sippi cone. However, from east to west of the Sigsbee Deep, the degree of enrichment is marked. It is postulated that this difference is a result of contrasted flow regimes between the two physiographic provinces. The cone, because of its slope and high sedimentation rate (compared with the deep), was characterized by both slumping (low-velocity mass transfer of sediment) and high-velocity turbidity currents. The latter supplied the main source of sediment to the Sigsbee Deep. Once the break in slope was encountered, velocities diminished rapidly. Such a velocity diminution resulted in the Sigsbee Deep constantly being supplied by currents representative of the lower flow regime. Thus the selective and relatively rapid degradation of undulatory quartz is more marked in that physiographic province dominated by traction currents.

Other sample traverses in fluvial, shallow-marine, and deltaic complexes confirm the relative instability of undulatory quartz. The total quartz extinction assemblage also is affected by variations in hydrodynamic conditions between environments within such a complex, yielding an additional tool for the reconstruction of paleoenvironments.

DAVIS, RICHARD A., JR., Dept. of Geology, Western Michigan University, Kalamazoo, Michigan

"Canadian-Ozarkian" Unconformity in Upper Mississippi Valley

In 1924, E. O. Ulrich described an unconformity at the boundary between his Ozarkian and Canadian systems in the upper Mississippi Valley. This systemic boundary was based on physical and paleontological data, and occurs within the Prairie du Chien Group ("Lower Magnesian" of earlier years) which had been accepted as Ordovician in age.

Prairie du Chien strata have been problematical to stratigraphers for many years, primarily because of a lack of systematic regional study. Most investigators denounced Ulrich's unconformity but a few workers reported local evidences of erosion between the lower Oneota Formation and the upper Shakopee Formation.

Recognition and investigation of rock-stratigraphic boundaries presuppose recognition of the units themselves, which has been the major problem in Prairie du Chien stratigraphy. Once this had been accomplished the presence of an unconformity on the upper surface of the Oneota Formation was obvious.

Physical criteria for erosion at this horizon are (1) local truncation of bedding; (2) irregular upper surface of the Oneota Formation; (3) basal conglomerate of chert pebbles and/or Oneota-type lithology in the lowermost Shakopee Formation; and (4) truncation of grains at contact as seen in thin section.

This unconformity can be recognized throughout the outcrop belt of Prairie du Chien strata. Erosion took place after lithification and seemingly after dolomitization of the Oneota. It may have been subaqueous erosion and probably does not represent the great period of time postulated by Ulrich.

DELLWIG, LOUIS F., AND ROBERT EVANS, Dept. of Geology, University of Kansas, Lawrence, Kansas

Depositional Processes in Salina Salt of Michigan and New York

The contrast between the salt section exposed in mines at Retsof, New York, and Detroit, Michigan, can be explained by differences in the environment of deposition. Where local recrystallization has occurred, primary bedding or laminations have not necessarily been destroyed; the major changes are enlargement of grains, the expulsion of insolubles from within crystals, and the consequent destruction of primary crystal structure. Primary features dominate both sequences.

Alling and Briggs (1961) presented evidence of water depth of more than 300 ft 25 mi inside the fringing Niagaran reefs of the Michigan basin. Throughout the Detroit mine, laminations are uniformly spaced, a feature documented by Richter-Bernburg (1953) and others as characteristic of deep-water deposition. Deposition apparently was at a depth sufficiently great to prevent the disturbance of primary bedding structure by turbulence in the basin water.

In contrast to the typical "normal" anhydrite-dolomite laminae (Jahresringe) exposed in the Detroit mine, bedding in the Retsof, New York, mine is expressed as contrasting bands of light and dark, uniformly sized halite crystals through which insoluble material is diffused. Contrast in bands is a function of insoluble content, the separation being gradational rather than abrupt. Primary structures offer additional substantiating evidence of shallow-water deposition in New York.

The differences in physical characteristics of the salt point to less turbulence (greater water depth) in the Michigan segment of the Salina evaporite basin. Increased turbulence and consequently bottom disturbance not only would have disrupted primary bedding features but also would have destroyed or prevented the development of density stratification in the basin waters.

Although the problem of defining depth in absolute terms may remain, characteristic features can be identified for "deep" and "shallow" environments of halite deposition. It seems more appropriate to consider bedded salt as a normal marine sediment than as a "chemical freak."

DICKINSON, KENDELL A., U. S. Geological Survey, Denver, Colo.

Clay-Mineral Facies in Upper Jurassic Rocks in Northeastern Texas and Adjacent Parts of Louisiana and Arkansas*

X-ray analyses of rotary-drill cuttings and cores of Upper Jurassic rocks show a distinct relation between clay-mineral suites and environments of deposition.

Offshore marine shale and lagoonal-mudflat evaporitic mudstone contain chlorite and illite in a ratio of about 1:7. The chlorite is predominantly a high-iron variety in the marine shale and a low-iron variety in the lagoonal evaporitic mudstone. In most nonmarine mudstone there is no chlorite, but the rock contains kaolinite and illite in a ratio of about 1:7. Nearshore marine and transitional nonmarine shale and mudstone contain chlorite, kaolinite, and illite in ratios of 1:1:12. The degree of crystallinity of illite in the lagoonal-mudflat evaporitic mudstone is greater than in any of the shale or other mudstone.

* Publication authorized by Director, U.S. Geological Survey.

Although differentiation of clay suites of sandstone according to environment is not so pronounced, the pattern generally conforms with that found in shale and mudstone. However, significant differences exist in the relative amounts and in the degree of crystallinity of the minerals. The chlorite:kaolinite:illite ratio is about 2:1:3 for nonmarine sandstone and 1:1:4 for nearshore marine sandstone. All species of clay minerals in the sandstone are more crystalline than are those in the shale and mudstone.

Chlorite probably enters the depositional basin in a cation-depleted condition and accepts Mg^{++} in the oxidizing environment of evaporitic mudflats and lagoons and Fe^{++} in the reducing environment that occurs after burial in the normal marine environment. The absence of chlorite in the nonmarine shale and of kaolinite in the offshore marine environment is the likely result of differential flocculation during sedimentation. The greater degree of crystallinity of the illite from mudstone in evaporitic rocks probably results from the increase in the availability of cations, particularly K^+, in the evaporite brine. The complete lack of expandable-lattice clays may result from deep burial and accompanying incipient metamorphism. All processes, except differential flocculation, probably did not occur until temperature and pressure rose to a significant level in response to increased depth of burial.

DIXON, MARK A., Mobil Oil Corp., Shreveport, La.

FISH OTOLITH ASSEMBLAGE OF GASTROLITHIC BEACH GRAVEL

The richest recorded sample of fish otoliths, most of which are pelican gastroliths, was collected at the shoreline of a "mudlump" island in the lower Mississippi delta. It is dominated by gravel-size ear stones of sea catfish, common croakers, and sea trout, with abundant sand-size ear stones of a tropical gadoid. The remainder of the approximately 6,400 otoliths make up a rich, polyenvironmental assemblage ranging from fresh-water catfishes and killifishes to conger eels and deep-sea brotulids of anomalous origin.

DOBKINS, JAMES E., JR., AND ROBERT L. FOLK, Dept. of Geology, The University of Texas at Austin, Austin, Tex.

PEBBLE SHAPE DEVELOPMENT ON TAHITI-NUI

Abrasional shaping of basalt pebbles was studied in nine rivers and on 14 high- and low-energy beaches of Tahiti-Nui. Measurements were made on four size classes, ranging from 16 to 256 mm. Surf ranged from 10-ft combers at Punaauia to few-inch ripples at Point Venus.

Roundness was measured by sharpest-corner/inscribed circle, adapted from Wentworth (1922); fluvial pebbles had mean roundness of .38 whereas beach pebbles averaged .45–.50 in low-energy areas, and .60 in high-energy areas.

Maximum-projection sphericity (Sneed and Folk, 1958) averaged .68 for river pebbles, and .60 for beach pebbles. A new measure of oblateness-prolateness, $OP = L/S(L\text{-}I/L\text{-}S - .50)$, is introduced; river pebbles averaged $OP = +0.2$ (neutral), and beaches $OP = -1.7$ (oblate), with greatest difference between the two environments shown by the smallest pebbles (16–32 mm). Using isotropic rock of uniform basaltic composition, there is no doubt that, on Tahiti, accumulations of beach pebbles distinctively have lower sphericity and more discoidal form compared with river pebbles.

The above generalities are modified by some complicating factors. On some high-energy beaches consisting almost entirely of coarse gravel (*e.g.*, Papenoo and Punaauia), large pebbles (128–256 mm) have lowest sphericity (.55) whereas small pebbles average .68; apparently the waves are so large that they can slide the large pebbles, but toss the small ones randomly. On some low-energy beaches (*e.g.*, Maraa, Arue, Venus), the smallest pebbles (16–32 mm) are nearly coin-shaped (sph. = .54, $OP = -5$, strongly oblate) because they are able to be slid by the gentlest waves, whereas large pebbles relatively are immobile and do not achieve typical beach shapes (sph. = .67, $OP = +1$, weakly prolate). Thus the particular pebble size at which most extreme oblateness and lowest sphericity occur is a measure of wave energy.

Where pebbles are scattered on a dominantly sandy beach (Mahaiatea, Papeiha), abnormally great concentrations of low-sphericity discs occur. On sand beaches with gravel cusps (Taaone), discs are scarce in the gravel cusps but abundant in the sandy intervening zones. In a few areas discs tend to be thrown far back on the beach, and rods and equants accumulate at the beach foot. Despite the definite evidence of shape-sorting in some localities, the great increase of discs in the beach pebbles as a whole, compared with the river pebbles as a whole, must be the result of surf abrasion. The change in shape is accomplished within distances of a few feet to a few hundred feet of the river mouth.

DOUGLASS, RAYMOND C., U.S. National Museum (U.S. Geological Survey), Washington, D.C.

MORPHOLOGIC STUDIES OF FUSULINIDS FROM LOWER PERMIAN OF WEST PAKISTAN

The "Lower Productus Limestone" of West Pakistan yields an abundant and well-preserved fauna of fusulinid Foraminifera. The fusulinids are found in the lower part of the Amb Formation of the Zaluch Group of Early Permian age described by Teichert in 1966. About 50 samples of the fusulinids, collected by C. Teichert in 1961–62 and R. E. Grant in 1964–65, contain the genus *Monodiexodina*. Each sample of fusulinids is relatively homogeneous in morphologic characters, having a fairly normal distribution of values through a limited range for most characters. There are large differences between many of the samples with little or no overlap in the dimensions of some characters at specified volutions. Distinct species could be described by conventional methods based on a few specimens or even on reasonably large samples, and statistically meaningful differences could be demonstrated. Cutbill and Forbes' 1967 discussion on the significance of the prolocular diameter and its effect on comparisons by volution has led to a re-evaluation of the data on these samples. Comparison of measurements at equal radii instead of by volution brings out many similarities between samples. For example, two samples that are quite distinct when compared by volution cannot be distinguished at equal radii. The biologic significance of the prolocular diameter needs reconsideration. Microspheric and megalospheric forms