar/back-reef conditions. The glauconitic facies 2 was also deposited in a relatively tranquil environment of the back-bar. Facies 3, of alternating thin *Orbitolina* and rudist-wackestone, contains numerous biogenic tubular structures filled with *Orbitolina* grainstone. The rudists (caprinids and *Toucasia*) are mostly unoriented and matrix-supported. This facies probably represents local reefal-biostromal development on an oxygenated marine shelf. The oolitic grainstone (facies 4) is a facies diagnostic of shoaling-upward sequences within or at the margin of the platform. Ammonites and ahermatypic solitary corals at the top indicate a gradual deepening of the environment. The overlying basinal Luna Formation represents the acme of transgression of the Cretaceous period which resulted in an overall upward-fining megacyclothem sequence.

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#### Morphometry of Late Ordovician Microbial Borings

Microborings within Late Ordovician shells of the brachiopod *Raphinesquina alternata* from the Tanner Creek Formation, Richmond Group, of southeastern Indiana, were studied by scanning electron microscopy of their resin casts. The shells have been exposed to microbial boring in quiet and illuminated waters below the wave base and then buried with skeletal fragments of ramose bryozoans, echinoderms, trilobites, and rugose corals.

Four morphotypes of microborings have been characterized on the basis of shape, branching patterns, and diameter size and variation. Statistically evaluated measurements for populations of microborings indicate four ichnotaxa.

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#### Deposition of Enewetak Atoll Reef, Middle Pleistocene to Holocene

Cyclic deposition and diagenesis of a large atoll reef, associated with major eustatic sea-level fluctuation, is documented in six cores from the northeast (windward) reef of Enewetak Atoll. To 250 ft (76 m) depth, the reef section comprises six primary depositional packages that represent periods of reef growth during Pleistocene and Holocene high sea-level stands. These depositional packages are separated by unconformities, former subaerial exposure surfaces, which are demarcated by paleosols. During emergent periods at low sea-level stands, the reef was subjected to meteoric-water diagenesis. However, the depositional textures generally are well preserved. Diagenetic textures, most indicative of

meteoric-vadose diagenesis, usually have only partly replaced original textures. An oceanward shift of reef environments through time is apparent in a large-scale view of the cores. Reef crests in succeeding younger depositional packages apparently are offset oceanward. Younger marginal lagoonal deposits unconformably overlie older backreef deposits that unconformably overlie older reef-crest deposits. Within depositional packages, influence of rising sea level on facies development is evident. Subaerial surfaces flooded by rising sea level were rapidly colonized by both solitary corals and patch reefs of diverse composition. Rapid upgrowth of oceanward reef crests led to moderation of wave energy in backreef areas and great increase in deposition of sediment which locally buried and killed patch reefs. Shoaling of backreef areas by sediment aggradation to a stabilized sea level resulted in renewed development of patch reefs and deposition of coarser sediment.

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#### Calcification Model and Secondary Calcification Effects on Fossil *Bolivina seminuda*

Fossil individuals of *Bolivina seminuda*, studied with an SEM, reveal a tripartite test-wall ultrastructure composed of (1) an underlying organic lining with pore structures, (2) a radial calcitic layer bounded by organic membranes, and (3) a calcitic surface veneer. A calcification model for *Bolivina seminuda* is proposed where the inner organic lining is precipitated first. Overlying this is a layer composed of radial calcite with the crystallographic C-axes aligned perpendicular to the test wall. This calcite is laid down in successive packets bounded above and below by organic membranes. Above this is a surface veneer composed of randomly oriented calcite rhombs. This model differs from some proposed models by the absence of a randomly oriented calcite rhomb layer incorporated with each packet of radial calcite and by attributing the surface veneer to inorganic precipitation.

The surface veneer is interpreted as diagenetic in origin and not precipitated by the organism. The diagenetic calcification patterns at first enhance preexisting surface sculpture and then gradually mask it. This coating makes the different phenotypes of *Bolivina seminuda* similar to one another and to other species in appearance. The effects of this calcification must be considered in taxonomy, biostratigraphy, and paleoenvironmental interpretations.

SEM studies of the ultrastructure of *Bolivina seminuda* indicate which test-wall parameters are controlled by genetics, environment, and postdepositional (or postmortem) history. The raw data may be of use in subsequent investigations of paleoenvironments, taphonomy, and postdepositional (or postmortem) history.

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#### Application of Statistical Models in Continental Margin Biostratigraphy

Stratigraphic events defined by the highest or lowest

occurrences of fossils in a group of wells or natural sections can be ordered into an optimum sequence. In the statistical model used, the relative position of the events in the most likely sequence is an "average" of all the relative positions encountered. The frequency of cross-over (miscorrelation) of events in the sections correlated has been used to estimate average distances between successive events in the optimum sequence. The events can be clustered by using the estimated distances between them, which gives results similar to those of the assemblage zone approach in biostratigraphy.

The computer program prepared for the statistical model has been used to create a zonation for our Cenozoic benthonic and planktonic foraminiferal record (209 taxa) in 22 wells on the Canadian Atlantic continental margin between 43 and 60°. Northern and southern optimum sequences have been recognized containing 40 and 60 taxa, respectively, about half of which are in common. The southern sequence contains 11 Eocene and 7 Miocene planktonic foraminiferal species and the northern sequence contains 6 Eocene species. The difference reflects more pronounced post-Eocene latitudinal watermass heterogeneity and differential post-Eocene shallowing across the margin.

The northern and southern probabilistic zonations each consists of eight clusters of Paleocene through Pliocene-Pleistocene age.

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#### Implications of Geologic Structure and Regional Sedimentation Patterns for Rifting Geometry of Arctic Basin

The smooth, passive continental margin north of Alaska is geometrically more complex than its simple physiography suggests. Multichannel seismic reflection profiles across the continental shelf reveal three sectors of contrasting structure and stratigraphy. The Barrow sector of central northern Alaska is characterized by a prominent arch in lower Paleozoic metasedimentary basement rocks overlain by a southward-thickening wedge of Mississippian to Lower Cretaceous (Neocomian) shelf sediments and a northward-thickening prism of Lower Cretaceous (Albian) to Tertiary clastic sediments. The Chukchi and Barter Island sectors, lying respectively west and east of the Barrow sector, comprise Mesozoic and Tertiary basins so deep that acoustic basement was not reached. We suggest that this geometry (in which lower Paleozoic basement rocks extend much farther north in the central sector than they do in the east and west) is inherited from the configuration of the rift that opened the Arctic basin, probably beginning in Early Jurassic time. In this scheme, old, pre-rift highlands, originally continuous with the basement rocks of the central Barrow sector, were rotated northward away from Alaska along two sectors of the rift that lay well south of the present-day shelf edge. In these, the Chukchi and Barter Island sectors, the rift created room for the deep shelf basins observed there now. In the intervening Barrow sector, the rift opened along the present-day shelf edge, leaving a broad tongue of lower Paleozoic rocks, the site of upper Paleozoic and lower Mesozoic highlands, attached to Alaska.

Presumably the sector boundaries were ridge-ridge transform faults during nascent rifting. The Chukchi-Barrow sector boundary is well defined by the trend of the Northwind Escarpment and the abrupt termination of the Barrow arch against the North Chukchi basin. The Barrow-Barter Island boundary is more obscure and is inferred from the provenance and distribution of Mesozoic sediments in northeastern Alaska and Yukon Territory.

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#### Oil and Gas Potential of San Luis Basin, South-Central Colorado

Are there major oil and gas traps in the San Luis basin? Gas and oil seeps have been reported and used at ranches in this basin since the late 1800s. Despite the presence of porous and permeable sandstones, thick widespread clays for seals, and hydrocarbons, only 15 oil and gas tests have been drilled in 2,500 sq mi (4,023 sq km), most before 1955.

Recent seismic work has helped delineate the structure and stratigraphy of the eastern half of the basin where gas occurs in all water wells. A high on the Precambrian basement surface dominates the center of the basin with sediments faulted and dipping down to the east to a depth of about 20,000 ft (6,096 m) adjacent to the Sangre de Cristo Mountains. The basin fill is Tertiary clastic and volcanic rocks that can be divided into four units using seismic work, well samples, and paleontology. The uppermost unit, the Alamosa Formation (Pliocene-Pleistocene), is green lacustrine clay and sandstone. The underlying Santa Fe Formation (Miocene-Pliocene) is red fluvial-lacustrine clay and sandstone with a few thin volcanic flows. An unnamed unit (middle Paleocene to Eocene) is angularly unconformable with the overlying Santa Fe and similar in lithology. The oldest unnamed unit consists of thick volcanic flows interbedded with volcanoclastics and claystones and is also unconformable with the overlying unit.

Potential trapping mechanisms are major sedimentary-rock pinch-outs and truncations in the unnamed unconformable units as well as in channels in the overlying fluvial sandstones. Porous volcanic rocks and sandstones on the fault blocks, fault traps, and structural closures are also possible traps in the oldest unit. The paucity of drilling and the presence of traps and hydrocarbons make the outlook optimistic for this basin.

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#### Siderite Textures in Cardium Formation, Ferrier Field, Alberta

Siderite in the Upper Cretaceous Cardium Formation of Alberta, Canada, is unusual not only because it is the dominant carbonate cement, but because it is more abundant in Cardium offshore sands and conglomerates than in similar Cretaceous stratigraphic and depositional units such as the Shannon, Sussex, and Gallup Sandstones or the Viking Formation. Core and thin sections have been studied to understand the occurrence of siderite in the Ferrier field (T38-42, R6-10W5).

On the basis of texture, the siderite in the Cardium can be divided into two groups. Siderite associated with