and intrastratal solution will require revision of some previous interpretations of their provenance and of some prior reconstructions of the paleoclimate and paleotectonics.

HIRSCH, ALFRED M., Rutgers Univ., Camden, N.J., and DAVID GOVONI, State Univ. New York, Stony Brook, N.Y.

FOOD SUPPLY—LIMITING FACTOR OF FORAMINIFERAL POPULATIONS

The standing crop of benthonic Foraminifera declines during the fall and increases during the early spring in Great Bay, New Jersey. Population sizes correlate with seasonal variations in phytoplankton and particulate organic carbon abundances, but do not correlate with changes in temperature or salinity or with differences in substrate textures.

Foraminiferal populations at 7 stations were repeatedly examined from the head to the mouth of the bay. The substrate ranged from a silty clay to a shelly, gravelly sand. Maximum salinity-temperature range within the bay on any sampling day never exceeded 8 °/oo or 2°C, although salinities and temperatures varied from a maximum of 31 °/oo and 26°C in late summer to a minimum of 10 °/oo and 0°C in mid-winter, respectively.

The foraminiferal fauna is a typical midlatitude estuarine assemblage. The dominant species differ among stations and appear to be controlled by substrate texture and salinity; however, the standing crop at all stations exhibits a consistent seasonal variation. The live percentage of the total foraminiferal population decreases by more than 30% in the fall and winter and increases more than 10% in late winter-early spring. The decrease coincides with a decrease in chlorophyll *a*, but not with any marked change in temperature or salinity. In early March the increase coincides with an increase in chlorophyll *a* or particulate organic carbon, although temperatures in the bay are 5-6°C and salinities are depressed by runoff. The dominant zooplankton, copepods and nauplius larvae, as determined by others, exhibit a similar seasonal pattern.

HITCHON, BRIAN, Research Council Alberta, Edmonton, Alta., and M. K. HORN, Cities Service Oil Co., Tulsa, Okla.

PETROLEUM INDICATORS IN FORMATION WATERS FROM ALBERTA, CANADA

A statistical study, including discriminant analysis, was carried out on a suite of 438 formation waters from Alberta, Canada, which had been analysed for Cl, Br, I, $HCO_3$, $SO_4$, Ca, Mg, and Na. The analyses were divided into 2 populations, depending on whether the initial status of the well was producing oil and/or gas (322 samples) or nonproducing, *i.e.*, abandoned (116 samples). The populations were further subdivided into Paleozoic and Mesozoic groups, and these 2 groups, together with the entire suite of analyses, were subjected to statistical study. With 95% assurance, the Alberta formation waters associated with producible hydrocarbons are chemically different, in a multivariate sense, from the formation waters from abandoned wells. Further, iodine and magnesium are the most important discriminators in the Paleozoic group, whereas sodium and chlorine are the most important in the Mesozoic group. These discriminators reflect the different organic geochemical, geologic, and hydrodynamic history of the Paleozoic and Mesozoic strata. Reclassification of the analyses using the discriminant functions resulted in only a 0.65 success ratio, thereby indicating that the chemical analysis of formation water is not a completely reliable predictor of the occurrence of hydrocarbons, at least at the Paleozoic-Mesozoic level. The 0.65 probability of successful classification may be increased with the acquisition of a larger data base and consequent statistical analysis at the formation level.

HOERING, THOMAS C., and P. E. HARE, Geophys. Lab., Carnegie Inst. Washington, Washington, D.C.

COMPARISON OF NATURAL HUMIC ACIDS WITH AMINO ACID—GLUCOSE REACTION PRODUCTS

Amino acids and carbohydrates disappear rapidly in recent marine sediments. Most of the organic matter exists as a high-molecular weight, insoluble polymer which has properties similar to humic acids. Glucose and amino acids react rapidly at neutral pH in the laboratory by the Maillard reaction, to produce a polymer that has many properties common to natural humic acids.

Both form gels that bind large quantities of water. They have comparable elemental compositions. The synthetic reaction produces a polymer with a wide molecular weight range extending to very high values similar to humic acids. They react rapidly with added amino acids. Both give a similar electron spin resonance spectrum. Degradation of the natural and synthetic humic acids by methylation, chlorination, and mild oxidation yields a similar suite of low-molecular-weight, chlorinated organic acids.

Carbohydrate-amino acid-reaction products are likely precursors of part of the polymeric organic matter in recent sediments.

HOWARD, JAMES D., Skidaway Inst. Oceanography, Savannah, Ga.; ROBERT W. FREY, Univ. Georgia, Athens, Ga.; and FRANK A. KINGERY, San Diego State Univ., San Diego, Calif.

PHYSICAL AND BIOGENIC CHARACTERISTICS OF SEDIMENTS FROM OUTER GEORGIA CONTINENTAL SHELF

Eighty-eight box cores were taken on the outer Georgia continental shelf, in water depths from 15 to 200 m. Textural analysis indicates that the midshelf area is covered by medium to coarse sand, evenly distributed, with no north-south linear trends. Areas of fine sand are present on the inner and outer shelf edges, and in 2 distinct lobes extending seaward from the Georgia coast. Parts of the lobes suggest that the finer material forming them was supplied by the Savannah and Altamaha Rivers. Local patches of semiconsolidated mud indicate the location of remnant marsh or estuary deposits.

Offshore shell assemblages indicate a mixing of faunas in terms of both environment and age. Pleistocene regressions and transgressions across the shelf resulted in alternate oceanward and landward migrations of nearshore and estuarine faunas, reworked subsequently with open-ocean faunas. Live animals offshore are adding their shells to the already mixed assemblages.

Biogenic sedimentary structures significantly exceed those of primary physical structures. All box cores show some degree of biogenic reworking, and most were more than 60% bioturbated. Physical sedimentary structures include crossbedding, ripple lamination, interbedded sand and mud, wavy bedding, and graded bedding.

Physical and biogenic reworking of the outer Georgia continental shelf sediments has removed or greatly modified most of their original depositional characteristics. Thus, reference to these sediments as "relict" is misleading.

HUANG, T. C., and N. D. WATKINS, Graduate School Oceanography, Univ. Rhode Island, Kingston, R.I., and R. H. FILLON, Woods Hole Oceanog. Inst., Woods Hole, Mass.

DIAGNOSIS OF PROCESSES MODIFYING DISTRIBUTION OF ATMOSPHERICALLY TRANSPORTED VOLCANIC GLASS IN DEEP-SEA SEDIMENTARY CORES

Analysis has been made of tephra in deep-sea sedimentary cores downwind from Pleistocene and late Pliocene eruptions on the Balleny Islands in the southwest Pacific. The volcanic glass is finely dispersed and megascopically indistinguishable in the cores examined. Despite modification of the vertical distri-

bution by several causes, volcanic maxima can be correlated between cores separated by up to 2,000 n. mi. Paleomagnetic, micropaleontologic, and sedimentologic methods have been used.

The glass shards are mostly transparent, bubble-walled or platy in shape, and are silt size or smaller. The grain-size distribution of glass strongly parallels that of other sedimentary constituents wherever submarine transport or prolonged bioturbation has occurred, as determined by X-ray radiography. Concentration of glass also varies systematically with minor sedimentation-rate fluctuations, as independently shown by variations in microscopic manganese nodules and ice-rafted debris concentrations. Utilization of fine volcanic glass by siliceous plankton has resulted in productivity and diversity changes, and, perhaps, a corresponding modification of the glass distribution. High-power transmission and scanning electron microscope methods show that the relative amounts of glass finer than 10 microns decreased rapidly during volcanic episodes.

HUDSON, JOHN D., and ALASTAIR H. F. ROBERTSON, Dept. Geology, Leicester Univ., Leicester, England

## SEDIMENTATION ON CRETACEOUS OCEAN RIDGE, TROODOS MASSIF, CYPRUS

The igneous rocks of the Troodos massif have been interpreted as an uplifted segment of Cretaceous ocean crust, formed at a spreading ridge. If so, the sediments overlying them should be similar to those forming at ocean ridges and to Tertiary basal sediments found by JOIDES drilling. Directly above the Troodos pillow lavas are iron- and manganese-rich mudstones ("umbers") that are closely comparable to the iron-rich sediments associated with the latest stages of volcanism on present ridges. They are enriched in trace elements, including copper, molybdenum, lead, zinc, and vanadium. These mudstones pass upward into Campanian radiolarites and radiolarian mudstones with a diverse and well-preserved siliceous microfauna. Silica diagenesis can be compared with that of deep-sea cherts. In the simpler sequences, the radiolarian rocks are overlain by Maestrichtian chalks.

In some areas, illite-montmorillonite clays above the radiolarian mudstones include major developments of mélange, with transported blocks of diverse Mesozoic sedimentary and igneous rocks. These include quartz sandstones of continental derivation. Chalks also overlie the mélange. The umbers, radiolarites, and chalks are interpreted readily as oceanic sediments, and the presence of the mélange implies proximity of a continental margin.

HUEBLER, JACK, Vice-President, Research, and C. L. TSAROS, Manager, Process Economics, Inst. Gas Technology, Chicago, Ill.

## COAL GASIFICATION DEVELOPMENTS

The production of pipeline quality gas from coal will become an important source of supplementary gas by 1990 when more than 3 Tcf/year are expected to be available. By the year 2000 the total may reach 8 Tcf/year; that is, 40% of present gas consumption. Elements such as coal quality and cost, plant location, water environment protection, and others contribute to the cost of gas.

HUH, JOHN M., and LOUIS I. BRIGGS, Dept. Geology & Mineralogy, Univ. Michigan, Ann Arbor, Mich.

## STRATIGRAPHY AND DIAGENESIS OF NIAGARAN PINNACLE REEFS (SILURIAN) IN NORTHERN MICHIGAN BASIN

In the Michigan basin, the Middle Silurian Niagaran reef facies directly underlies the Upper Silurian Salina evaporite facies. The basal Salina Formation includes the $A_1$-evaporite, subjacent to the $A_1$-carbonate and the $A_2$-evaporite in successive order. Subsurface study of 40 drill cores disclosed that most of the Niagaran pinnacle reefs in the inner-basin slope environment ceased growth by $A_1$-evaporite time and were regenerated during deposition of the $A_1$-carbonate.

The uppermost section of the algal stromatolite and algal boundstone facies at the top of the pinnacle reefs was deposited contemporaneously with the $A_1$-carbonate of the off-reef section. The algal-stromatolite facies of the $A_1$-carbonate overlies the $A_1$-evaporite on the reef flanks and extends laterally to the off-reef facies in the vicinity of the pinnacle reefs. The general lithology of the $A_1$-carbonate in the off-reef sections differs greatly from the lithology of the $A_1$-carbonate reef facies.

Some of the pinnacle reefs apparently continued to grow during the early formation of the $A_2$-evaporite. There is no significant erosional contact between the $A_2$-evaporite and the algal stromatolite at the top of the reef. Furthermore, LLH- and SH-type algal stromatolites show repeated stages of growth *in situ*, within the lowermost few feet of the $A_2$-evaporite section.

A vadose zone representing subaerial exposure is present in the pinnacle reefs at the top of the organic reef facies, which overlies the basal biohermal facies. This zone is characterized by a more complex sequence of diagenesis than either the basal biohermal facies or the uppermost algal stromatolite facies.

HUNT, JOHN M., Woods Hole Oceanog. Inst., Woods Hole, Mass.

## UNSOLVED PROBLEMS CONCERNING ORIGIN AND MIGRATION OF PETROLEUM

Current research suggests that most of the hydrocarbons in petroleum are formed from the organic matrix of sedimentary rock at depths greater than 5,000 ft. The increased generation of light hydrocarbons with depth is offset by decreases in the permeability of source beds and in the volume of migrating fluids. Empirical field studies may outline source-reservoir relations, but the mechanisms by which the hydrocarbons originate, migrate, and accumulate still are poorly defined.

INDEN, R. F., and J. C. HORNE, Dept. Geology, Univ. South Carolina, Columbia, S.C.

## CALICHE SOIL HORIZONS ON OOLITIC SHOALS AND CARBONATE MUD MOUNDS IN CARBONIFEROUS (NEWMAN LIMESTONE) OF EASTERN KENTUCKY

A sequence of oolitic calcareous grainstone shoals and calcareous wackestone and packstone-bank and interbank deposits is exposed near Olive Hill, Kentucky. The shoals and banks underwent periods of exposure, as they are capped by beds that represent stages of deposition or caliche weathering in the supratidal zone. The caliche weathering zones are similar to those found on Caribbean Islands and in the southwestern United States.

The first type of caliche zone is analogous to the subaerial crusts of the Caribbean area. These crusts are brecciated, often silicified, laminated calcareous mudstones which formed on and within the shoals and mud mounds. They are present as beds or coat fractures which transect bedding planes. Petrographic characteristics include microbrecciation, grains coated with laminated or dense micrite, extensive micritization, pelletoid fabrics, root tubules, and micrite and yellowish-brown spar cements.

The second caliche type, similar to those of the southwestern United States, is a nodular, brecciated calcareous mudstone that developed from supratidal and intertidal calcareous muds. The basal part of this caliche unit is a fossiliferous, but intensely brecciated, parent rock; this zone grades upward into a nodular sequence which may be capped by a thin-brecciated, laminated crust. Original depositional fabrics have been obliterated in the nodular section; the nodules are composed of microspar containing breccia clasts and root tubules, and are disrupted by subhorizontal fractures. Both caliche types display