occurs in the *Thyrsocyrtis bromia* radiolarian Zone, the P15 foraminiferal Zone, and the *Discoaster barbadiensis* calcareous nannoplankton Zone. At each site, the layer is associated with the last appearance of several species of Radiolaria (e.g., *Thyrsocyrtis bromia, t. tetracantha, t. rhizodon, Calocyclas turris*). Previously published oxygen isotope data indicate a drop in temperature at about this time, which may be related to the tektite event and may have been responsible for the radiolarian extinctions. An iridium anomaly has recently been found associated with the microtektite layer that supports an impact origin for the tektites. The extent of the strewn field and the calculated mass of microtektite material ($\sim 10^{12}$ kg) indicate that the North American tektite event was a relatively large event.

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Late Cretaceous Multicolored Shales and Phosphatic Sedimentary Rocks in Egypt

Upper Cretaceous transitional fluvial to marine variegated shale (upper Nubia Formation) and the fully marine Duwi (phosphate) Formation occur as thin, widespread, shallow-marine deposits in an east-west-trending belt spanning the lower-middle latitudes of Egypt. These deposits consist of a heterogeneous suite of hemipelagic and shallow-water carbonate rocks that lie near the base of a generally transgressive marine sequence that was deposited on the fringes of the Arabo-Nubian craton in Cenomanian-Maestrichtian time. On a larger scale, the phosphoritic rocks in Egypt represent but a small portion of a laterally extensive Middle Eastern-North African phosphogenic province of Upper Cretaceous–Lower Tertiary age that accounts for accumulation of minable marine phosphate in excess of 70 billion tons.

Phosphorites, porcelanites/cherts, organic carbon-rich shales, glauconitic sandstones, and bioclastic and fine-grained carbonate rocks variously reflect major hemipelagic and shallow-water carbonate sedimentation. Biosiliceous hemipelagic deposits, now diagenetically altered to porcelanite and chert, reflect low energy depositional conditions that were periodically interrupted by high energy, possibly storm-induced currents and/or downslope redeposition. Both dark shales and porcelanites locally contain abundant organic matter and are commonly finely laminated. These strata probably reflect conditions of high biologic productivity and periodic anoxia in the water column. Porcelanites and black shales are phosphatic, containing phosphatic grains identical, morphologically and chemically, to those found in associated phosphorites, and are probably the source from which the phosphorites were derived. Several lines of evidence suggest that the phosphorites of the Duwi Formation are clastic sedimentary deposits that have accumulated through mechanical winnowing, reworking, and concentration of preexisting phosphatic fine-grained sediment.

The organic carbon-rich shales of the Duwi Formation appear to be quite laterally extensive and may, depending on thermal maturity, represent potential hydrocarbon source rocks in other portions of the region (e.g., Western Desert, Gulf of Suez), where they are more deeply buried.

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Storm Deposits (Tempestites) in Ordovician Cratonic Carbonates (Arbuckle Group, South-Central Oklahoma)

The Early Ordovician Kindblade Formation (Arbuckle Group), exposed in the Arbuckle Mountains of south-central Oklahoma, is a shallow marine epicontinental carbonate sequence that contains numerous storm deposits. Similar deposits also occur in other Arbukle Group units, although not as abundantly as in the Kindblade Formation. The storm deposits (tempestites) are of two types, proximal and distal; the latter dominates in terms of both number and aggregate thickness. Distal tempestites consist of a fining upward sequence, 5 to 50 cm (2 to 20 in.) thick, that overlies an eroded hardground or firmground. The sequence consists of a lag lithoclastic grainstone that grades up into a laminated peloidal grainstone and then into mudstone. Firmgrounds are characterized by hummocky, sharp, and erosional contacts (relief 2 to 7 cm, 0.75 to 2.75 in.) with grainstone-filled erosive pockets. Hardgrounds are characterized by sharp hummocky-to-convolute surfaces (relief < 4 cm, 1.5 in.), which are mineralized and bored. Primary sedimentary features such as laminations, burrows, and allochems are truncated at the surfaces, and borings are filled with unsorted lithoclasts. The lithoclasts at the base of the sequence are bored, generally well rounded, discoid in shape, and consist of mudstone, peloidal packstone, and oolitic grainstone. Infiltration fabrics within the lithoclastic grainstone include cement-filled shelter voids beneath large clasts and internal sediment perched on the upper surfaces of lithoclasts. The overlying peloidal grainstones contain ripple cross-laminations, plane-laminations, and hummocky cross-stratification as well as rare escape burrows. The overlying mudstone is sparsely fossiliferous and bioturbated with burrows either selectively dolomitized or infilled with lithoclastic grainstone. Although there are many examples of the ideal sequence described above, complex composite or amalgamated beds are also common.

Proximal tempestites consist of coarse lithoclastic flat pebble conglomerate beds approximately 1 m (3.25 ft) thick that are interbedded with ooid grainstone and overlie mudstone. The contact between the units is sharp and erosional. The lithoclasts are of variable composition and may be up to 20 cm (7.75 in.) in diameter.

The two types of tempestites occur in crude cycles, which consist of distal deposits overlain by proximal tempestites and ooid grainstones. The cycles are interpreted as shallowing-upward progradational sequences. The abundance of the storm deposits in the section, approximately one every 20 cm (7.75 in.), indicates that hundreds of storm-induced events are recorded in the Kindblade Formation. The tempestites represent rare catastrophic events, while the hardgrounds-firmgrounds are discontinuity surfaces that represent gaps in the sequence.

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Skeletal Fine Structure of Polycystine Radiolaria

The skeletons of most living Polycycstina are covered with a veneer of very fine, particulate opal that imparts a smooth finish to specimens viewed by the scanning electron microscope. In contrast, the opaline skeletal surfaces of Polycystina preserved in Miocene and older sediments have slightly "etched" appearances, with small dissolution pits presumably representing the removal of the finer particulate opal and revealing a substratum of opaline microspherules approximately 1 to 3 μ in diameter. The cross-sectional surfaces of broken spine bars on the vast majority of specimens have a somewhat conchoidal fracture, but otherwise they are smooth and give no indication of internal microspheralic ordering.

We have observed three specimens of heavy-walled Polycystina from the Miocene of California and Eocene sediments of the Norwegian Sea that appear to be in a more advanced stage of dissolution. They display a highly ordered microspherulitic internal composition. After extensive observations of many specimens, we conclude that this structure is not unique to these three specimens and may be characteristic of robust polycystine skeletal elements in general.

Cross-sectional views of broken lattice bars and spines are composed of as many as 34 concentric lamellae consisting of beadlike strings of microspherules. The microspherules are oblong with their long axes parallel to the radius of the skeletal element, producing lamallae of about 0.5 μ thick. Lamellar thickness if remarkably uniform in both Spumullaria and Nassellaria. Dissolution of less resistant lamellae results in delamination, which may be followed by flaking of loose segments.

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Evolution of Three Trissocyclid Radiolaria Lineages Across "Terminal Eocene Event"

Twelve species (nine of which are new taxa) of trissocyclid radiolarians are arranged in three evolutionary lineages that have been traced through upper Eocene and lower Oligocene sediments from the Caribbean and central equatorial Pacific. The history of these radiolarians at and directly following the "terminal Eocene event" is obscured by hiatuses, but fine-scale correlation of seven sections provides an almost complete record of their evolution. Although the timing, evolutionary rate, and structural modifications differ, each lineage exhibits a similar phylogenetic trend in the early Oligocene, such that the skeleton underwent a significant inflation and assumed an approximately discoidal shape. This trend was of only short duration, however, and all three lineages reverted to their original morphology before the close of Oligocene time. These lineages have long independent Paleogene histories that are not considered here, but the oldest species at the base of the studied interval are: lineage I, *Phormospyris inferispina* (Goll); lineage II, *Trissocyclus geniculosus* (Goll); lineage III, *Phormospyris* sp.

Cephalic inflation has its simplest expression in lineage I, where the trend has its earliest appearance and longest duration. At the base of the Oligocene, the simple lattice shell abruptly expanded to completely enclose the sagittal ring (*Nephrospyris anthocyrtoides* morphology). The first appearance of *N. anthocyrtoides* is a good secondary marker for the base of the *Theocyrtis tuberosa* Zone.

The discoidal lattice shell modification occurred only very briefly in lineage II, and apparently it had no permanent impact. *Trissocyclus geniculosus* has a compact skeleton characterized by massive, regularly disposed lattice bars. For a brief episode during the early Oligocene, a morph abruptly appeared with a ribbonlike concentric ring of distal lattice in the plane formed by the vertical and lateral axes.

This evolution commenced later and proceeded at a slower pace in lineage III, with each successive stage appearing sequentially. The most extreme development of lattice inflation occurred briefly approximately 2 m.y. after the first indication that cephalic inflation impacted the lineage. Additionally, the thorax underwent inflation as well in this lineage and eventually surrounded the cephalis as a discoidal "cortical" chamber. Subsequently, a reversal of the trend is apparent in the occurrence of a morph with a small supracephalic chamber that is homologous to the apex of the "cortical" chamber of its precursor.

Two possible explanations are proposed for the evolution of these lineages. The approximate synchroneity with which this skeletal modification occurred suggests that this evolution is interrelated genetically. The development of "cortical" morphology in lineages II and III is analogous to spumellarian skeletal structure. Alternatively, lattice inflation could have been an adaptive response to changing pelagic environments of the Oligocene equatorial oceans.

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Microbial Endoliths: Benthic Overscript in Sedimentary Record

Microbial endoliths are known from intertidal and shallow water marine environments with only a few reports on their occurrence in greater oceanic depths. We find microbial endoliths and microborings in abundance down to depths of over 4,000 m (13,000 ft), which means that a significant portion of the ocean floor is the site of microbial endolithic activity. Microbial endoliths are a strictly benthic phenomenon, and no endolith activity takes place in the water column. Endoliths leave a specific and well-preservable overprint on the sedimentary record of the oceans. The taxonomic composition of endolith assemblages reflects their environmental requirements and is depth related. The extent of endolith activity is a function of their exposure time at the sediment-water interface, which in turn is a function of sedimentation rate. Thus, the endolithic signature in the sedimentary record contains information on the conditions at the site and time of sediment formation.

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Pyrolytic Generation of Oxidized Carbon Species Estimated from Rock-Eval FID Response

The hydrogen index is defined as the amount of the S2 pyrolysis peak (in mg hydrocarbons) normalized to grams of total organic carbon (TOC) obtained from the usual Rock-Eval procedure. This value has been used to determine the type and, in part, the maturity of the organic matter in source rocks. When the same S2 peak (in mg hydrocarbons) is normalized to the grams of reactive organic carbon (ROC) actually consumed in the pyrolysis (measured by difference), one should expect a reasonably constant value between 1,110 and 1,330 mg S2/g ROC if all of the products of pyrolysis are hydrocarbons. However, this is not the case. The values of S2/ROC range from 700 to 1,400 mg S2/g ROC for samples having hydrogen index values above 200 mg HC/g TOC. Below a hydrogen index of approximately 200 mg HC/g TOC, the value of S2/ROC decreases sharply. The low values of S2/ROC mean that FID-nondetectable carbon is being released probably as CO and CO_2. The sharp decrease of this value in samples with lower hydrogen indices indicates that a large proportion of the reactive carbon is transformed to the oxidized species. This is true not only for type III kerogens, but also for the more mature type II kerogens with lower hydrogen indices. The amounts of CO and CO_2 can be estimated from a plot of S2/ROC versus S2/TOC. The calculated amounts of CO and CO_2 produced exceed that of CH_4 in source rocks having a hydrogen index of 100 mg HC/g TOC. The effects of this phenomenon are significant both with respect to natural gas compositions and with respect to the role of CO_2 as a possible medium for hydrocarbon migration.