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.

GLENN, C. R., Univ. South Carolina, Columbia, SC, R. E. GARRISON, Univ. California, Santa Cruz, CA, and M. A. ARTHUR, Univ. South Carolina, Columbia, SC

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.

GOLDHAMMER, ROBERT K., and R. DOUGLAS ELMORE, Univ. Oklahoma, Norman, OK

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.

GOLL, ROBERT M., Cities Service Technology Center, Tulsa, OK, and KJELL R. BJØRKLUND, Univ. Bergen, Bergen, Norway

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