northward, the part below the position of zone II conodonts becomes progressively thinner, and only a thin wedge of the lower part extends into southernmost Ohio. Here this lower unit is overlain by the Dayton limestone, which underlies a shale sequence called the Alger formation in Ohio. The Alger is a northern extension of the Estill clay.

Zone I is represented in the Kankakee limestone of northern Illinois, and zone III conodonts have been obtained from the Joliet limestone of northern Illinois and the basal few inches of the Osgood formation of southern Indiana. Insufficient work in other areas of the United States precludes precise correlation. The close resemblance of the European and central Kentucky conodont faunas, together with the other known occurrences, shows the potential value of these fossils for stratigraphic work in this part of the column.

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EXPERIMENTAL CONSOLIDATION OF CARBONATE MUD†

About 200 compression and heating experiments simulating diagenesis and low-grade metamorphism have been performed on samples of $CaCO_3$ sediment obtained from the banks west of Andros Island in the Bahamas; the mud consists mainly of aragonite needles, 0.1μ by 1μ, and ovoid pellets, about 100μ across. The ranges of conditions and the precisions of the experiments were as follows: pressure P, 1–3,000 bars, $\pm 10\%$; temperature T, 25°–400° C., $\pm 10\%$; and time t, 3 hours to 2 months, $\pm 1\%$. The chemical compositions of the sea water in the mud and the vapor driven off were not determined.

Consolidation is effected by compaction of grains, recrystallization, and by increase of integranular bonding. Pressure of 30 bars causes a compaction of about 20% for a given temperature; at $T=25°$ C. the density increases from that of the initial mud, 1.7 g/cm³, to a final 2.0 g/cm³; essentially, some of the interstitial water is squeezed out. Heating at T between 100° and 200° C., under $P<30$ bars, causes an apparently anomalous decrease in density because of an exchange of air for water in the void spaces, and the products remain friable.

Heating at $T=400°$ C. under low pressure, $P<100$ bars, for $t>1$ day, lithifies the mud, apparently during inversion of aragonite to calcite; electron micrographs show coalescence, increasing with time, of the original needles to rounded grains and then to a subhedral, interlocking texture; the product has a compressive strength >100 bars. Higher pressure, $P>100$ bars, causes increasing breakage of the aragonite needles.

About 30 experiments on aragonitic mud from Kapingamarangi Atoll in the Caroline Islands produced results similar to those obtained on the Bahamas mud. However, in none of 6 experiments performed on deep-sea, coccolithic, calcite ooze from near the Hawaiian Islands could the sample be lithified, even at $T=400°$ C., $P=1{,}000$ bars, $t=11$ days; apparently consolidation of calcite sediment requires the circulation of dissolving water.

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RELATION OF MINERALIZATION TO PRECAMBRIAN STRATIGRAPHY, BLIND RIVER AREA, ONTARIO

The study is a result of a continuing surface-mapping program that was begun in 1953, with additional data provided by the drilling and underground activities of mining companies. The Archean rocks are Keewatin greenstones intruded by Algoman granites, for which the geological age has been determined as about 2,500 million years. These granitic rocks consist of gneissic granodiorites and massive, slightly radioactive quartz monzonite. The Archean complex was eroded to a peneplain with valleys in the less resistant rock types. The Lower Huronian formations are a sequence containing a great variety of sedimentary rocks such as conglomerate, arenites, argillite, siltstone, greywacke, limestone, and quartzite. Thickness and facies changes indicate a northwesterly source, northerly overlap, and deposition in shallow water controlled by basement topography. The Lower Huronian formations unconformably overlie the Archean rocks and in turn are unconformably overlain by the Middle Huronian formations. The Middle Huronian rocks consist of the Gowganda and Lorrain formations of conglomerate, greywacke, quartzite, and arkose.

Age-dating methods give the age of the Nipissing diabase as 1,950 million years and of the granite at Cutler as 1,750 million years (Penokean orogeny). A few dikes of Keweenawan olivine diabase have been tentatively dated at 1,000 million years.

Copper mineralization is associated with the Nipissing diabase. Uranium ores in oligomictic conglomerates are post-Archean placers modified at a later date. Uranium production to the end of 1962 consisted of 44,937,871 tons of ore grading approximately 0.1% U_3O_8, valued at $944,373,250.

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EARLY AND MIDDLE PENNSYLVANIAN FUSULINIDS FROM HORQUILLA LIMESTONE, SOUTHEASTERN ARIZONA

The lower 1,000 feet of the Horquilla limestone of southeast Arizona contain abundant early and middle Pennsylvanian fusulinids. Unconformities lie at the base of the Horquilla and at the top of the zone of *Fusulina* about 1,000 feet above the base of the formation. The lowest fusulinid zones, the zones of *Millerella* and *Profusulinella*, are relatively thin and in combined thickness make up about 100 feet of strata. The overlying zone of *Fusulinella* varies from about 100 to nearly 400 feet thick and has a diverse fusulinid fauna which is divisible into three subzones. The evolution of species of *Fusulinella* from early into later fusulinid groups is remarkably complete. Above this the zone of *Fusulina* reaching 600 feet in thickness is divisible into four subzones.

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BASEMENT STUDIES IN MIDWESTERN UNITED STATES

As the midwestern United States is covered largely by Paleozoic sedimentary rocks, geologic studies of the basement complex are based primarily upon extrapolation of trends from the Laurentian shield and samples from approximately 50 basement wells in Illinois, Indiana, Ohio, and Michigan. Age determinations and lithologic studies of samples from these basement tests suggest an extension of the Grenville province from Ontario into the area of the Indiana-Ohio platform. Geophysical surveys also have revealed structural and lithologic patterns in the basement complex that can be

† Approved for publication by director of the U. S. Geological Survey.

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.

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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.

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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.

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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