samples of conventional core, were studied. We believe that the present temperatures are maximal in the history of these late Miocene and younger rocks. The determined gradients are 24 to 35°C/km and 0.033 to 0.090% vitrinite reflectance per kilometer.

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Ichnology and Depositional Environments of Upper Cretaceous Chalks, Southwestern Arkansas (Annona Formation; Chalk Member, Saratoga Formation)

Both Annona and Saratoga chalks were deposited during transgression of middle to outer-continental-shelf environments. The basal contact of each chalk is a discontinuity surface underlain by marl. At these contacts chalk was piped across the discontinuity into marl through omission and postomission-suite burrows. Taxonomic composition of chalk-filled burrows below the Annona basal contact changes along a 60-km outcrop belt from dominance by *Thalassinoides* in the northeast to dominance by *Zoophycos, Planolites,* and *Chondrites* in the southwest. Such change indicates that this discontinuity surface was formed on a relatively steep slope which dipped southwest. Conversely, taxonomic composition of chalk-filled burrows below the Saratoga basal contact is unchanging (primarily one species of *Thalassinoides*) over a 90-km outcrop belt, thus indicating that this discontinuity was formed on a relatively shallowly sloping surface.

The basal 0.2 to 2.0 m of each chalk is a condensed bed rich in phosphate nodules and glauconite. Saratoga chalk was deposited at shallower depths, is generally much coarser grained, and contains more terrigenous detritus than Annona chalk. Saratoga quartz silt and sand may have been transported from a more shoreward area by poststorm seaward-directed currents.

The trace-fossil assemblage within the Annona, consisting primarily of *Planolites, Zoophycos,* and *Chondrites,* is similar to that documented from modern deep-sea carbonate oozes. Bioturbation within the Saratoga chalk is preserved only as mottles. Thixotropic preservation and large size burrows in each unit indicate that during deposition these chalks had very soft substrates and that oxygen content was not limiting.

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Retrogradational Shelf Sequence—Upper Cretaceous (Campanian-Maestrichtian) Cape Sebastian Sandstone, Southwestern Oregon

In the tectonically active Circum-Pacific belt, thick retrogradational ("transgressive") sequences are not uncommon, in contrast with the Cretaceous of the Western Interior. Retrogradational sediment packages reflect rapid sedimentation rates but even more rapid rates of relative sea-level rise. A well-exposed and convincingly documented example is the Cape Sebastian Sandstone, a 250-m-thick, fining-upward sequence representing foreshore to offshore accumulation.

Progressively increasing depth of deposition is reflected in both physical and biogenic sedimentary structures in the Cape Sebastian Sandstone. The basal, shelly boulder conglomerate is overlain by trough-cross-bedded pebbly sandstones, plane-laminated coarse-grained sandstones, and graded conglomerates. A single, subvertical trace-fossil type is locally abundant. These sediments represent foreshore to nearshore depositional environments.

The middle and bulk of the formation comprises hummocky cross-stratified sandstones. Grain size, frequency of pebble lenses, and thickness of hummocky laminae decrease upward. Burrowed zones, diversity of burrows, plane-laminated zones, plant debris, and oscillation-ripple preservation increase upward. These sediments reflect storm-influenced, inner-shelf sedimentation.

The uppermost part of the formation consists of alternating laminated, fine-grained sandstones and progressively thicker, burrowed sandy siltstones. Increased trace-fossil size and diversity, as well as abundant plant debris, characterize these sediments, which represent an outer-shelf sedimentary environment.

Modern examples of the described structures have been observed off the Oregon and California coasts, corroborating the hypothesis that the Cape Sebastian Sandstone represents a retrogradational shelf sequence. Also, evidence for Late Cretaceous faulting in southwestern Oregon supports the proposition that thick, retrogradational sequences may be deposited in tectonically active regions.

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Hurricanes and Rainfall—Key for Dolomitization in Tidal Flats of Western Andros, Bahamas

The geomorphology, sedimentology, and diagenesis of the tidal flats of western Andros, from Williams Island to Wide Opening, are controlled by hurricanes which transport pellet mud from a subtidal accumulation zone to the supratidal zone where diagenetic processes begin under humid, tropical weather conditions.

The directions of hurricane tracks (statistically determined) since 1871 show preferential orientations which coincide with hummock orientations. Thus, hummocks are interpreted as "traînées cycloniques," or hurricane trails.

Between these hurricane trails (hummocks), seawater and rainfall fill tidal and polyhaline (18.00 g/L to 30.0 g/L) estuaries and channels, as well as tidal and mesohaline (5.00 g/L to 18.00 g/L) basins. Below sea level and away from tidal influences, oligohaline lakes and ponds (0.00 g/L to 5.00 g/L) contain living Charophytae.

Diagenesis with lithification, cementation, or dolomitization occurs around the hurricane trails, particularly in white, thick dolomitic polygons of dry sediments. It thus appears that the very early dolomitic diagenesis in the Bahamian tidal flats can be correlated with (1) a high supratidal position resulting from hurricane action and, consequently, (2) the phreatic lenses of the tidal flats which produce oligohaline and hypersodic lakes and ponds rich in Na^{+}, Ca^{++}, K^{+}, and HCO_3^{-} ions. An intermediate phase could either be a transitory magnesium carbonate or a transitory alkali-bearing carbonate.

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Mid-Cretaceous Calcareous Nannoplankton Paleobiogeography and Paleo-oceanography of Atlantic Ocean

The abrupt lithologic change from Neocomian pelagic carbonate rocks to widespread organic-rich shales of middle Cretaceous age and the return to mostly oxidized sediments in the Cenomanian suggest significant changes in paleocirculation and productivity patterns. A quantitative study of calcareous nannofossils from DSDP and IPOD cores and selected land samples allowed delineation of paleo-oceanographic and paleoecologic patterns. Major factors controlling the distribution of calcareous nannoplankton are: (1) surface-water temperature and polar or equatorial temperature gradients, (2) aggressiveness of bottom water and associated position of the calcite compensation depth (CCD), and (3) diagenesis. Paleobiogeographic patterns of calcareous nannofossils change significantly during the middle Cretaceous.

In the Barremian to early Aptian, both Atlantic basins showed sluggish surface circulation resulting in a broad tropical assemblage and a weakly developed austral assemblage. During the late Aptian through middle Albian carbonate dissolution was most pronounced. Neither austral nor boreal nannoplankton assemblages could be distinguished. During late Albian to Cenomanian time boreal and austral assemblages are well developed and tropical assemblages are compressed with respect to latitude. Gyre-margin assemblages become more dominant and there are indications of more widespread upwelling in the eastern North Atlantic and over the Walvis-Rio Grande Ridge system.

This would indicate that stronger polar-equatorial temperature gradients developed in the latest Albian to early Cenomanian. More vigorous deep- and surface-water circulation would result in better ventilation of the deep ocean and the deposition of more oxidized sediments. Oxygen isotope determinations support the underlying assumption for this hypothesis. Nannofossil paleobiogeographic studies thus allowed us to document a comprehensive picture of middle Cretaceous paleo-oceanography in the Atlantic.

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Changing Perspectives in Paleoecologic Use of Trace Fossils

Historically, trace fossils have been described as "tricks of the devil, plant or fucoid remains, or the specific tracks of organisms," and more recently, as "the behavioral responses of organisms to a particular substrate." Moreover, there are now many attempts to use trace fossils to model community structure, to interpret depth zonations, diversity, nutrient levels, etc. However, it stretches the point to treat traces as pseudo-organisms. They can be excellent paleoindicators when accepted as the complex structures they are—especially surface traces. Surface traces represent the preservation of an ephemeral animal, combination of sediment, and fluid that can provide us with information about the size, weight, style, and locomotory types of animals present; they can set limits for values of the engineering or geotechnical properties of the substrate (such as bearing capacity, water content, and shear strength); and they can indicate the fluid regime (current velocities and directions) associated with the site area. This information can be gleaned from fossil traces by treating them as structures created by organisms (nothing more), that to be preserved must respond to local, transitory conditions at the seabed.

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Intisar "D" Oil Field, Libya

The Intisar "D" reef oil field was discovered by Occidental in October 1967; the discovery well tested 75,000 BOPD. The prospect was based on reflection seismic data, which indicated the presence of an isolated reef. Three such prospects had been drilled previously with varying degrees of success.

The Paleocene of the Sirte basin is characterized by carbonate rocks and shales deposited in an epeiric sea. The Intisar reefs grew in a late Paleocene embayment bounded on three sides by carbonate banks. Three distinct stages of organic development are recognized.

The Intisar "D" reef is roughly circular in plan and approximately 5 km in diameter. Its maximum thickness is 1,262 ft (385 m). The reef is coral and algal with grain- and mud-supported biomicrites. Porosity averages 22% and is mostly solution and intergranular. Measured permeability is as high as 500 md and averages 87 md. The main reservoir is remarkably homogeneous without noticeable layering typical of other reefs in the area.

The reef was full to spill point with a maximum oil column of 955 ft (291 m). The 40° API gravity oil has a paraffinic base and is low in sulfur. The original solution GOR was 509 cu ft/bbl. Original stock tank oil in place is estimated at 1.8 billion bbl. The field currently produces 200,000 BOPD oil from 13 wells; 11 water injection and 7 gas injection wells are used. Cumulative oil production as of September 30, 1978, totaled 777 million bbl. Ultimate recovery efficiency is expected to approach 75%.

No pressure support was expected. Supplemental recovery operations were begun early and include pressure maintenance by both water and gas injection. The reservoir pressure is now maintained at the 4,000-psi level, high enough for miscible gas displacement.

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Seismic Sequence Analysis; New Approach for Exploration in Offshore Brazilian Coastal Basins

Twelve Late Cretaceous to Holocene depositional se-