ride-calcium or chloride-magnesium gave a positive index of base exchange when classified by Schoeller's method. Waters known to be in contact with petroleum were classified by Sulin's method and were found to be of the chloride-calcium, chloride-magnesium, and bicarbonate-sodium types, but not of the sulfate-sodium type.

It was concluded from the study that classification of the above types of data from water analyses would not be positively indicative of petroleum, but might have some application as an aid in exploration. Water classification could, in some instances, be used to identify formations, analyses for organic and minor constituents dissolved in waters associated with petroleum formation will add to the value of data from water analyses. It was found that unless extreme care is used in obtaining water samples for classification or formation identification, contaminated samples will give erroneous results.

PERKINS, BOBBY F., Shell Development Company, Houston, Texas

ROCK-BORING ORGANISMS AS MARKERS OF STRATIGRAPHIC BREAKS

Borings made by various kinds of organisms are characteristic of many disconformities from the Ordovician to the Recent. Borings are especially abundant on Jurassic, Cretaceous, and Tertiary discontinuity surfaces in shallow-shelf carbonate sequences. The organisms that made most of these borings are mollusks, sponges, various kinds of worms, barnacles, and algae. Of these groups the bivalve mollusks are the most common and most highly adapted borers.

The recognition of the rock borings and their distinction from burrows made in unlithified sediment commonly is necessary for the identification of otherwise obscure disconformities. Rock borings in carbonate sequences imply stratigraphic breaks with histories of (1) emergence, (2) lithification, and (3) resubmergence; whereas, in the same sequences burrows do not necessarily imply any sort of stratigraphic break. Shapes of burrows and borings and relations with sediments and structures are reviewed as the essential criteria for recognizing borings and bored surfaces and for distinguishing them from burrows and burrowed surfaces.

Cretaceous and younger rock sequences of Texas and Mexico include many disconformities characterized by borings. The magnitude of the stratigraphic breaks which these bored surfaces represent ranges from local intraformational interruptions to major intersystemic unconformities. Examples of these surfaces are compared in terms of (1) surface morphology, (2) encrusting faunas, (3) shape and variation of borings, (4) corrosion features, (5) areal extent, and (6) lateral correlatives.

PESSAGNO, EMILE A., University of California, Davis, California

EAGLEFORDIAN (CENOMANIAN—TURONIAN) STRATIGRAPHY IN MEXICO AND TEXAS

The biostratigraphy of the San Felipe Formation of Mexico and the correlative Eagle Ford Group of Texas has been studied extensively from well cores and measured sections. The San Felipe was examined in outcrop at Boca Canyon south of Monterrey whereas the Eagle Ford was studied at Chispa Summit in Jeff Davis County, at Lozier Canyon near Langtry, at Sycamore Canyon near Del Rio, on Bouldin Creek in Austin, at Atco near Waco, and at the type locality at Dallas.

Previously, Eaglefordian strata in Texas and Mexico were included in the *Rotalipora cushmani-greenhornensis* Subzone of the *Rotalipora* s.s. Assemblage Zone and the *Marginotruncana sigali* and *Whiteinella archaeocretacea* Subzones of the *Marginotruncana helvetica* Assemblage Zone. At Boca Canyon in Mexico all of these units are represented. Through most of Texas, however, sampling indicates that the *Marginotruncana sigali* Subzone is consistently absent, and the *Whiteinella archaeocretacea* Subzone rests unconformably on strata assignable to the *Rotalipora cushmani-greenhornensis* Subzone of the *Rotalipora* s.s. Assemblage Zone.

In view of these discoveries, the writer proposes to subdivide the Eaglefordian Stage of the standard Gulf Coast Upper Cretaceous section into three substages: (1) the Lozierian (late Cenomanian), (2) the Bocian (early Turonian), and (3) the Sycamorian (late Turonian).

PETERSON, JAMES A., University of Montana, Missoula, Montana

DISTRIBUTION AND ORIGIN OF PENNSYLVANIAN CARBONATE MOUNDS, PARADOX BASIN

Shelf carbonate mounds of Desmoinesian (Pennsylvanian) age were developed in cyclic repetition along the southwestern flank of the Paradox basin. Optimum carbonate deposition occurred in an elongate northwest-southeast belt, approximately 50 miles wide and over 100 miles long, which contains about 35 Pennsylvanian oil and gas fields. Porosity occurs in three types of carbonate reservoirs: algal plate mounds, foraminiferal mounds or bioherms, and "leached oölite" banks. Most of the production is from limestone, but dolomite also is important as a reservoir rock.

Stratigraphic-facies mapping of the mound-bearing strata can be done on the basis of basin-wide, black, sapropelic shale marker beds, in conjunction with lithologic-petrographic analysis of rock types and associated faunal content. Shelf carbonate rocks occur in each main cycle of the Paradox Formation, grading basinward into evaporite and shoreward into sandy limestone and terrigenous clastic rocks.

The origin, distribution, and cyclic repetition of the carbonate-mound belts are thought to be related to periodic eustatic changes in sea-level associated with late Paleozoic glacial cycles of the Southern Hemisphere. The mounds probably developed along shallow-water mud banks or platforms which built basinward during the early clastic phase of each cycle. Completeness and duration of a cycle were major factors in determining the size attained by the mound complex.

PETERSON, MELVIN N. A., and VON DER BORCH, CHRISTOPHER C., Scripps Institution of Oceanography, La Jolla, California

RATES AND MECHANISMS IN FORMATION OF DOLOMITE

Dolomite is forming in Deep Springs Lake, California, and marine-associated Coorong lakes of South Australia. Dolomite forms via a surface-layer precursor, which is commonly calcium-rich in comparison 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