and are commonly preserved in fossil shells. The microborings studied have the following morphological elements in common: sac-like enlargements (sporangia) with narrow necks (for spore release) opening to the substrate surface, and fine filaments (hyphae) interconnecting the sporangia.

The following characteristics of these three elements are compared: sporangia—shape, size, direction of the main axis, and degree of complexity; necks—length, cross section, and profile; hyphae—average width, constancy of diameter, branching, and mode of sporangial connection. The separation of three ichnotaxa within this cluster of forms is based on reconstruction of probable life cycles, morphometric analysis on the population level, and identification of the influence of different substrates on the morphology of the borings.

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Channel-Fill Deposits Formed by Aggradation in Deeply Scoured, Superimposed Distributaries of Lower Kootenai Formation

Three well-exposed channels of the lower Kootenai formation have several unusual features in common. The channels are contained within crevasse and bay-fill sequences, but the contacts between channel-fill deposits and laterally adjacent strata are erosional. The channels have a broad U-shape, range up to 300 m (985 ft) wide and 35 m (115 ft) deep, and exhibit a distinctive style of fill. Channel filling occurred in increments by accretion from the bottom up and sides in, to form a concave layering which is more or less symmetrical about the axis of each channel. Lithology of the fill of each channel is quite different, however, and ranges from mudstone, to interbedded sandstone and mudstone, to sandstone.

The channels are interpreted as superimposed distributaries formed by avulsion when the locus of sedimentation moved from one lobe to another. The lithology of the channel-fill deposits appears to be a function of the abandonment mechanism. A mud-filled channel forms where abandonment is rapid, as is the case with upstream diversion of a trunk river system. Sand and mixed sand-mudfills predominate where a distributary is progressively abandoned, for example where the discharge is diverted into an alternate favored distributary.

Superimposed channels are difficult to map in the subsurface by geologic means alone. They cut across the trend of adjacent facies so their presence cannot be predicted from analysis of the containing strata.

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Carbonate Sediment Produced by Rock-Boring Urchin, *Echinometra lucunter*, and Infauna, Black Rock, Little Bahama Bank

Bioerosion studies on Black Rock Island, Little Bahama Bank, were conducted during 4 cruises in 1982-83 on the 405-m (1,300-ft) long island of carbonate eolianite. The urchin population (mean 37 adults m^{-2}, 92 × 10^3 total) bores in a 6-m (20-ft) wide zone at depths of 0.5-3 m (2-10 ft). Scuba divers using rock chisels collected rocks, some with urchins in their boreholes and similar size rocks without urchins. The samples were placed separately in 20L, 62.5 μm screen-walled buckets for 2 days (18 useable measurements). Urchins produced spherical to elliptical pellets 1-2 mm in diameter. Disaggregated pellets contained no particles greater than 1.00 mm, 46% unimodal sand (mode = 177 μm), and 54% mud. Urchins produced a mean of 242 ± 146 mg sediment $urchin^{-1}$ day^{-1} (dry weight), equivalent to a mean of 8.9 g m^{-2} day^{-1} or 9 tons $year^{-1}$ for the entire population. Urchin boreholes were 17-126 cm^3 (mean = 72 cm^3). Calculating from boring-rate measurements, the boreholes were excavated in 0.7-10.3 years (mean = 2.9 years).

Rocks without urchins (controls) produced a mean of 0.50 ± 0.07 mg organic-free sediment cm^{-2} day^{-1} (dry weight). These particles were produced by bioerosion of an infauna (4.5-13.8 g dry weight) of eunicid and sipunculid worms, sponges, *Lithotrya* barnacles, pelecypods, and microborers. Inorganic sediment weight was correlated (r = 0.97) with surface area of the control rocks. Controls produced 5.0 g m^{-2} day^{-1} (36% of total), equivalent to 6.5 tons $year^{-1}$.

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Estimation of Oil and Gas Resources in Frontier Basins from Field-Size Distributions in Analogous Explored Basins

Oil and gas resource estimates for frontier outer continental shelf basins were expressed as field-size distributions. A list of AAPG basins was prepared to include field-level information on "original reserves" (reserves plus cumulative production) for oil and gas based on data from files maintained by the U.S. Energy Information Administration and the University of Oklahoma Petroleum Data System. Various distributions, including the 2-parameter lognormal distribution, were fit to each of the basins. In addition, basin-wide geologic characteristics were assigned to each basin. The research analyzed the statistical linkage between the fitted distributions and the geologic characteristics so that inferences could be made about the appropriate parameters for the field-size distributions in the basins to be evaluated.

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Intergranular Pressure Solution and Porosity Evolution in Quartzose Sandstones

Compared to cementation by quartz, carbonates, and clay minerals, intergranular pressure solution has long been viewed as a minor control of porosity evolution in quartzose sandstones. However, quantitative cathodoluminescence petrography and scanning electron microscopy of Paleozoic and Mesozoic sandstones from various geologic settings suggest that intergranular pressure solution is the diagenetic process that most fundamentally influences porosity and permeability evolution in a majority of cases.

Intergranular pressure solution dictates tightness of grain packing, size and geometry of primary pores, and diameter and morphology of contacts between framework grains; it also commonly predates pervasive cementation. Consequently, intergranular pressure solution is the fundamental control of minus-cement porosity. Although there is a close relationship between intergranular pressure solution and cementation in some sandstones, they are independent in others. For this reason, the percentage of minus-cement porosity actually occluded by cement is not systematic and is therefore difficult to predict.

Numerous geologic variables have been documented that influence the amount of intergranular pressure solution that occurs in quartzose sandstones. On a local scale, relatively fine-grained sandstones and sandstones containing between 3 and 9% early authigenic clay have experienced more intergranular pressure solution than other sandstones. Regionally, among sandstones of equal age, grain size, and clay percentage, those that have been exposed to greater rates of burial, greater total depth of burial, and higher temperatures have experienced more intergranular pressure solution.

These results suggest that an enhanced understanding of intergranular pressure solution may lead to a capability of predicting quartzose sandstone reservoir quality.

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Textures Formed During Shallow Water Halite Deposition—An Example from Permian of Palo Duro Basin, Texas

The Palo Duro basin, part of the broad northern shelf of the Midland basin during the Late Permian, accumulated cyclic, regressive, carbonate-anhydrite-halite sequences. Detailed interpretation of more than 2,000 m (6,500 ft) of halite core from 9 wells drilled by the United States Department of Energy in the northern Palo Duro basin permitted recognition of textures formed during halite deposition.

Textures formed on the bottom of a halite-saturated water body include color banding due to variation in composition and amount of impurities in halite beds, and vertically elongated anhedral halite mosaic, formed due to competition for space on the pool floor. Abundant fluid inclusions trapped along halite growth faces reflect rapid precipitation of halite in shallow water. Darker halite with sparse inclusions may have formed less rapidly in slightly deeper water.

Anhydrite partings, truncating the bottom-deposited fabrics, represent

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influx of marine-derived brine concentrated during transport across the broad, shallow shelf. The brine corroded existing halite and deposited gypsum before evaporation increased salinity and reinitiated halite deposition.

Halite precipitation ceased when brine supply decreased and the flat became emergent. Mudstone was transported onto the flat by wind and sheetwash. Exposure of the halite to meteoric water during this phase caused development of halite karst and destruction of other fabrics by recrystallization.

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Sedimentologic and Tectonic Factors Controlling Growth and Dimensions of Submarine Fans

The morphology, development, composition, and structure of submarine fans reflect five controlling factors. (1) Grain-size distribution—sandy debris results in radial fans, whereas mud-dominated debris promotes elongate fans. (2) Eustacy—during high sea-level stands, fan growth is curtailed as sediment, especially coarse sediment, is trapped in paralic settings, whereas during low stands, fan growth is accelerated owing to direct access of sediment to canyon heads and the flushing of debris from shelf areas. (3) Basin architecture—confined or unconfined. (4) Penecontemporaneous tectonics from seismic triggering to migrating source terranes. (5) Postdepositional tectonics that bias or alter lithofacies preservation—bias in sediment subduction results in the preferential loss of distal facies.

Some examples that demonstrate these five controlling factors include the following. (1a) The Navy and Arguello fans of the California continental borderland are sandy, radial fans, whereas (1b) the Bengal and Indus fans are muddy elongate fans. (2) The Eocene Farello fan, southern California borderland, is composed of thick intervals of sand and conglomerate lithofacies, corresponding to low sea level stands, and thin fine-grained intervals, corresponding to high sea level stands. (3) Relatively unconfined fans are most typical of passive or trailing continental margins, e.g., the Bengal, Amazon, and Mississippi fans, although even here diapir fields, seamounts, and fracture zones offer local impediments. In contrast, fans in confined basins are characteristic of convergent or transform continental margins, e.g., borderland, forearc, and backarc basins, although passive margins may also have confined basins. The Laurentian fan, for example, is blocked by the Kelvin Seamounts. (4) Large infrequent earthquakes (one to several per millenium) may trigger large depositional events, e.g., the 1929 Grand Banks shock. Shingling of depositional units occurs in pull-apart basins of strike-slip fault systems; such sequences may have stratigraphic thicknesses (not vertical accumulations) of 10 km/m.y. (33,000 ft/m.y.). Examples include the Neogene Ridge basin in California and the Cretaceous Izumi basin in Japan. Where a canyon head lies seaward of a transform fault, a large fan develops with multiple sources, e.g., the Monterey and Delgada fan systems. Where a canyon lies landward of a transform boundary, multiple small fans of one source terrane are strung out along a continental margin, e.g., the Baranoff fans of southeastern Alaska. (5) Inferred subduction complexes, e.g., the Torlesse of New Zealand, are composed principally of thousands of meters of tectonically thickened (thrust faulted) thick-bedded sandstone lithofacies. This composition may be due to decoupling of the more distal, fine-grained facies from the proximal facies and its transportation into the mantle along with the underlying oceanic crust.

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Coal from the Swash Zone—Herrin (No. 11) Coal in Western Kentucky

The Herrin (No. 11) coal in the southern portion of Moorman syncline in western Kentucky represents an important resource with relatively consistent properties and thickness. To the north, however, subsurface information reveals that the position of the coal is occupied by a limestone across a narrow (less than 0.5 km or 1,600 ft), east-west transition zone.

The Herrin is typically a bright, banded coal, with abundant vitrain and bright clarain, and has a parting, the "blue band," in the lower third of the seam. Herrin coal from a core in the transition zone, however, is largely a coarse breccia with calcite cement. The blue band is present in its usual position as a slickensided clay rather than as indurated siltstone as at nearby sites. A fossiliferous limestone is present in the upper third of the seam. Breccia lithotypes are duller than would be expected in the Herrin coal, but do include fragments with the appearance of vitrain and bright clarain. Microscopically, however, the predominate macerals of the lithotypes are not vitrinite, as would be expected, but rather semifusinite. Vitrinite group macerals are frequently "pseudovitrinite" or forms showing signs of degradation.

The presence of limestone "offshore" and as a parting within the coal and the pervasive calcite cementing between breccia fragments points to the strong influence of marine conditions on the peat. Nonbrecciated bands indicate that at least some of the seam is autochthonous. The breccia suggests a high-energy environment where peat fragments were ripped up in place or transported in from elsewhere. Any peat transport was probably along the strike of the transition zone. The peat was oxidized during fragmentation and transport, resulting in alteration of humic macerals to semifusinite and fusinite.

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Accretionary Styles in Shelf-Edge Reefs, St. Croix, Virgin Islands

Fourteen reef cores were taken in water depths of 8–30 m (25–100 ft) along two contrasting shelf margins on St. Croix, Virgin Islands. Seven of the cores were drilled vertically into the deep reef rimming the narrow (150–300 m, 500–1,000 ft) shelf of Cane Bay. Seven horizontal cores were drilled into the steeply sloping reef walls of Salt River submarine canyon.

The Cane Bay cores indicate initial *Acropora* colonization on a rubble slope of 5,000–6,000 years B.P. (at a water depth of 5 m or 16 ft). A subsequent 3,000-year hiatus in reef accretion was ended by recolonization of head corals (at a water depth of 8 m or 25 ft). The Salt River cores show alternating *Montastrea annularis* framework and open or sediment-filled voids up to 2 m (6 ft) across. This pattern is related to the complex system of channels, caverns, and overhangs common in this steep reef face.

At Cane Bay, vertical accretion rates averaged 1.16 m/1,000 years (45.7 in./1,000 years), with a range of 0.17–1.69 m/1,000 years (6.7–66.5 in./1,000 years). Lateral accretion rates at Salt River averaged 1.03 m/1,000 years (40.6 in./1,000 years), with a range of 0.84–1.38 m/1,000 years (33.1–54.3 in./1,000 years). The surprisingly high lateral accretion rates at Salt River are largely the result of down-faulted reef blocks causing repetitions of section.

Comparison of reef-accretion rates based on the cores with calcification potential for the reef (primarily as coralgal growth) indicates that more than 60% of the carbonate incorporated in the reef is ultimately reduced to sediment. Unlike that on Pacific reefs, this material is moved seaward and off the shelf edge, primarily during major storms. Such early degradation of the reef relates to the under representation of reef framework in the ancient record.

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Seismic Stratigraphy of Winedale Prospect: Updip Wilcox Trend, Onshore Texas Gulf Coast

In the central Texas Gulf Coast, the Eocene lower Wilcox Formation consists predominantly of massive sands updip of the Lower Cretaceous shelf margin. In northeast Fayette County, near the town of Winedale, an inflection point was found at the Lower Cretaceous Edwards and Sligo levels on reconnaissance seismic data. There was a corresponding "wipe-out" of reflectors within the lower Wilcox section above. Prospect-detailing seismic data indicated that the inflection point had localized lateral continuity. A flat spot was mapped at lower Wilcox, Edwards, and Sligo levels.

A well drilled to test the lower Wilcox "wipe-out" zone resulted in a lower Wilcox discovery with initial potential of 2.5 MMCFGD and 50 BCPD. Two delineation wells were dry. The producing sand is near, but not in, the seismic "wipe-out" zone. Genetically indistinguishable from the other lower Wilcox sands, it has a blocky, massive character, decreasing-upward grain size, and is bounded by thin coals. It pinches out updip and is not in the two later wells. An upper delta-plain point-bar depositional model is proposed.

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