custrine. Fluvial cycles consist of basal channels, channel-filling sandstone, and silty claystone floodplain deposits capped by soil(?) horizons. "Deep" lacustrine cycles are alternations of oil shale and thin carbonate rock. Complex nearshore cycles contain a basal terrigenous sequence, grading upward from mudstone to sandstone, and an upper carbonate sequence of oömicrite and oösparite capped by discontinuous algal mats and stromatolites. Cycles in other paleogeographic settings are modifications or combinations of these three basic types. Through correlations of groups of cycles, fluctuations in the extent of Lake Uinta and resultant changes in local base level are interpreted to have produced the cycles.

Walther's Law, which relates lateral facies changes to similar vertical sequences, cannot be applied to the Parachute Creek if only lithofacies are considered. For example, fluvial disconformities are equivalent to terrigenous lacustrine rocks, but none of the cycles contains both. Thus, Walther's Law must be modified to consider events and history, rather than lithofacies. Then the fluvial disconformities and terrigenous lacustrine rocks are seen to represent a single event, a fall in base level, and should not occur in vertical sequence.

This modification of Walther's Law does not violate its original intent. Rather, the applicability of this useful principle is broadened by removing the general requirement of regionally extensive lithofacies. Furthermore, attention is focused on history and causes, rather than on products.

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BOTTOM SAMPLING OF GEORGIA ESTUARIES WITH NEL SPADE CORER[1]

This is a progress report of a recently begun study to investigate in detail the bottom sediments of the Georgia estuaries and continental shelf. The potential significance of this project is enhanced greatly by the use of the NEL spade corer as the principal sampling device. This corer is capable of taking large, oriented, and undisturbed samples from unconsolidated substrates.

Hans-Eric Reineck, director of the Senckenberg Institute, invented the original box-corer. This was modified subsequently by Bouma and Marshall, and more recently it has been changed further by personnel of the Naval Electronics Laboratory of San Diego. The corer has a surface area of 10 by 12 in. and can penetrate to a depth of 24 in. A self-locking compass designed by Rosfelder and Marshall of Scripps Oceanographic Institution records the orientation of the core at the instant of sampling.

Physical and biogenic sedimentary structures which are of principal interest to this study are being examined by stereo X-ray radiography and preserved as epoxy peels. Wave- and current-formed structures preserved in the sediments are being mapped and compared with patterns of current flow; biogenic structures represented by burrows and bioturbate textures are being examined and recorded for their environmental significance; and sediment grain size and composition are being determined.

In addition to obtaining fundamental information on the conditions of sedimentation of the Georgia shelf and estuaries today, this study is producing information which permits direct comparisons with clastic facies of the Pleistocene strata of Georgia.

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TRACE FOSSILS AS CRITERIA FOR RECOGNIZING SHORELINES IN STRATIGRAPHIC RECORD[2]

Biogenic sedimentary structures offer a new and exciting approach to the interpretation of ancient sedimentary environments. Although trace fossils have been studied extensively by European geologists since early in this century, it is only in recent years that they have received much more than passing mention in North America. The increased interest in tracks, trails, burrows, and borings is due primarily to the environmental or facies approach to the study of sedimentary rocks. Whereas, in the past, attention has been directed toward descriptive studies of rock units, the present paleoecologic approach demands a genetic interpretation of the sedimentary record.

Appreciation of biogenic sedimentary structures as facies indicators has been influenced significantly by the emphasis on studies of physical sedimentary structures which in the past two decades have introduced many new keys to paleoenvironment interpretation. Additional impetus to the utilization of trace fossils has come from detailed studies of modern sediments which illustrate clearly the important relations that exist between the animals and sediments in a particular environment.

In the study of ancient and present-day nearshore sedimentary environments, the facies significance of biogenic sedimentary structures can be demonstrated readily. Striking similarities exist between nearshore clastic facies of Holocene and Pleistocene sediments of the Georgia coast and Upper Cretaceous shorelines of the western interior. Such similarities dramatically point out the value of trace fossils in environmental interpretation. These comparisons exist not only on the regional stratigraphic level but also between and within specific facies. Field studies which utilize trace fossils in conjunction with physical sedimentary structures, lateral and vertical changes in the sedimentary sequence, and geometry of the rock body offer new opportunities in the search for stratigraphic accumulations of oil and gas.

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SIGNIFICANCE OF PROVINCIALISM IN RICHMOND (UPPER ORDOVICIAN) CORRELATIONS

Richmondian strata have been recognized in large areas of North America. Study of brachiopod faunas provides a basis for evaluating Richmondian correlations and the extent to which provincialism characterizes separate but supposedly time-equivalent sedimentary basins.

A comparison of the brachiopod faunas of the standard Richmond section with the nearby Maquoketa Shale shows a marked dissimilarity between the two. Of 14 diagnostic species common to the type Richmond (Ohio Valley), only three are found in the Maquoketa sections in Iowa. Of 13 diagnostic species common to the Maquoketa, only two are found in the

[1] This study is supported by the National Science Foundation and U. S. Army Corp of Engineers.

[2] Work supported by National Science Foundation Grant GA 719.

type Richmond, whereas 12 species are shared by the Aleman and Cutter Formations (Texas and New Mexico) and six with the Arnheim and Fernvale Formations (Central basin of Tennessee). The evidence demonstrates a strong provincial aspect for the type Richmond fauna. The Maquoketa fauna is more widespread and provides a better standard for comparison.

The absence or scarcity of certain genera and species in one area is difficult to explain in view of their abundance in supposedly equivalent beds in the other. New studies show that the apparent absence of a species possibly can be explained by subspecific variation from one sedimentary basin to another, *e.g., Plaesiomys subquadrata* Hall.

The Arnheim and Fernvale faunas of Tennessee apparently occupy an intermediate position between those of the Maquoketa Shale and the Ohio Valley as they contain both unequivocal Maquoketa elements and diagnostic type Richmond forms.

Additional work is needed before the succession and lateral distribution of Upper Ordovician brachiopod faunas are clearly established.

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RECENT OFFSHORE DEVELOPMENTS, ATLANTIC COAST OF CANADA

Geophysical surveys indicate the following sedimentary features: a 20,000-ft sequence on the outer Labrador shelf, a 24,000-ft section in the Gulf of St. Lawrence, a 15,000 to 20,000-ft section on the Scotian shelf, and an 18,000-ft section on the Grand Banks of Newfoundland.

On the Scotian shelf shallow core drilling and grab samples indicate the presence of Quaternary, Tertiary, and Cretaceous sediments. On the Grand Banks, 10,084 ft of drilling in two holes penetrated Tertiary and Cretaceous sediments. One well was abandoned in salt at 4,839 ft.

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DISPERSAL PATTERNS AND DIAGENESIS OF OÖLITIC CALCARENITES, STE. GENEVIEVE LIMESTONE (MISSISSIPPIAN), MISSOURI

Oölitic calcarenite of the Ste. Genevieve Limestone was deposited in shallow water along the southwestern margin of the Illinois basin northeast of the Ozark shoal. Considerable divergence in shelf current patterns is indicated by the large variance (6,363) for azimuths of cross-bed sets of oölitic calcarenite and by outcrop polymodal windrose diagrams. Tidal current deposition is suggested locally by 180° reversals in sequences of cross-bed sets. The dominant currents flowed northwestward, as evidenced by the 326° vectorial mean for cross-bed azimuths and the northwestward migration of the thicker (40–90 in.) cross-bed sets.

During early diagenesis of the carbonate sand, aragonite in fossils and in oöid laminae was dissolved by low-Mg water to form extensive moldic porosity within insoluble micrite envelopes. Earlier precipitation of thin calcite crusts around the grains prevented collapse of most micrite envelopes. Intergranular and moldic pores were subsequently filled by mosaic calcite cement.

Oöids with calcite spar interiors and off-center nuclei are explained by (1) solution of aragonitic oöid laminae within an insoluble micrite envelope, (2) gravitative settling of the nucleus to the bottom of the mold, and (3) filling of the mold by calcite cement that displaced the nucleus to a nongeopetal position. Ferroan calcite spar of $(Ca_{.990}\ Mg_{.006}\ Fe_{.004})\ CO_3$ composition (electron microprobe analyses) was precipitated within the oöid molds in some beds. The presence of ferroan calcite reflects concentration of iron in the water inside the molds derived from dissolution of iron-bearing oöid laminae.

Postlithification chert, chalcedony, calcite, ferroan calcite, and dolomite formed along joint and solution openings by precipitation and/or replacement processes.

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DIAGENESIS AND PALEOCLIMATIC SIGNIFICANCE OF ALLOWAY CLAY

The Alloway Clay Member of the middle Miocene Kirkwood Formation (New Jersey) contains an interval unlike any described in the literature. This interval, which has a total areal extent of about 10 sq mi and ranges in thickness from 1 to 10 ft, is composed chiefly of kaolinite, with many of the kaolinite grains exceeding 0.2 mm (200 μ) in size. The individual platelets are so large that, for years, their kaolinitic nature was unrecognized and the material was mistakenly described as "a micaceous talclike clay." The formation of the macrokaolinite, and the simultaneous enrichment in kaolinite of the clays which lie beneath it, are thought to be the result of diagenetic transformation of previously deposited marine illite and montmorillonite clays to kaolinite by upward leaching (dialysis) of groundwater. Primary kaolinite, and possibly some of the converted material, was enlarged subsequently (or concurrently) by lateral epitaxy.

The macrokaolinite, and the Kirkwood Formation in general, are thought to reflect humid, subtropical climatic conditions existing in the region during the time of deposition of the Kirkwood. The presence of gibbsite, lepidocrocite, and goethite in the clay fraction of the sediments and the conversion of part of the Alloway Clay Member to an opaline-cemented orthoquartzite by silica-rich groundwater, possibly derived by the above transformation process, are additional evidence for such conditions. Hence, the boundary between the humid, subtropical and temperate zones must have been as far north as southern New York during the middle Miocene rather than in northern Delaware where it commonly is placed.

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SUBSURFACE TEMPERATURES IN SOUTH LOUISIANA

Subsurface-temperature observations, made by gas-producing companies in south Louisiana during the course of bottom-hole pressure determinations, were compiled on a magnetic tape by the Federal Power Commission. The measurements were taken long after the wells were completed, and they are therefore more nearly true than those taken during electric-logging operations. Reliable temperature *versus* depth plots could be made for 132 gas fields. The temperature