ward, toward the west side of Blue Diamond Mountain, where the Virgin Limestone consists of 900 ft of marine limestone, dolostone, claystone, and shale; weaker units in the Moenkopi are covered largely by alluvium. About 6–8 mi farther south, in the Cottonwood Wash-Bird Spring Range area, total Moenkopi is about 2,000 ft, of which Virgin Limestone consists of 1,025 ft of cyclically accumulated marine limestone, dolostone, claystone, and shale.

The leading edge of the Keystone overthrust is 2–3 mi west of Triassic outcrops of the Blue Diamond Mountain-Bird Spring Range localities; Triassic strata on the upper plate are exposed superbly in the Lovell Wash-Lovell nose area, and in the Grapevine Springs locality near Kyle Canyon, about 10–15 mi west and northwest, respectively, from the Blue Diamond locality. Total thickness of interbedded and cyclically accumulated marine limestone, shale, and claystone is at least 2,435 ft; west-dipping strata are beneath Quaternary alluvium.

Lower Triassic strata of the autochthonous sections east of the Keystone overthrust are disconformable on the Harrisburg Member (gypsiferous) of the Kaibab Formation in most localities, and in turn are overlain disconformably by Shinarump Conglomerate. In the allochthonous block, however, the Harrisburg Member is absent, and only locally do Lower Triassic sediments lie on the Kaibab; elsewhere, channels were cut through the Kaibab and Toroweap, and the Mesozoic sediments have thick cobble and boulder conglomerate resting with marked unconformity on Permian redbeds.

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An Application of Upper Pennsylvanian Palynological Data to Interpret Environment of Deposition

Spore assemblages from samples of three known environments—(1) coal (fresh-water) swamp, (2) nonmarine, and (3) offshore-marine of the Upper Pennsylvanian—are described to the generic level. The number and types of spore and pollen genera are different in each assemblage.

The five dominant genera from each of six coals were placed in one group representing a fresh-water environment. The airborne saccate pollen were put in another group representing an offshore-marine environment. The two groups were combined into a ratio that indicates the predominance of one of the two environmental groups. This is termed the "swamp-marine ratio" which, combined with a third assemblage variable—generic diversity—was used to construct an environmental chart. Spore and pollen assemblages from each of the known environments occupy mutually exclusive areas on the chart.

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Bryozoan Ecology and Sedimentary Environments in Central Appalachian Upper Ordovician

Trepostomatous bryozoans are abundant in the upper Reedsville Formation (Ordovician) in the central Appalachians from Pennsylvania to Tennessee. A study of their faunal associations and zoogeographic distribution has emphasized the close relation between sedimentary environments and bryozoan morphology, abundance, and diversity. Reconstruction of the Late Ordovician environmental setting outlines a broad, gently sloping shelf with a prominent clastic wedge or deltaic complex in south-central Pennsylvania. Coarse sand and silt were common on the shelf in the north, and graded southward into silty mud and mud.

The external morphology of the central Appalachian trepostomes shows little change along the north-south shoreline. The zoarial types usually are branching, either subcylindrical or flattened plates; such forms are most common today in quiet sublittoral waters. The Ordovician trepostomes are abundant only north and south of the clastic wedge. Recent bryozoans usually are found in nonturbid environments on a slightly mobile surface of attachment; therefore, they are abundant only away from delta fronts and sediment-laden currents. Similarly, there is no reason to expect that the Upper Ordovician bryozoans reflect any lesser sensitivity to substratum mobility or to have been more tolerant of turbidity.

Where taxonomic diversity is mapped in Recent environments, those bryozoan assemblages with the highest diversity are found only where the rates of deposition are moderate to low. Generic diversity along the central Appalachian Upper Ordovician shoreline shows a sharp gradient from low diversity in the north to high diversity in the south. Two genera are common in the north, each isolated from the other but both equally abundant on the flanks of the clastic wedge. In southwestern Virginia and northern Tennessee, well off the apron of the clastic wedge, as many as 5 to 7 genera may be abundant at any one locality.

The distributional pattern of the Upper Ordovician trepostomes in the central Appalachians, especially the pronounced diversity gradient, appears to be directly related to areas of sediment influx and to rates of sedimentation.

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Digital Simulation Models of Evaporite Sedimentation

The factors that control evaporite sedimentation include basin configuration and tectonics, basin-water circulation, supply and composition of brine, rainfall, and evaporation, and the periodic variation of each. There are basin-center, basin-margin, shelf, and nonmarine types. All have their own controlling factors with peculiar magnitudes and variations.

The evaporite sedimentation system thus had tectonic, physical, and chemical subsystems as its main components. Their dimensioned associations are the conceptual evaporite model. Tectonic, physical, and chemical components, their spatiotemporal gradients, and their dynamic interaction define the simulation model. It is four dimensional and time variant.

Geology of evaporite deposits provides the setting, evaporite components, and facies to be simulated through the model. Experimental variation in spatiotemporal gradients of the controlling parameters explicitly defines the association of factors that produce the evaporite deposit, whose distribution patterns most clearly approximate those of the geologic system. The test of the experiment lies in how closely the two patterns coincide.

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PERMIAN EVAPORITES IN NORTH SEA BASIN

Thick evaporites are present in the Permian beneath the North Sea, and can be correlated with the known successions in Germany and in England. The evaporites are more widespread in the upper division (Zechstein) than in the lower (Rotliegendes). This paper deals chiefly with the Zechstein of the English side of the basin, in which four main evaporite cycles are present.

Zechstein salt movement commenced near the end of the Early Triassic when the overburden was only about 2,000 ft, and continued throughout the Mesozoic and Tertiary. Movement was earlier in the west than in the east. Salt plugs are associated particularly with the margins of a large NNW-SSE-trending trough which became fully developed during the Jurassic.

Important structural features and thickness changes in the Mesozoic and Tertiary rocks originated as a result of the salt movement, and are compensated almost entirely by salt at depth. As a result, the base of the Permian nearly is parallel, on a regional scale, with the base of the Quaternary though separated from it by about 10,000 ft of moderately complicated strata.

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RECENT DOLOMITIZATION OF PLEISTOCENE LIMESTONES BY HYPERSALINE BRINES, GREAT INAGUA ISLAND, BAHAMAS

Pleistocene carbonate rocks were sampled beneath a shallow saline lake on Great Inagua Island, Bahamas, to test the hypothesis of dolomitization by seepage refluxion. Commercial salt has been produced in part of the lake by solar evaporation of sea water for more than 100 years; hence, the writers reasoned that brines formed might have affected the Pleistocene carbonate bedrock. The upper few inches of rock beneath salt ponds consists of fine-grained, moldic dolomite; no dolomite was found in the Pleistocene limestone marginal to the lake or in rock underlying the lake in areas away from the salt ponds. Relict structures in the moldic dolomite show that it formed by replacement of partly cemented, aragonitic, oölitic limestone identical with the underlying and adjacent Pleistocene limestone. The dolomite crystals are cryptocrystalline ($< 5\,\mu$) in size and have a calcium-rich composition (about $Ca_{60}Mg_{40}$ to $Ca_{56}Mg_{44}$). The dolomite is enriched in O^{18}; measured apparent fractionation values for δO^{18} between the dolomite and the aragonite and calcite of the parent oölitic limestone range from 3.8 to 4.6‰. This O^{18} enrichment should be expected from dolomitization resulting from interaction of carbonate material with hypersaline brines formed by solar evaporation. Radiocarbon dates of the dolomite range from 2,930 to 3,420 yr B.P. These dates, older than anticipated if the dolomitization is controlled by brines formed since salt production began, may be in error because of incorporation of "old" carbon atoms from the replaced Pleistocene limestone.

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CLAY MINERALS IN ARCTIC OCEAN SEA-FLOOR SEDIMENTS*

Sediments of the sea floor of the Alpha Rise, 500 mi north of Point Barrow, Alaska, were cored to a depth of about 3 m below the sea-sediment interface beneath Ice Island T-3, where the ocean is slightly deeper than 2,000 m. The sediments contain about 80 percent clay and silt, the remainder being fine sand. They are either gray or brownish gray in color, the brown color being caused mainly by the oxidation of ferrous monosulfide. Although organic matter seems plentiful, it is of colloidal size and amounts to about 3 percent of the sediments. The clay minerals present are mica (both muscovite and biotite), mixed-layer mica and organic matter, vermiculite, chlorite (two polytypes), together with quartz, feldspar, and, in some samples, dolomite. The predominant clay minerals are mica and mixed-layer micas. Chlorite commonly is present, but vermiculite is scarce. Dolomite appears to be authigenic, but the micas, most of the chlorite, quartz, and feldspar are detrital. The mixed-layer mica with organic matter is authigenic.

* Authorized by the Director, U.S. Geological Survey.

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FAUNAL ISOLATION NEAR PRIMARY STRANDLINES*

Faunal isolation near primary strandlines has been studied quantitatively in Miocene, Pleistocene, and Recent sedimentary units in the Carolinas and Georgia. The contact between sediments deposited in marine and continental environments is sharp in most areas. The marine sequence consists of a *basal transgressive sand* dipping abruptly from the contact zone and flattening seaward, about 45 ft below the interpreted maximum mean sea level. The contained megafauna consists of (1) taxa living within the sea during the transgression; (2) taxa living within landward estuaries and swamps being eroded during the transgression; and (3) taxa derived from previous stratigraphic units. At the base of the sand, (1), (2), and (3) are present, (2) and (3) comprising most of the paleobiotal assemblage. A few feet above the unconformity, (2) and (3) comprise less than 5 percent of the assemblage, but a few forms are in place. *Littoral and sublittoral sand-silt* gradationally overlies the basal transgressive sand seaward and upward. Microfaunal content rises from less than 1 percent (by weight) in the basal sand to 3–5 percent in the overlying sand-silt. The species consist almost entirely of calcareous shallow-marine Foraminifera.

Few pelagic forms are present. Faunal preservation progressively becomes better, and exogenic forms are rare. Overlying the sand-silt facies is *bar and barrier island, generally unfossiliferous sand.* Intervening areas, isolated from the open ocean, accumulate *silt-clay*. The fauna consists of less than 0.5 percent shallow-marine Foraminifera, abundant oyster species,

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