

base is consistent. Strong regional trends are also present for the calcium carbonate fraction and the aragonite/calcite ratio on the shelf south of Cape Hatteras. The existence of a nearshore zone of present sediment reworking, longshore clastic transport, and skeletal comminution is implied by the low  $\text{CaCO}_3$  values along the coastline.

Generally, the combination of cluster, ordination, and trend surface analysis proves to be an excellent strategy for the extraction of sedimentary trends, particularly where local variations obscure the regional gradient.

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#### Equilibrium in Modern Coral Reefs, Western Gulf of Mexico—Role of Ecology and Ostracod Microfauna

Two groups of modern patch reefs exist off Veracruz, Mexico. Terrigenous sediments of the Rio Jamapa are being deposited between the two complexes. Longshore drift of these sediments is causing declining coral growth on the southern group (Anton Lizardo), whereas corals on the northern group (Veracruz) are thriving. These differences in coral vitality should be reflected in the water chemistry and microfauna. Environmental data (depth, salinity, pH, temperature, Eh, and dissolved oxygen) were collected and treated as random samples from populations whose normality was established by chi-square goodness-of-fit tests. Chi-square testing at the 0.01 level demonstrated that, out of the six sample populations, only depth, pH, and dissolved oxygen were distributed normally. Depth, pH, and dissolved oxygen data were assembled into two populations representing the Veracruz and Anton Lizardo groups. This permitted us to test the null hypothesis that the variances of the respective populations were equal ( $F = 0.005$  level). The variances were found to be equal. T tests (0.01 level) on the population-means of depth, pH, and dissolved oxygen of both Veracruz and Anton Lizardo groups disclosed that there is no significant difference between the two groups of reefs in terms of these characteristics. However, the mean-percent relative abundance of the most common ostracod species (*Loxocorniculum tricoratum*) on both reef complexes is significantly different. Ostracod species dominance also differs radically between the two groups. Therefore, ostracod species abundance and dominance are more sensitive indicators of reefal equilibrium than the environmental parameters themselves.

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#### Nature and Field Application of Plumose Structures

Development of plumose structures in brittle rocks has been investigated by analogy to fracturing experiments on glass and ceramic bodies. Plume morphology shows that structures commonly lumped as plumose are a composite of discrete features, formed at all scales, during fracture propagation.

Inclusion hackle forms when an advancing planar fracture front becomes locally distorted at an inhomogeneity. The planar fracture, locally split by the inclusion, does not rejoin in a single plane behind the inclusion. This causes the lagging fracture portion to curve into the leading one forming a steplike tail elongate in the propagation direction. Twist hackle forms when a fracture front abruptly encounters changed stress directions along an extended frontal section. The entire fracture front breaks into individually advancing en echelon twist-hackle faces, each face perpendicular to the new resultant principal tension. Faces diverge and are elongate in the propagation direction. The faces form hackle steps by curving into each other to complete separation. Velocity hackle, uncommon in rocks, forms at a limiting propagation velocity.

Plume axes mark areas of greatest tensile stress and lightest propagation velocities. Plume asymmetry indicates intrastratum fracturing stress distributions. Axes consistently at the top or bottom of each stratum in a layered sequence indicate overall downward and upward (perhaps basement induced) propagation directions respectively. Recognizing twist-hackle faces and steps as differently oriented planes produced by a single fracture event eliminates identification and misinterpretation of false fracture sets.

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#### Fractographic Distinction of Coring-Induced Fractures from Natural Cored Fractures

Fracture surface structures (hackle plumes, arrest lines, origins) on coring-induced petal-centerline and disc fractures from three Appalachian Devonian shale cores indicate fracture sequence and propagation directions, relative propagation velocities, and tensile-stress distributions at failure.

Surface structures on coring-induced fractures are symmetrically and dimensionally related to the core. In contrast, surface structures on natural fractures, originating away from the core, are asymmetric and oversized. Plume asymmetry shows that stress intensity across natural fractures varied vertically during propagation.

Curvilinear petal-centerline fractures are propagated downcore as shown by convex downward arrest lines and hackle plumes that diverge downward about the core axis. Inclined petal sections curve to vertical from core margin toward core center. Some petals continue to spread vertically downcore, forming the centerline section. Petal-centerline fractures can change downcore from one preferred orientation to another, indicating differing orientation of stresses and thus of any fractures induced in a stimulation program. Petal curvature, absence of cored origins, and the 15-cm curvature radius of closely spaced arrest lines show that petal-centerline fractures originated in front of the bit's cutting surface. Chipped right-hand core to fracture margins, produced by plucking action of the bit, and arrest line-hackle morphology show these fractures were drilled through after propagation.

Bed-parallel disc fractures started at bit level, within the core, at bedding irregularities. Hackle plumes indicate that spreading velocity of disc fractures was greatest toward core centers and decreased toward core margins in response to changes in tensile stress intensity.

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#### Radiolarian Preservation in Present and Past Oceans

Three methods were used to collect living and recently dead radiolarians and fecal pellets containing radiolarians—plankton tows for those in the water column, and gravity cores and box cores for recovery from surficial sediments. Deep Sea Drilling Project cores were used to study radiolarians from fossil sediments. Our techniques differ from previous studies by the investigation of individual skeletons and suggest that radiolarian skeletons are removed from the water column primarily by dissolution and, secondarily, by settling as individuals or via fecal pellets. Laboratory experiments suggest that metallic coatings help to protect the skeletons from dissolution in the water column and in sediments. Other factors of extreme importance are differential rates of settling, thickness of the "radiolarian dissolution zone," productivity of overlying waters, amounts and ratios of terrigenous and authigenic sediment, presence of different water masses in the water column and at the sediment-water interface, degree of bioturbation, and chemical conditions at and below the sediment-water interface.

Paleobiologic developments such as the evolution of diatoms appear to be related to radiolarian conservation. The use of silica by diatoms may be partly responsible for the preferential dissolution of some Neogene radiolarians. Major changes in oceanic circulation appear to be related to such changes as the cessation of radiolarian preservation in the middle and tropical Atlantic during the middle Miocene.

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#### Sedimentologic Facies in Modern Glacial-Marine Environment

Studies of recent Antarctic glacial-marine sediments have enabled us to delineate facies associations that reflect the influence of fundamental glaciologic and glacio-isostatic processes on continental-margin deposition. Glacial-marine deposits can be broadly categorized as representing three sedimentary provinces. These are (1) the grounded shelf province—that portion of the continental shelf where sediments have been deposited by grounded ice at some time during glaciation; (2) the nongrounded shelf-upper-slope province; and (3) the middle to lower slope-rise province.

Sediments in the grounded shelf province consist predominantly of orthotills deposited by grounded ice, related till-flow deposits, and paratills deposited from floating ice. Glacial erosion and deposition by subglacial

streams are also important processes. Seaward of the maximum grounding line, on the nongrounded shelf and upper slope, deposition is primarily by floating ice. However, substantial sediment reworking occurs, forming coarse residual deposits and sediments enriched in fine-grained material. From a sedimentologic standpoint, distinction between the outer shelf and upper slope is problematic. The middle to lower slope and continental rise may be dissected by submarine canyons or may be nonchannelized. Gravity-flow deposits are commonplace. Laminated muds, perhaps deposited by contour currents, are also widespread. The boundary separating the two slope provinces is related to a zone of glacio-isostatically induced slumping where sediment gravity flows are generated, and perhaps to the shallowest depth at which contour currents occur.

These facies associations are useful in characterizing older sequences; they have been used to interpret several ancient glacial-marine sequences.

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#### Organic Geochemistry of Sediments Recovered by DSDP/IPOD

Since the beginning of the Deep Sea Drilling Project more than 10 years ago, organic geochemical studies have been undertaken on almost 2,000 sediment samples from beneath the ocean floor. These studies have provided fundamental information regarding the distribution of carbon in oceanic sediments and have yielded a better understanding of the processes that alter and transform organic matter in the marine environment. Of particular practical importance have been those investigations directed toward the occurrence of liquid and gaseous hydrocarbons in sediment of the continental margins and ocean basins; however, work has not been specifically directed to finding oil and gas. Instead, such discoveries have been purposely avoided, and information about possible occurrences of petroleum has been extrapolated from studies of anoxic basins, such as the Carioca Trench and the Black Sea, and from continental-margin sediments such as those off Norway, northern Africa, and southwest Africa. It is evident that significant concentrations of organic matter are sequestered in certain marine sediments, and it appears that much of this organic matter has come initially from the continents. Studies of the continental rise off Morocco show that organic material is undergoing diagenetic processes leading to petroleum. The organic geochemical conditions for petroleum formation, therefore, are present in the outer continental margins, but it remains to be determined if the geologic settings there are favorable for petroleum accumulations.

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#### Silica Dissolution from Montmorillonite; Effect of Solution Chemistry

The rate of silica removal from two montmorillonites (Chambers and Polkville) has been measured as a func-