with the main body of the crystal, and which yields a calcium-rich dolomite by solid-state diffusion. This can be demonstrated to be true of most dolomite which forms in the absence of extraneous phases of calcite and magnesian calcite, from both the marine-associated Coorong lakes and Deep Springs Lake, by employing the following methods: (1) progressive leachings, with attendant chemical analyses; (2) X-ray diffraction; and (3) electron microscopy. X-ray diffraction data show that it is also true of dolomite forming in the presence of such extraneous phases. Dolomite also forms in the presence of magnesite or calcian magnesite, in certain of the marine-associated Coorong lakes; such dolomite is slightly magnesium rich. This dolomite probably forms via a magnesium-rich precursor, deposited as a layer on the individual crystals of dolomite, in much the same manner as the calcium-rich layer on the calcium-rich dolomite. Carbon-14 dates of the calcium-rich dolomite from Deep Springs Lake yield growth rates of 500–900 angstroms/10^3 years.

PRAY, LLOYD C., and CHOQUETTE, PHILIP W., Marathon Oil Company, Littleton, Colorado

Genesis of Carbonate Reservoir Facies

Carbonate rocks with porosity characteristics adequate to form petroleum reservoirs commonly are highly specific bodies of rock. They are rare in occurrence and diverse in type. Most are complex, both internally and in their relations with associated non-reservoir rocks. Yet the occurrence of porosity in carbonate rocks is in very few cases fortuitous; some discernible order normally prevails in the facies complex containing the specific reservoirs. Examples of highly specific reservoir facies, where a knowledge of the rocks and an understanding of their genesis can be helpful, are Pennsylvanian phylloid algal reservoirs of the Paradox basin, stromatoporoid-rich bank margin facies of Devonian age in Alberta, and widely distributed algal mat reservoirs. Detailed study of the rocks and their pore systems can lead to more effective exploration and exploitation.

The existence of limestone and dolomite reservoirs commonly is directly related to the nature of the original sediment and to early diagenetic processes. In reservoirs retaining significant primary porosity, the size and interconnection of the original pores are more important than the amount of original porosity. Many carbonate reservoirs have pore systems of diagenetic origin. In these, the key factors are rock fabrics with components of different solubilities, or of different susceptibilities to such diagenetic processes as cementation or dolomitization. Factors favorable for reservoirs of primary porosity may be unrelated or opposed to those favoring diagenetic porosity. For example, some primary reservoirs consist of coarse, well-sorted calcarenites. In other facies complexes, these well-sorted rocks have low porosity and permeability, and the specific reservoirs occur in contemporaneous, poorly sorted, and mud-rich carbonates that were selectively dolomitized and leached.

Modern carbonate sediments of many textural types (mud, sand, and mud-sand admixtures) have porosities of 40–70 per cent. Newly deposited or reworked carbonate mud and some skeletal sand or growth frameworks may exceed 70 per cent porosity. Yet most ancient carbonate rocks have porosities of but a few per cent. Even the better carbonate reservoirs have only a small part of their original pore volume. This wholesale reduction in porosity is an important but commonly neglected factor in carbonate rock interpretation. Reduction of porosity is accomplished mainly by introduced carbonate cement, probably involving thousands of pore volumes of interstitial water. In much limestone the volume of cement may approach or exceed that of the initial sediment. Compaction normally is minor, because of early cementation and compaction resistance of carbonate sediment. Locally, pressure-solution processes are important in porosity reduction. The aragonite-to-calcite volume increase can be only a small factor in the reduction of porosity.

VON RAD, ULRICH, Scripps Institute of Oceanography, La Jolla, California, and HESSE, REINHARD, Institut für Geologie, Technische Hochschule, Munich, Germany

Possible Non-Turbidite Origin of Deep-Sea Sands in Cretaceous Flysch (Bavarian Alps, Germany) and Recent San Diego Trough (California)

The Bavarian-Austrian flysch between the Rhine River and Vienna consists of Cretaceous clastic rocks, about 1,500 m. thick, deposited in an east-west-trending trough more than 500 km. long, 20–40 km. wide, and more than 200 m. deep. The directions of sediment supply, as inferred by sedimentary structures, grain-size variations, and heavy- and light-mineral distributions, were remarkably constant and parallel with the trough axis during long time intervals. Filling took place from both ends of the trough. The source area was at the west (Switzerland) during the Early Cretaceous, at the east (Bohemian Massif) during Turonian time, and at the west again during the Late Cretaceous. Within this flysch sequence the quartz-graywacke of the 200-m.-thick "Gault" Formation of Early Cretaceous (Albian) age was deposited as a continuous blanket. Single beds can be traced continuously for as much as 115 km. toward the western source area. Correlation was accomplished by comparison of the distinctive sequence, thickness, and petrography of individual beds ("fingerprint-type identification"). Grain-size, thickness, and content of unstable minerals in correlated sandstone beds increase slightly toward the source. Observations in the Bavarian flysch not easily explained by the hypothesis of avalanche-type, spasmodic turbidity currents include the following.

1. Sedimentary structures indicating breaks in sedimentation within graded beds or fluctuations in current velocity and type of material (concentrations of heavy-mineral layers in the upper part of graded beds; repeated grading within millimeter-thick laminae).
2. The consistency of bed thicknesses and current directions, as well as heavy- and light-mineral associations of individual beds through a distance of 115 km. The enormous amount of sand contained in one single bed (2–10 $km.^3$) is more easily explained as grain-by-grain deposition from constant bottom currents with perennially fluctuating velocities.

Study of a large number of oriented, undisturbed box cores from the central San Diego trough and the La Jolla submarine fan shows that most of the sand layers have well-preserved sedimentary structures very similar to those observed in the Bavarian flysch. However, because of the absence of distinctive compositional differences in the mineral associations, individual sand layers could not yet be correlated through longer distances within the San Diego trough. Parallel and current-ripple cross-lamination, as well as imbricated mud pebbles, reworked from the underlying old clay, are more abundant than distinct grading. Study of grain fabrics (imbrication) by the use of magnetic susceptibility anisotropy and evaluation of cross-lamination foresets generally show downslope direction of sediment transport, confined to the canyon-fan valley system. Current measurements and observations from deep submersible vehicles indicate that bottom currents capable of transporting medium to coarse sand have a pulsating (tide-related?) flow (maximum velocity, 10–25 cm./sec.) both up and down La Jolla Canyon. These data suggest that probably most of the sand in water depths up to 1,100 m. was transported, or at least reworked, by ordinary tractive bottom currents (or diluted "steady" suspension currents), rather than by occasional "spasmodic" turbidity currents.

REYNOLDS, DOUGLAS W., Flag Drilling Co., Greenville, Kentucky

Relation of Hydrocarbon Accumulation to Deltaic Sedimentation in Western Kentucky

Deltaic and fluvial sedimentation processes are recognized as primary dispersal mechanisms that operated to contribute sediments to the Chesterian depositional area in Illinois, Indiana, and Kentucky.

As the fluvial cycle was initiated, erosion channels were incised into the underlying strata. Clastic sediments were delivered to the depositional area by the Michigan River system. The channel fill may be traced from its outcrop into the subsurface and across Kentucky more than 300 miles. The fill may be projected, with considerable success, into areas where few tests have been drilled. Successful projections have been accomplished by making isopachous maps of the channel fill. Once the distributary network is outlined, a direct relation is apparent between the channel system and hydrocarbon accumulation within the Bethel Sandstone. The recently discovered Midland, St. Charles, Barnsley, Luzerne, and Sharon School fields occur within the distributary network.

All of these fields are combination traps. They are restricted to the channel fill and are localized by subsequent structural deformation.

ROBERTSON, EUGENE C., U. S. Geological Survey, Silver Spring, Maryland

Compaction Tests on Aragonitic Sediment

Microcrystalline aragonite from the Bahama Banks was compacted in the laboratory at pressures from 10^{-1} to 10^5 psi. at room temperature; the effects of heating were explored. The important conditions affecting the maximum compaction were total pressure, rate of loading, rate of removal of water, grain-size, and cohesion of grains. Conditions having a minor effect were initial water content, time period of compaction (for periods of more than 3 hours), and temperature (for water-saturated samples).

A new parameter is proposed to characterize compaction: grain proportion (g), which is equal to the volume of grains divided by the bulk volume; g is equal to one minus porosity expressed as a decimal fraction. Grain proportion is a useful index of compaction because it is also the ratio of the dry bulk density to the grain density of the sediment, and thus is a linear measure of the approach to solid rock.

The effect of raising the pressure from 1 psi. to 10^5 psi. on Bahaman aragonitic sediment is to increase the compaction from $g = 0.3$ to $g = 0.8$. Rapid loading of the sediment (at 10^4 psi./min.) results in differential compaction ranging from $g = 0.85$ under the moving piston to $g = 0.65$ at the stationary piston; differential compaction also seems to occur at very slow loading rates (10^{-6} psi./min.). Constricted egress of water as the sediment is compressed can reduce the amount of compaction by $\Delta g = 0.1$. Sediment of 1μ median grain-size compacts to $g = 0.5$ under 500 psi., but sediment of 200μ median grain-size compacts only to $g = 0.4$ under the same pressure; furthermore, the compacted coarse sediment falls apart, but the fine sediment is relatively coherent.

SAITO, TSUNEMASA, Lamont Geological Observatory, Palisades, New York, and LIDZ, LOUIS, Institute of Marine Science, Miami, Florida

Biostratigraphy of Blake Plateau (Atlantic) Drill-Hole Samples

Paleontological study of cored sediments from six drill holes on the continental margin off eastern Florida, in water depths ranging from 25 to 1,030 m., has made possible the reconstruction of faunal successions of planktonic Foraminifera through most of the Tertiary. The oldest assemblage cored includes species characteristic of the middle Paleocene *Globorotalia pusilla pusilla* Zone. With the exception of the Oligocene, the foraminiferal sequences present beneath the continental shelf, Florida-Hatteras slope, and Blake plateau are in general accordance with those established in the Caribbean region for marine beds now exposed on land. The Oligocene interval is identified on the basis of foraminiferal faunas found in the Vicksburg Group of the Gulf Coast, this equivalent being absent from the otherwise well-developed Tertiary of Venezuela and Trinidad. Miocene sections are best developed in J-3 hole in the southeastern part of Blake plateau, where approximately 49 m. of lower Miocene, 16 m. of middle Miocene, and 10 m. of upper Miocene consist entirely of *Globigerina*-ooze facies.

A marked contrast in sedimentary facies, *i. e.*, shallow-water calcarenite and silty phosphatic clay in nearshore holes, versus *Globigerina*-coccolith ooze in offshore holes, appears to have persisted from Eocene through Miocene times. Eocene and Oligocene sediments from nearshore sites contain assemblages of planktonic Foraminifera mixed with the benthonic species characteristic of Gulf Coast stratigraphy, thus enabling clear correlation of the Gulf Coast stages with established planktonic foraminiferal zones.

SCHMALZ, ROBERT F., Pennsylvania State University, University Park, Pennsylvania

Role of Kinetics in Early Diagenesis of Carbonate Sediments

Because most modern carbonate sediments are a mixture of several metastable carbonate phases, studies of such deposits necessarily represent instantaneous observations of disequilibrium systems which may be undergoing slow but significant change. Conventional thermodynamic (equilibrium) models may be of little value in interpreting such observations, but kinetic and steady-state models promise to afford a clearer understanding of depositional and early diagenetic processes in natural environments.