quartz, as well as small intraclasts or oölites, trapped between laminations and in small cut-and-fill structures.

In the mats, laminae are essentially smooth and parallel. Mats are composed almost entirely of fine silt-size dolomite and commonly bear desiccation features which suggest a calm shallow environment. This is in contrast to the presence of intraclasts and algal clasts in the mounds which indicate a relatively high-energy environment. Together, both forms of stromatolites suggest a shallow, intertidal, locally hypersaline environment very much like that of the areas where algal stromatolites occur today.

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Facies Relations of Hystrichospheres in Onesquethaw Stage (Devonian) of Central Appalachians

Eighteen stratigraphic sections in the Valley and Ridge area of Virginia (10), West Virginia (6), Maryland (1), and southern Pennsylvania (1) were sampled in detail to establish the distribution of hystrichospheres in the Onesquethaw Stage of that region. The localities were chosen carefully relative to the stratigraphic and paleogeographic interpretation of Dennison (1961). Rock-stratigraphic units sampled include the Tioga Metabentonite, Huntersville Chert (including Bobs Ridge Sandstone Member), Onondaga Limestone, and Needmore Shale (with three subfacies: calcitic shale and limestone, calcitic shale, and Beaver Dam black shale).

No hystrichospheres were observed in the Bobs Ridge or other glauconitic sandstone beds in the Huntersville Chert. Only one fragmentary form was seen in the Tioga Metabentonite. The Onondaga Limestone, the three subfacies of Needmore Shale, and the chert of the Huntersville all contain hystrichospheres. Hystrichospheres are rare in Huntersville Chert adjacent to the Monroe Island of middle Onesquethaw age but are abundant in chert elsewhere. Similarly, they appear to be absent in all three subfacies of Needmore Shale adjacent to Monroe Island (at Covington, Virginia). Farther from land, in a basin toward the east between the island and a source of clastic mud near Baltimore, hystrichospheres are abundant in the calcitic shale and common in black-shale, calcitic-shale, and limestone subfacies.

Nineteen species have been identified, assignable to *Hystrichosphaeridium*, *Veryhachium*, *Polyedryxium*, *Michrystridium*, and *Cymatiosphaera*. *Michrystridium* seems more abundant and *Veryhachium* less common in the calcitic-shale and limestone subfacies of the Needmore Shale than in the other hystrichospherid-bearing rocks. *Cymatiosphaera* is less abundant in Beaver Dam black shale than in other rock types. No other statistically valid distribution trends could be observed.

There is no evidence that hystrichospheres can be used to subdivide the Onesquethaw Stage in this region.

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Effects of Ductility and Planar Anisotropy in Folding of Rock Layers

The mechanisms of folding that can operate within a sequence of layered rocks are dependent on the relative ductilities and on the nature of inherent anisotropy in the rocks. Flexural mechanisms require the presence of mechanical anisotropy, and folding is effected by slip between layers, by flow within layers, or by a combination of the two. Flexural folding represents a true bending of layers. Passive mechanisms operate only in rock sequences that are mechanically isotropic. This condition may exist either because of the absence of effective planar anisotropy or because of the ineffectiveness of anisotropy resulting from high ductility. The geometry of flow in passive folding reflects only the stress field and velocity gradients existing during deformation. Flow occurs across the layering, and the layering serves only to record the relative displacements. A gradational mechanism, by which certain layers are flexed in response to passive behavior in the associated rocks, causes quasi-flexural folding. This mechanism operates primarily in layered sequences characterized by high-ductility contrast, and produces strongly disharmonic folding.

Because changing environmental conditions can alter both the ductilities of the rocks involved and the effectiveness of planar anisotropy, the mechanism that initiates folding may be superceded by one or more other mechanisms during the course of deformation. The effect of layering in the folding process decreases with increasing ductility, and every gradation exists between ideally flexural and ideally passive folding.

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Cohesion and Flow Phenomena in Clastic Intrusions

Physical differences between water-saturated cohesionless sand and cohesive fine mud account for many sedimentary structures. Relative bulk cohesion is controlled by relations of intergranular adhesion caused by electromagnetic or Van der Waal's forces versus the disturbing effect of forcible migration of pore fluid or gas. Where expulsion of fluid is slow, mud retains greater cohesion than sand. If sand is loosely packed, movement of fluid, especially if sudden, may cause spontaneous liquefaction and conversion to a viscous slurry with negligible strength.

Empirical evidence of major differences of cohesion comes from abundance of shale pebbles, load structures, current sole marks, contorted stratification, and clastic intrusions. These are most characteristic of alternating sand-mud sequences which possessed many inherent-strength discontinuities. All degrees of liquefaction, flow, intrusion, and stopping are "frozen" in rocks—from local in-place liquefaction of sand strata to immense dike complexes and sand volcanoes. Clastic dikes are of special interest. Typically they contain fine sand, but in a few places may have coarse gravel. Wall rock is generally mud, and stoped cohesive mud xenoliths are common; some dikes split and even rejoin along strike. Internal lamination and some grain alignment may occur, and these suggest chiefly laminar flow of viscous suspensions. A few dikes display excellent groove and flute marks on their sides, evidencing scouring of cohesive wall rock during intrusion and indicating direction of intrusion. Some large dikes completely evacuated their source stratum with concomitant subsidence of all overburden.

Important relative age criteria are provided. Most dikes are straight, suggesting that compaction was completed largely before intrusion. In fact, compaction of mud probably provided most of the pore water which liquefied intercalated sand. The exceptional wavy dikes apparently were intruded earlier and compacted later with their wall rock. Sill-like masses are more problematical; some evidence clearly indicates liquefaction after burial, but others of these masses could have formed at the depositional interface. Certain strata were liquefied in place after burial and are not true intrusions, although they strongly resemble sills. Some synsedimentary folds can be distinguished from tectonic ones where sandstone dikes cut through them and prove an early, soft-sediment origin. Dikes along slaty cleavage have been cited as evidence of early formation of such cleavage. Some intrusions are useful in determining dates of migration and deposition of ores or fluids. Dikes may show close relations with regional structures, but many do not. Though more common in tectonically mobile regions, they also occur in stable ones. They most probably originated by shocks from earthquakes or from sudden loading. They are more common than is generally realized and their usefulness to the geologist has not been appreciated fully.

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DISTRIBUTION OF LATE CRETACEOUS ROTALIPORIDAE AND GLOBOTRUNCANIDAE IN CALIFORNIA AND NORTHWESTERN MEXICO

A study of planktonic Foraminifera from the Upper Cretaceous of California and northwestern Mexico forms a basis for erecting a preliminary biostratigraphic zonation.

The *Praeglobotruncana stephani* assemblage zone, of late Cenomanian age, is characterized by species of Rotaliporidae.

Strata of early Turonian age are recognized by the first appearance of bi-keeled globotruncanids which characterize the *Globotruncana imbricata* assemblage zone. Within this zone occur *Praeglobotruncana helvetica, G. kuepperi,* and several undescribed species. The *Globotruncana coronata-G. inornata* assemblage zone includes rocks of late Turonian to early Senonian age and contains distinct species of *Globotruncana, Clavihedbergella,* and *Hedbergella.*

The *Globotruncana arca* assemblage zone, of late Senonian age, contains several important stratigraphic markers, *e.g., Globotruncana ventricosa, G. havanensis, G. elevata,* and *Rugoglobigerina rugosa.* These indicate a Campanian to early Maestrichtian age. The planktonic Foraminifera which define the late Maestrichtian in other parts of North America are unrecorded in the eastern Pacific.

The stratigraphic and geographic distributions of selected species of *Praeglobotruncana, Globotruncana,* and *Rugoglobigerina* are compared with those from the Atlantic Coast and Gulf-Caribbean area. This comparison suggests that *Globotruncana arca, G. linneiana, G. fornicata,* and several other species were cosmopolitan, whereas such species as *G. calcarata* were latitudinally restricted during the Late Cretaceous. The genera *Abathomphalus* and *Plummerita* are found exclusively in the Tethyan region. *Globotruncana gagnebini, G. subcircumnodifer,* and others are reported only from the western margin of the Atlantic Ocean; *G. kuepperi, G. churchi,* and *G. putahensis* are unknown outside of the Pacific basin.

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LATE CRETACEOUS-PALEOCENE PHYTOPLANKTON, UPPER MORENO FORMATION, CALIFORNIA

Dinoflagellates and acritarchs are abundant in the upper Moreno Formation (Late Cretaceous-Paleocene) in Escarpado Canyon, California, the type area for the members of the Moreno Formation. Samples of the Marca Shale and the overlying Dos Palos Shale Members were studied from a subsurface cored section. The age of these units is well established by use of criteria independent of palynology, such as ammonites and foraminifers. The Cretaceous-Tertiary boundary usually has been placed somewhat arbitrarily at the contact of the Marca and Dos Palos Shales, but by the use of palynological evidence is placed in the Dos Palos Shale about 20 feet above the top of the Marca Shale. The phytoplankton assemblages exhibit marked changes at this level and further changes are evident higher up in the Dos Palos Shale.

The Maestrichtian is characterized by *Gymnodinium nelsonense* Cookson, *Deflandrea cretacea* Cookson, and a distinctive new species of *Hystrichosphaera.* The Danian is characterized by new species of *Areoligera, Hystrichosphaeridium, Cannosphaeropsis, Deflandrea,* and *Palmnickia.* A new species of *Palaeostomocystis,* and *Membranosphaera maestrichtica* Samoilovitch are abundant in the Danian but occur rarely in the Maestrichtian. Forms restricted to the lower Danian of the Dos Palos Shale include *Peridinium* and a new genus of Deflandreaceae. Forms restricted to the upper part of the Dos Palos Shale include *Cordosphaeridium inodes* Klumpp, *Deflandrea speciosa* Alberti, and *Glyphanodinium facetum* Drugg. Pollen and spores are present also in large numbers in the upper Moreno Formation. With a few exceptions, they are generally inferior to the phytoplankton for purposes of age-dating and zonation. There is good reason to believe that the phytoplankton eventually will prove to be as useful as planktonic foraminifers for correlation purposes.

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DIAGENETIC MODIFICATION OF RECENT SEDIMENTS ASSOCIATED WITH A LIMESTONE ISLAND

Recent carbonate sediments on Ambergris Cay, British Honduras, occur as a thin veneer of supratidal and intra-island lagoonal deposits, incompletely mantling an irregular Pleistocene limestone surface. Both sediments and rock exhibit different degrees of diagenetic modification. The supratidal mud flats usually adjoin very shallow hypersaline ponds, where sediments are subjected to extremes of chemical and physical environmental conditions; the raised rims of the mud flats prevent rapid drainage after periods of heavy rainfall or sea-water flooding.

Etching by rainwater and boring by algae tend to destroy or comminute sediment particles on the mud flats. Furthermore, extensive blue-green algal mats commonly are associated with a near-surface crust of dolomitized sediment. Degree of induration of this crust is related to the degree of dolomitization. Low pinnacles of Pleistocene limestone, where exposed near the dolomite crust, also have been partly dolomitized. Recent sediment particles commonly are recrystallized to cryptocrystalline carbonate, without mineralogic change, prior to burial.