associated with certain geologic provinces. Recent gravity and magnetic studies suggest a possible structural relationship between the Lake Superior syncline and the Michigan basin and suggest the presence of basalt flows along the Cincinnati arch similar to the Keweenawan flows of Michigan.

Configuration of the basement surface is conventionally interpreted from well data, aeromagnetic surveys, and projection of dips. Recent development of the continuous velocity log, however, has led to a resurgence of spot correlation seismic surveys. The technique, based on widely spaced seismic shot points, has been successfully applied in Illinois, Indiana, and Ohio as a low-cost method of regionally mapping the basement. In general, preliminary seismic results and gravity and magnetic studies show close relation between the major sedimentary structures of the midwestern United States and the regional configuration of the basement surface.

SAITO, TSUNEMASA, Lamont Geological Observatory, Columbia University, Palisades, New York

MIOCENE-RECENT PLANKTONIC FORAMINIFERA FROM AMPERE BANK, NORTHEASTERN ATLANTIC OCEAN

Eight submarine cores, obtained by the Lamont Geological Observatory from Ampere Bank (a sunken island located at 35°00′ N. Lat. and 13°00′ W. Long. about 630 km. WSW of Gibraltar), were studied with the purpose of long-distance correlation of mid-Tertiary stratigraphic sequences by means of planktonic Foraminifera. Ampere Bank rises from the floor of the ocean at a depth of about 4,000 m. to a minimum depth of 53 m. from the sea-level.

The core sediments consist of white or light brown calcareous sand and lutite, except for one core taken from the western slope of Ampere Bank where the coarse fraction includes particles of volcanic rock and pyroxene. Planktonic foraminiferal tests are a major component of these calcareous sediments with a few benthonic species representing various habitats from shallow to deep water.

Miocene planktonic foraminiferal faunas occur in 4 out of 8 cores. The Miocene sediments are usually very thinly covered (10–20 cm.) by the younger sediments. Based on the stratigraphic distribution and species composition of planktonic Foraminifera, three concurrent-range zones were recognized. These are in ascending order: *Globorotalia mayeri/Globigerina nepenthes*, *Globorotalia menardii/Globigerina nepenthes*, and *Sphaeroidinellopsis seminulina* zones. However, no single core contains more than two of these zones. The boundary between the *G. mayeri/G. nepenthes* zone and *G. menardii/G. nepenthes* zone indicates that of the Helvetian-Tortonian stages. The planktonic faunas as found in Ampere Bank are very similar to those of the Donni sandstone in Saipan, the Nobori formation in SW Japan, and the Pozón formation in Venezuela. This evidence confirms the supposed value of planktonic Foraminifera for long-distance stratigraphic correlation.

In this region *Globorotalia hirsuta*, which has not yet been reported from equivalent zones of the Pacific regions, makes its first appearance at the top of the *G. mayeri/G. nepenthes* zone and occurs abundantly in the overlying two zones.

The post-Miocene sediments are distinguished by the predominance of *Globorotalia truncatulinoides*, sparsity of *G. menardii*, and dominant dextral coiling of *G. hirsuta*. Several phylogenetic trends of Recent planktonic foraminiferal species are found within these three zones. Since many Recent species appear near the end of the Miocene, more refined biostratigraphic subdivision of the post-Miocene sediments is a difficult task and requires further studies.

SANDERS, JOHN E., Department of Geology, Yale University, New Haven, Connecticut

PRIMARY SEDIMENTARY STRUCTURES PRODUCED BY TURBIDITY CURRENTS

Turbidity currents produce numerous primary sedimentary structures, depending on mechanism of particle movement and sediment load-current-bottom interaction. Because the sediment is responsible for the current, depositional loss of load systematically changes conditions and structures produced. Only a few sediment-current-bottom combinations are unique to turbidity currents; many combinations, hence sedimentary structures, also occur in other current-sediment systems.

Two types of collective behavior in cohesionless sands are inferred to occur in turbidity currents: (1) high-velocity sheet flow, where grains, probably not in true suspension, shear over the bottom below and underneath the truly suspended load above, outrunning the latter; and (2) traction-carpet flow, in which the grain layer may become relatively passive with respect to underlying bottom, but is subjected to shear, with or without sand fallout, from the overlying current with suspended sediment. Drag relationships between turbidity currents and traction carpet have not been investigated in the laboratory, but probably could be. Bagnold's analysis indicates that drag varies inversely with grain size and is a minimum in very fine sand. When the current has covered the bottom with fine sand, therefore, the decreased drag may trigger an abrupt increase in current velocity. This possible "auto-acceleration" might explain the otherwise enigmatic increase in current velocity without change in grain size, which the writer previously invoked in analysis of convoluted laminae.

SCHMIDT, VOLKMAR, Socony Mobil Oil Company, Dallas, Texas

FACIES, DIAGENESIS, AND RELATED RESERVOIR PROPERTIES IN THE GIGAS BEDS (UPPER JURASSIC), NORTHWESTERN GERMANY

The Gigas beds were studied in a subsurface area adjacent to the northern subcrop limits of the Lower Saxony basin, west of the Weser River. Fossiliferous beds were deposited, in supersaline epicontinental seas as the basal beds of a major saline cycle. Isopach maps reflect a pattern of low-thickness sills and near-shore areas adjacent to basins of greater thickness. Shale and sulfates predominate in the basins. Bioclastic and oölithic calcarenites and micrites form most of the shallow-water deposits.

Early diagenetic protodolomite replaced more than 50 per cent of the total sedimentary calcium carbonate. The extent of dolomitization varies from a trace to complete replacement. Dolomitization increases: (1) as the northern boundary of the Lower Saxony basin is approached, (2) as thickness decreases, and (3) as clay content increases. The three parameters are interdependent.

Dolomitization of the shallow-water carbonates postdates initial lithification. Here, protodolomite replaced calcium carbonate volume per volume, but due to dolomitization part of the calciclastics have been dissolved, creating voids. Dolomitization of basinal carbonates predates lithification and created no porosity. In both environments, protodolomite originated

before the conversion of aragonite to calcite and before tectonic fracturing. The magnesium content of protodolomite ranges from 41.5 to 47.5 mol. % $MgCO_3$. It is influenced by depositional environment and the calcite/dolomite ratio of the individual sample. Dolomitization is selective. Dolomitization affects first the high-clay matrix, second the low-clay matrix, third the aragonitic calciclastics, and last the calcitic calciclastics. The original aragonite content in the carbonates is extremely important for the material balance during diagenesis.

Large scale replacement of protodolomite by calcite, encountered in one oil field, is related to weathering prior to a transgression. Intensive late diagenetic cementation by mostly calcite occurred before and following oil migration.

Dolomites with high diagnetic porosity are the main reservoir rocks. Undolomitized calcarenites with original high intergranular porosity form a secondary reservoir rock type. The reservoir properties of the Gigas beds change markedly in isofacies and isodolomite areas as a result of the variable intensity of the late diagenetic cementation. The occurrence of reservoir rocks is determined by the local coincidence of favorable facies with favorable diagenesis.

SCHNEIDER, ERIC D., AND HEEZEN, BRUCE C., Department of Geology and Lamont Geological Observatory, Columbia University, Palisades, New York

SEDIMENTS OF THE CAICOS CONE, BAHAMAS

A large sedimentary ridge extends east of Caicos Passage (Bahamas) toward the Silver Abyssal Plain. This asymmetrical ridge is steepest on the south side and lies parallel with the Bahama Banks. Small V-shape depressions observed on the crest and north slope may be submarine channels. Three 6-meter-long cores taken at approximately 2,850 fathoms consist of pelagic clays (illite and chlorite) with interbedded calcarenites. The calcarenites consist of foraminifera (benthonic and pelagic), pteropods from both noritic and littoral depths (indicating considerable displacement of fauna), and finer material. Primary structures such as graded bedding, cross-bedding, convolute bedding, and parallel bedding were observed in the turbidite beds. Considerable mechanical sorting of faunal species due to differential settling in a single sequence resulted in two distinct sediment facies; the lower consisting of foraminfera and pteropod tests and the upper consisting of clay, discoasters, and coccoliths. The pelagic sediments of the three cores show close correlation in their variation of carbonate content. These variations may reflect climatic changes.

A single stratigraphic sequence is seen in the three cores. Each has a similar carbonate curve, similar sequence of manganese-stained layers and a similar sequence of sediment colors. One correlative calcarenite thins from 24 cm. to 13 cm. and the mean grain size decreases from .04 mm. to .018 mm. as distance from the probable source increases by 50 miles.

SCLAR, C. B., CARRISON, L. C. AND SCHWARTZ, C. M., Batelle Memorial Institute, Columbus, Ohio

HIGH-PRESSURE STUDIES IN THE SYSTEM $MgO$—$SiO_2$ AND THE CONSTITUTION OF THE UPPER MANTLE

The compositions $MgO \cdot SiO_2$ (enstatite) and $2MgO \cdot SiO_2$ (forsterite) were studied over the pressure range 20 to 130 kilobars at temperatures between 500° and 1,200°C. This pressure range corresponds with depths of about 75–400 km. which include part of the 200–900-km. seismic discontinuity zone in the upper mantle.

Orthoenstatite is the high-pressure high-temperature polymorph, and clinoenstatite is the high-pressure low-temperature polymorph. The equilibrium boundary for the orthoenstatite-clinoenstatite transition intersects the temperature axis at 540°C.; at 100 kb the equilibrium temperature is 870°C. At 115 kb and 600°C. clinoenstatite breaks down to forsterite plus stishovite. Forsterite is stable to at least 130 kb.

The experimental results: (1) support Birch's (1952) hypothesis that the inhomogeneous region in the upper mantle is due to pressure-dependent phase transformations; (2) confirm Ringwood's predictions that (a) enstatite breaks down to forsterite plus stishovite at about 120 kb, and (b) higher pressures are required for the forsterite-spinel inversion; (3) explain, when coupled with the results of Bowen and Tuttle (1949) on the system $MgO$—$SiO_2$—$H_2O$, the absence of clinoenstatite in terrestrial rocks and its occurrence in meteorites; and (4) explain the experimental results of Turner, Heard, and Griggs (1960) which show that orthoenstatite may be transformed to clinoenstatite by deformation; the latter exemplifies the Becke concept of shear-induced diaphthoresis.

SHARMA, G. D., University of Alaska, Douglas, Alaska

GENESIS OF SILICA CEMENT IN SANDSTONES AND ITS REPLACEMENT BY CARBONATES

Paragenetic history of the cementation observed in many sand-carbonate rocks can best be explained by understanding the complex physical-chemical changes which cause the precipitation and solution of cements in sediments.

Beta quartz and other metastable forms of $SiO_2$ are widely distributed by sedimentary processes and commonly make up a considerable volume of some sediments. Several sources of silica are available: (1) abrasion of siliceous sediments along beaches, (2) siliceous tests, and (3) eolian quartz dust. Silica contributed by these sources forms silica cements in sediments.

Three zones of diagenesis beneath the depositional interface may be recognized, each with differing chemical and physical characteristics. The metastable forms of $SiO_2$ are dissolved in the upper zone because the trapped sea water is universally undersaturated with respect to these phases. In the middle zone, alpha quartz precipitates as silica cement and overgrowths when the concentration of $SiO_2$ of the interstitial fluid rises above 14 ppm. This is due to the higher solubility of the metastable forms of $SiO_2$ (up to 140 ppm.) than that of alpha quartz (14 ppm.).

In the lowest or third zone, carbon dioxide concentration decreases while the temperature and pH increase slightly. These conditions favor precipitation of carbonate rocks and the solution of silica.

SHAW, D. M., McMaster University, Hamilton, Ontario, Canada; and KUDO, A. M., University of California at San Diego, La Jolla, California

TEST OF THE DISCRIMINANT FUNCTION IN THE AMPHIBOLITE PROBLEM

Amphibolites from Chandos Township, Peterborough County, Ontario, were classified by field criteria as