pelagic sediments from the incipient stage to the mature stage.

Oceanographic events, diagenetic effects, and lithologic boundaries related to the geodynamic evolution of the crust all affect large areas of the seafloor. Their imprints in the physical properties of the sediments can be recorded on seismic profiles over long distances between drill sites. Thus, for the first time, we can reconstruct the evolution of entire ocean basins from almost their time of creation and can separate basin-wide or even worldwide events from those that are only local in origin.

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Tyler Sandstones (Pennsylvanian), Dickinson Area, North Dakota—A 24-Million Barrel Soil-Zone Stratigraphic Trap

Approximately 24 million bbl of recoverable oil have been found in stratigraphic traps in the Lower Pennsylvanian Tyler Formation at the Dickinson, South Heart, and eastern Green River fields, Stark County, North Dakota. Production is from a multiple sequence of quartzose sandstones 5 to 18 ft (1.5 to 5 m) thick deposited as barrier islands along regressive shorelines. Where a shoreline sandstone is fully developed, a typical vertical sequence consists, in ascending order, of the following.

1. 1 to 6 ft (0.3 to 2 m) of black to greenish-gray, sparsely fossiliferous shale. Thin interbeds of fossiliferous carbonate mudstone may be present (shallow-neritic environment).
2. 1 to 6 ft (0.3 to 2 m) of very fine to fine-grained sandstone containing small, deposit-feeding burrow structures. Stratification is finely laminated to ripple cross-stratified. Thin interbeds of siltstone and shale are common (lower-shoreface environment).
3. 3 to 12 ft (1 to 3.6 m) of fine to medium-grained, well-sorted sandstone which commonly exhibits medium to low-angle sets of cross-stratification. These genetic units are the principal reservoir rocks (upper-shoreface environment).
4. 1 to 2 ft (0.3 to 0.6 m) of fine to medium-grained, well-sorted sandstone which commonly appears massive, but in a few cores exhibits parallel stratification. The upper few inches are clayey and mottled by root structures (foreshore environment).
5. 0.5 to 3 in. (2 to 7 cm) of coal (marsh environment).

In a landward direction (south) the shoreline sandstones interfinger with thin fossiliferous limestones, black shales, and oxidized mudstones which are interpreted to be lagoon, marsh, and mudflat deposits.

Throughout much of the subject area, porosity and permeability in the sandstones have been greatly reduced or completely destroyed by development of caliche paleosols. In the western part, the caliche consists of gray to brown limestone nodules or nodular layers of limestone in the sandstones and contains abundant pyrite. In the eastern part, the caliche has been strongly oxidized, and nodular to brecciated limestone in the sandstones is associated with reddish-brown to white clay, iron oxide cement, and scattered anhydrite nodules. It is estimated that the caliche destroys as much as 50% of the potential reservoir rock in the area and is an essential factor in the stratigraphic entrapment of the petroleum accumulations by providing an eastern (updip) barrier to migration.

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Isotopic and Trace-Element Geochemistry of Dolomite—State of the Art

Large variations in the stoichiometry, perfection of order, and substitution of iron for magnesium in sedimentary dolomite make precise interpretation of the trace-element and isotopic chemistry of this complex mineral difficult.

Redetermination of phosphoric acid fractionation factors yields values of of $10^3 \ln\alpha$ between 11.4 and 11.9 for most sedimentary dolomites (the redetermined value for calcite is 10.5). A few dolomite types apparently yield values of about 12.5, but the reasons are unknown.

Mathematical modeling of the diagenetic behavior of the trace element strontium, in conjunetion with oxygen isotopic changes during the diagenesis of limestones, substantiates recent suggestions that experimentally determined partition coefficients for calcite may not apply under actual diagenetic conditions. Presumably, an analogous situation exists with respect to dolomite.

At the present state of the art, quantitative interpretation of absolute isotopic and/or trace-element values is tenuous at best. Qualitative interpretation of regional or stratigraphic gradients in either or both of these variables appears to be of far greater utility.

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Tracks and Substrate Reworking by Terrestrial Vertebrates in Quaternary Sediments of Kenya

Reworking of sedimentary substrates by terrestrial vertebrates, especially hoofed herbivores, has stratigraphic significance comparable to that of marine sediments by benthic invertebrates. Environmental analysis of the Pliocene-Pleistocene Koobi Fora Formation in northern Kenya reveals many vertebrate footprints and trackways in fluvial and lake-margin strata. Some beds are completely reworked by trampling of many animals, presumably ungulates, with subsequent disarrangement of primary grain fabric and sedimentary structures. Examination of footprints and game trails in similar modern Kenyan environments, and comparison with those in older sediments, indicate characteristics useful for their recognition elsewhere. Preservation is best in mud and sand interbeds of medium thickness where the animal foot punches out a plug of coherent surface sediment (usually mud) and presses it into underlying units of contrasting lithology (usually sand). Thicker and less coherent muds simply mold the foot. In both situations the print is flat to concave upward with a discontinuous rim that surrounds a low spot where later wind- or water-laid sediments and bone fragments may concentrate. Further trampling of coherent surface mud disturbs the ground surface allowing wind and water to remove the

loose sand below, thereby creating shallow erosional depressions on the landscape. Heavy trampling in wet interbeds of sand and mud homogenizes the previously distinct layers into a thicker, more massive unit, typically without any obvious tracks preserved. Although we have identified individual prints of hippo and antelope—and a four-print trackway of *Homo erectus*—exact taxonomic assignments are not yet easily made.

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Late Mesozoic Plate Tectonics

Most of this world's oil was generated in the late Mesozoic, and most of these deposits consist of middle Cretaceous oil. A study of Deep Sea Drilling Project results combined with marine geophysical data has yielded a large-scale, plate-tectonic history for this period. The most significant events in this history are (1) the opening of the north-central Atlantic between North America and Africa about 180 m.y. ago; and (2) the fragmentation of Gondwanaland 130 m.y. ago, a worldwide phenomenon when Africa separated from South America, Australia-Antarctica separated from greater India, and spreading patterns in the Pacific were greatly altered in response to the large-scale continental breakup. The middle Cretaceous is not characterized by continental breakup, but has unusual, and probably highly significant, characteristics. An apparent increase in worldwide spreading rates occurred from 110 to 80 m.y.B.P., coincident with a period that lacked magnetic-field reversals. Subduction rates increased, sea levels rose, and batholiths formed behind subduction zones as results of these spreading-rate increases. Mid-plate volcanism created most of the seamounts and guyots present today in the western Pacific, as well as voluminous sills that are chemically similar to midocean ridge tholeiite. These events probably controlled the generation and subsequent preservation of late Mesozoic oil deposits in a yet unknown way.

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Uranium In-Situ Leach Mining—A Third Alternative

Uranium in-situ leach mining, when used as a single commercial mining method, represents a technologic breakthrough with which many people are not familiar. In the last 5 years, plant-installed capacities for uranium in-situ leach mining have increased approximately 12-fold. There are now at least seven western states which have activities of some type regarding uranium in-situ leaching.

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Chocolay Group—Early Proterozoic Cratonic Sequence

The Chocolay Group of the southern Lake Superior region (upper Michigan, Wisconsin, and Minnesota), a stable-shelf assemblage bounded by unconformities, resembles Phanerozoic cratonic sequences. The Chocolay Group consists of a lenticular basal conglomerate overlain successively by quartzite (0 to 700 m), dolomite (30 to 800 m), and locally slate; it is capped by a regional unconformity. This sequence, although generally thicker, is similar to cratonic sequences (e.g., Sauk) in that both become finer upward, contain texturally mature sediments, are areally extensive, and are contained by unconformities.

New data on the Chocolay Group show interesting divergences from a quiescent stable-shelf model. Paleocurrents from cross-beds in quartzites show strong unimodality (s = 20 to 60°) atypical of stable platforms. Current directions from ripple marks and cross-beds crudely parallel later Precambrian troughs. Locally there are apparent reversals in the fining-upward trend of the Chocolay Group. Granite and basalt pebbles and abundant feldspars are present locally in dolomitic formations, but are absent in the underlying quartzites. The presence of irregular topography and the occurrence of uplifting locally are suggested by data which include thinning of quartzite members, variations in modal percent of detrital feldspar, and intraformational unconformities in the dolomites.

Based on large stratigraphic thickness, variations in sedimentary texture and mineralogy, and unimodality of paleocurrents, analogy to a simplistic stable craton interior is rejected. Rather, the influence of pericratonic tectonic conditions, including fault-bounded troughs, is suggested.

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Interaction Between Overwash and Eolian Processes on Migrating Barrier Islands

Landward barrier-island migration is accomplished by three processes: (1) inlet dynamics, (2) overwash, and (3) eolian transport. Although these processes are well understood conceptually, few studies have been designed to define their relative roles and thus determine the actual mechanics of barrier-island migration in recent times.

From field surveys of sites on Nauset Spit, Cape Cod, Massachusetts, and Assateague Island, Maryland, an interaction between the two subaerial sediment transport processes can be recognized. Overwash surges during storm conditions deliver fairly large quantities of sand each year (often exceeding 10 cu m of overwash deposition per meter of dune breach). A large part of this material is then redistributed by the wind, eolian transport being largely governed by the winter northwest (offshore) winds.

The net result at Assateague Island is the transport of most of the sand back to the beach face. A small part (less than 10%) of the overwash sand is deposited on the backside of the primary barrier dunes. Although this amount of accretion may seem quantitatively insignificant, this sand may serve as the major source of material to the dunes for their landward translocation concurrent with the migration of the island. This same general model can be applied to the Cape Cod barrier beaches except that drift-line deposits can initiate dune development on the washover fans. These studies can be applied to barrier-island management as well as im-