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 mag-