devoid of landslide structures. Regional variation in stratigraphic position of the base of the landslide facies establishes the fact that the foot of the paleoslope migrated north-northwestwardly through time.

In strata of the landslide facies, directional-current structures show transport from south to north whereas rocks of the floor facies display evidence of paleocurrents moving from east to west, suggesting that gravity-driven paleocurrents were deflected by velocity loss from northwardly to westwardly flow at the foot of the paleoslope. Distinctive siltstones were deposited by the deflected currents against the foot of the paleoslope.

The landslide facies is characterized by landslide deposits, reddish and greenish colors, subgraywackes, conglomerates, good fissility, fragmental fossils, ripple marks, and load-structures whereas the floor facies is defined by brown and gray colors, graywackes, poor fissility, sole marks, and trace fossils.

FREDERICKSON, A. F., University of Pittsburgh, Pittsburgh, Pennsylvania

Introduction to Symposium on Geophysical and Geological Properties of the Crust and Mantle

New petroleum is found with ideas.

The explorationist must think in terms of scale and context. This symposium focuses attention on some very large scale features of both the upper mantle and crust. Deep-seated inhomogeneities and regional discontinuities periodically will leave their imprint on the upper crustal rocks on land and under the sea—perhaps even in the deepest ocean basins. By recognizing these major features and trying to understand their behavior, we will develop the context into which smaller-scale features must be fitted. By drilling these features we will find the petroleum of tomorrow. It is, therefore, timely that we lay the groundwork needed to develop these ideas that will lead to our discoveries of the coming decade.

GLAESSNER, M. F., University of Adelaide, Adelaide, Australia

The Cambrian Frontier

Precambrian fossils are no longer to be considered oddities of questionable scientific or practical value. New discoveries, new techniques, and the impact of radiometric dating on Precambrian stratigraphy make it possible to set out for the first time the sequence of fossils through Early, Middle, and Late Precambrian time. They fall into four major classes: microfossils (appearing first), stromatolites (including index fossils of economic importance), megafossils (rich faunas in Late Precambrian, with at least 25 taxa representing 6 phyla of soft-bodied organisms at one locality in Australia), and trace fossils (possibly the earliest remains of animals). These occurrences can be related to the history of the biosphere and to modern studies of biochemical evolution. Placed in proper relation to the geotectonic framework of sedimentation they support the view that the search for oil should be extended beyond the Cambrian frontier into at least Late Precambrian sedimentary basins. Considerations of the definition of the base of the Cambrian and of events at that time also support this view.

GOODELL, H. G., Department of Geology, Florida State University, Tallahassee, Florida

Environmental Geometry: Its Effect on and Interaction with Sedimentation

Environmental geometry is defined as the three-dimensional shape of a locus of sedimentation as delineated by its bathymetry below a base level. Most depositional loci can be considered as open systems that exist within the framework of a larger system. Their geometry is thus nested within a hierarchy of geometric shapes, the largest of which is delineated by oceanic boundaries. Within any locus of deposition at any level in the nest of loci, the distribution, and often the rate of application of energy are functions of (1) the geometry of the locus and (2) the relative position of that locus in the geometrical hierarchy. Therefore, the characteristics of sediments within a locus of known bathymetry can often be predicted from environmental geometry alone. However, the relative importance of environmental geometry as a parameter which produces sedimentary patterns depends upon the rate of deposition at any one hierarchical level and is most effective at low to medium rates of sedimentation. Since the geometry of the depositional loci at all levels of the nest is interdependent, influences on sedimentary patterns exist between all levels but are most effective between adjacent levels. Multiple non-linear regression provides, in environmental studies, a powerful tool that permits the analysis of the inter-level geometric effects on sedimentation. Examples are presented from estuaries, bays, lagoons, and the continental shelf.

GORMAN, DONALD R., Geology Department, Bradley University, Peoria, Illinois

The Stratigraphy of the Amsden Formation of Wyoming

The Amsden Formation was studied in 1) western Wyoming, 2) the Wind River Mountains, and 3) the Big Horn Mountains area. Thirteen sections were measured in detail and representative samples collected for petrographic analysis.

Based upon the range of percentage of clastic quartz and clasticity, the Amsden Formation is divisible, in ascending order, into: *Subunit 1*—the Darwin Sandstone and, where present, the overlying siltstone/shale; *Subunit 2*—a quartz-poor, predominantly carbonate sequence; *Subunit 3*—many thin, quartz-poor, cyclic pairs of carbonate/non-carbonate beds; and *Subunit 4*—many thin, quartz-rich, cyclic pairs of carbonate/non-carbonate beds.

The greater amount of clastic quartz in the Wind River Mountains compared with areas to the north and west suggests a source area south of the Wind River Mountains. The clasticity and percentage of clastic quartz, in conjunction with lithologic curves, indicate that shallow water environments persisted in the area of the Wind River and northern Big Horn Mountains, whereas the central and southern Big Horns and western Wyoming areas were deeper water environments. *Subunits 1* and *2* represent a general transgression, and *Subunits 3* and *4* a general regression. The presence of many diastems and clastic/carbonate pairs of cyclic sediments in the Wind River Mountains and northern Big Horn Mountains sections and their absence in the deeper water environments suggest many minor oscillations in sea level during both the transgressive and regressive phases.

GORSLINE, D. S., VERNON, J. W., and SCHIFFMAN, A., Department of Geology, University of Southern California, Los Angeles, California

Processes of Sand Transport in the Inner Margins of the Continental Shelf

During the past three years, the senior author and his students have been studying processes of sand transport in the surf zone, inner shelf, and submarine canyons along the eastern Gulf of Mexico and the Pacific Coast. Methods have included the use of fluorescent dyed sand, dynamometers, rapid beach profiling, SCUBA equipment, and time-lapse photographic apparatus. Transport phenomena have been investigated to depths of 30 meters.

It is evident that sands move in the surf zone in response to the distribution of kinetic energy and are channelized between the breaker line and the swash line by energy minima. These minima and intervening maxima are exactly matched by textural characteristics of the surficial sediments. The uniform average textures of all surf zone sediments are a reflection of the presence of a compensating system that produces a narrow range of drift velocities in spite of the large range of wave heights and transported water volumes. Bigger waves break farther from shore and move water through larger cross sections. Thus the velocities tend to be roughly the same as those generated by smaller waves. The absolute quantity of sand moved, however, is very much a function of breaker size as is evidenced by profiles of beaches from different energy regimes. Surf zone water motion is complex and multi-layered. Undertows are strong and periodically flow beneath the surface water flow.

Offshore, beyond the breakers, sediments move in ripples, in directions that are determined by bottom wave velocity and sediment size. Sediments of different size grades move in different directions in any individual wave condition. Inman's model of sand motion is documented. In some areas the ripple crest positions are essentially fixed while sand motion is going on, much after the fashion of standing waves.

GOULD, DON B., Geophoto Services, Ltd., Calgary, Alberta, Canada, and DE MILLE, GEORGE, Imperial Oil Enterprises, Ltd., Calgary, Alberta, Canada

PIERCEMENT STRUCTURES IN CANADIAN ARCTIC ISLANDS

The Sverdrup basin in the Queen Elizabeth Islands of northern Canada contains many piercement structures with exposed cores of gypsum and anhydrite. Several cores are more than 10 square miles in area. Adjacent anticlines may have unexposed evaporite cores. The basin is about 700 miles long and 250 miles wide. It is filled with more than 40,000 feet of Mesozoic clastic deposits underlain by possibly 5,000 feet of Pennsylvanian and Permian sediments including reefoid carbonates and an evaporite sequence. Salt is not known to be associated with these evaporites but its presence is suggested by gravity data.

Piercement structures in the western part of the basin are long, domal, and exhibit little or no evidence of tangential compression; they are probably salt domes resulting from halokinesis or geostatic loading. Ordovician salt is known to exist in the Cornwallis fold belt which presumably extends under the basin; it may have been involved in the early history of piercement structures in the central part of the basin.

In the eastern part of the basin some piercement structures are large and domal, but most are relatively small, elongate, and associated with major faults. These appear to have resulted from diapirism initiated by tangential forces during the Laramide orogeny.

GOULD, H. R., Esso Production and Research Co., Houston, Texas

THE MISSISSIPPI DELTA COMPLEX

The Mississippi delta complex is one of the largest and probably the best known of the world's major delta systems. Its subaerial surface—the Mississippi deltaic plain—extends from an apex at the mouth of the Mississippi alluvial valley to a base of 200 miles along the Louisiana coast. Underlying this plain and the adjacent continental shelf and slope is a huge mass of Late Quaternary river-mouth deposits which make up the deltaic complex. These sediments occupy a seaward deepening, trough-like depression in the underlying surface that developed contemporaneously with deposition and which is localized in the depositional area. Downwarping of this segment of the continental margin, together with the eustatic rise in sea level during Late Quaternary time, was sufficient to accommodate the great thicknesses of Late Quaternary deposits. These deposits reach a known maximum of about 1,000 feet under the continental shelf at the seaward limit of control.

Beneath the deltaic plain and inner shelf, the Late Quaternary deposits consist of a thick onlapping sequence, grading upward from basal fluvial and strandplain sands and gravels to deltaic and marine silts and clays with local sand lenses. This is overlain by a thinner sequence of offlapping deltaic sands, silts, and clays exposed on the deltaic plain. The onlapping sequence records the eustatic rise of the sea from its last low stand while the offlapping sequence represents progradation after the sea reached its present level some 3,500 to 4,000 years ago. At that time the Gulf shore coincided approximately with the present coastwise Pleistocene-Prairie contact and subsequently has been advanced far seaward by construction of the deltaic plain. In building this plain, the Mississippi River occupied and abandoned two courses and several deltas prior to establishing its present course and active delta. In order of decreasing age, these are the Teche, St. Bernard, LaFourche, Plaquemines, and modern birdfoot delta.

Except for the birdfoot delta, which is advancing into deep water of the continental slope, each of the deltas was built forward onto the shallow inner margin of the continental shelf. Sediments delivered to the deltas through leveed distributaries were deposited in a variety of environments. Most of the sand was laid down in distributary-mouth bars of the delta front and in distributary channels as they were abandoned. Silts and clays were swept further seaward into the marine prodelta zone and, during floods, into swamps, brackish marshes, bays, lakes, and channels of interdistributary and delta-flank depressions of the deltaic plain. Following river abandonment of an active delta, subsidence, caused principally by compaction, resulted in the encroachment of peats and organic mucks of the swamp-and-marsh environments across the delta, leaving only the levees exposed. Continued subsidence permitted local transgression of these deposits by marine sediments. Regional downwarping and compaction during and following delta building have depressed the deposits far below original depositional levels and account for their great thickness.

GRIFFITHS, JOHN C., The Pennsylvania State University, University Park, Pennsylvania

EXPERIMENTS IN SAMPLING SEDIMENTARY ROCKS

Random sampling to insure unbiased estimators of population characteristics is both critical and costly to achieve; if the internal "structure" of a population is defined as its patterned variability, then the sampling arrangement may be used to define the structure ob-