ment that might be either shallow and protected from water agitation by a physical barrier, or deep and protected by water depth itself. The presence of calcarenite composed of whole shells exhibiting little fragmentation or abrasion might indicate only local organic proliferation or lack of dilution by fine sediment. In contrast, calcarenite composed of fragmented, abraded, well-sorted, skeletal grains indicates water turbulence and winnowing of fines, processes which are more probable in shallow water.

Environmental syntheses based on stratigraphic, petrographic, and paleontologic criteria can bring into focus certain aspects of ancient marine environments that are difficult to determine from the record. On a local scale, detailed facies mapping in undeformed rocks may allow detection of original topography that controlled facies changes. On a larger scale, systematic lithic variation along the outcrop of an entire stage of rocks may provide a regional picture of the lateral succession of ancient marine environments across an epicontinental basin. Perhaps one of the best modern laboratories to study analogs of ancient marine epicontinental deposition is the Sahul-Arafura shelf and Gulf of Carpentaria between orogenic New Guinea and cratonic Australia.

HOLLIS D. HEDBERG, Princeton Univ., Princeton, N.J.

Continental Margins and Petroleum Geology

(No abstract submitted)

HOLLIS D. HEDBERG, Princeton Univ., Princeton, N.J.

Continental Margins from Viewpoint of Petroleum Geologist (Keynote Address)

Major features of the earth's surface are its continents and its ocean basins—which in turn reflect fundamental differences between continental and oceanic crusts. The broad zone of separation, or junction, between the continental and oceanic domains has been called the *continental margin.* It particularly includes the seaward part of the continental shelf, the continental slope, and the landward part of the continental rise.

Many of the most exciting events in the history of our planet have been concerned with the interplay between continental and oceanic crust and between continents and oceans; and the continental margin represents the stage where, throughout earth history, this drama has been played.

Important elements of the continental margin are the outer shelf, the borderlands, the marginal plateaus, the slope, the base of the slope, the rise, and the marginal trenches. The origin of these features and the nature of their sediments and local structures are the essence of geology. Of particular interest to the petroleum geologist are also the sediment-rich semi-enclosed basins or seas associated world-wide with the continental margin, the barrier ridges and reefs so commonly developed near the rim of the continental slope, and the growing evidence for impressive vertical movements of basin floors.

Great advances in our understanding of the processes active at the continental margins have come from the subsea geological and geophysical studies of the last decades, and rapid additional progress may be expected from the stimulus of "the new global tectonics"; but current hypotheses are still largely in a developmental stage. Factual data are still woefully inadequate. Moreover, continuing studies are needed, not only of the present continental margins but also of the past continental margins.

For the petroleum geologist, it is significant that through the ages the continental margin has been the great mixing bowl in which has been brewed the bulk of the world's petroleum and from which the bulk of its petroleum production to date has been derived. The continental margin should be the fruitful meeting ground of the petroleum geologist, the geologist of the oceans, and the student of earth history.

NORMAN CURTIS HESTER, Illinois State Geol. Survey, Urbana, Ill.

Depositional Environment of an Upper Cretaceous Deltaic Sandstone in Southeastern United States

A detailed sedimentologic, mineralogic, and paleontologic study of an Upper Cretaceous sequence of clastic sediments in Alabama and Georgia has defined three regional deltaic facies for the Cusseta Sand.

Fluviatile and upper delta.—This facies is medium- to coarse-grained, poorly sorted sandstone and kaolinitic clay, with cut-and-fill structures, and unimodal trough-type cross-stratification.

Delta front.—The delta-front facies includes carbonaceous, micaceous siltstone and sandstone and mixed kaolinitic and montmorillonitic clay, abundant small mollusks and ostracods, estuarine and tidal channel deposits, bimodal cross-stratification, and *Ophiomorpha* borings associated with well-sorted, cross-bedded, "barrier-island" sandstone.

Prodelta.—The prodelta facies is fine- to coarse-grained, calcareous, glauconitic, fossiliferous sandstone and montmorillonitic clay. The mollusks *Ostrea* and *Anomia* are dominant, and there are abundant calcareous benthonic and planktonic Foraminifera.

Paleocurrent and light- and heavy-mineral data demonstrate southward transportation of immature sediments derived from a high-rank metamorphic and acid-igneous source in the southern Appalachians and Piedmont Plateau.

The Cusseta Sand has been interpreted previously as a basal unit in a transgressive sequence. The present study indicates that it represents the final coarsening upward or destructional phase of a positive regressive sequence. Previous difficulties in correlating thin discontinuous sandstone bodies in Alabama with the Cusseta Sand in Georgia are explained by their interpretation as barrier-island bars which developed during the destructional phase of the deltaic sequence.

LEE R. HIGH. JR., Oberlin College, Oberlin, Ohio, and M. DANE PICARD, Univ. Utah, Salt Lake City, Utah

Sedimentary Cycles in Green River Formation (Eocene): Modification of Walther's Law

Along Raven Ridge in northeastern Utah, the Parachute Creek Member of the Green River Formation contains contemporaneous sedimentary cycles that range in environment from fluvial through "deep" lacustrine. 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.

JAMES D. HOWARD, Univ. Georgia Marine Inst., Sapelo Island, Ga.

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.

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

JAMES D. HOWARD, Univ. Georgia Marine Inst., Sapelo Island, Ga.

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.

HERBERT J. HOWE, Dept. Geosciences, Purdue Univ., Lafayette, Ind.

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

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