"reefs," which are elongate and differentiate facies on either side, and "mounds" which are merely bumps on the sea floor. Ecologic reefs can be either geologic reefs (barrier and fringing) or mounds (patch reefs); a bank is a geologic reef with no organic framework.

All calcareous organisms are capable of providing sediment to buildups. The more important modern contributors are algae, foraminifers, corals, and mollusks; in the Paleozoic they include pelmatozoans, bryozoans, and brachiopods. Organisms providing framework in large-scale ecologic reefs today are mainly hexacorals, but formerly have included rudistids, stromatoporoids, and perhaps tetracorals. Sediment binding on the same scale is provided mainly by red algae today and has involved blue-green algae, stromatoporoids, and Problematica in the past. Builders of small-scale "mounds" that also are ecologic reefs, include red algae, foraminifers, sponges, corals, bryozoans, brachiopods, polychaete worms, oysters, and sessile gastropods. In many of these mounds, the same organism served as frame and binder; in others, blue-green algae, red algae, Problematica, or bryozoans were binders. Some modern carbonate mounds are not organic in origin, but are merely hydrodynamic accumulations of sediment; perhaps some ancient carbonate mud mounds have a similar inorganic origin.

Formation of organic carbonate buildups results from any combination of environmental factors that causes localized organic proliferation. Favorable oxygenation, water circulation, and nutrient replenishment are necessary for all organic buildups; other factors may have different optima for different organisms, and exclusively invertebrate buildups can form at any depth. Buildups containing algae, however, are restricted to the photic zone, thus are more predictable as to initiation and maintenance. Algal buildups tend to start on better-lit topographic highs, and with bottom subsidence, grow upward where the algae remain in optimum photic conditions. Invertebrate buildups, however, form where other factors are optimal, which may or may not be on highs.

Initiation of a geologic reef involving algae requires simply a bottom slope upon which algae proliferate only above a certain depth. The interval on the slope within which subsidence is equally compensated by algal sedimentation eventually becomes steeper and forms a "reef front" as algal and associated sedimentation keeps the entire shallower side near the surface, whereas the deeper side on which algae are inhibited receives progressively less autochthonous sediment and eventually depends primarily on allochthonous material from any source.

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FACTORS CONTROLLING CHEMICAL COMPOSITION OF FORMATION WATERS, ALBERTA

Twenty major and minor components were determined in 79 formation waters from oil fields and gas fields in Alberta. An R-mode statistical factor analysis revealed that the major influence on composition has been from the original seawater, with additional effects due to the uptake of Br and I from organic matter and the decomposition of sulfides or H_2S. Other possible processes which may have been operative include differential solution of evaporites, exchange of alkali metals on clay surfaces, and the removal of hydroxides of Fe, Mn, Ni, and Co from the surrounding sedimentary rocks.

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REEF-MARGIN AND BASIN SEDIMENTATION, MIETTE REEF COMPLEX, JASPER NATIONAL PARK, ALBERTA

The southeastern margin of the Devonian Miette reef complex exposed in the Miette thrust sheet near Marmot Cirque has been reexamined and the geometric arrangement of strata from the reef margin to the basin established by tracing units laterally and by detailed examination of several closely spaced stratigraphic sections.

These observations, together with those from other reef-margin exposures in the Miette and Ancient Wall reef complexes, provide a model for reef-margin sedimentation.

The reef margin at Marmot Cirque (which comprises a series of dolomitized units built up as successive layers) remained "passive" throughout its history; *i.e.*, sediments seaward of the reef complex for the most part do not grade into the reef complex, but rather lap onto it. Reef-derived sediment in the offreef position came from lateral "active" reef margins where sediment from the reef was carried into the basin.

Sedimentation at the margin of the reef complex is a function of 4 important processes: (1) sea-level fluctuations and stillstands, (2) production rates and nature of materials building the reef complex, (3) local currents and wave action, and (4) rate of influx of fine terrigenous sediment. The last process has not been stressed in the past and is thought to be particularly important.

Availability and volume of fine terrigenous sediment in the surrounding basin at any particular time influenced the nature and form of reef development. Part of the Miette reef complex and the subsurface Leduc reefs may be explained on this basis.

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GEOCHEMICAL PROSPECTING FOR PETROLEUM

Geochemical methods have been applied in exploration that hydrocarbon gases migrate, essentially in a being employed, perhaps to an extent greater than ever.

All geochemical techniques are based on the assumption that hydrocarbon gases migrate, essentially in a vertical direction, from oil and gas accumulations to the surface of the earth. This assumption is supported by the observation that the saturated hydrocarbons that are present in near-surface soil air, or adsorbed on the soil itself, can be related to buried deposits.

Data have been published which appear to discredit hydrocarbon geochemical techniques by attempting to show that saturated hydrocarbons heavier than methane occur in the soil from sources other than petroleum. In 1963, Smith and Ellis reported the presence of unsaturated hydrocarbons and saturated hydrocarbons, ranging from propane through the pentanes, in grasses and roots, and suggested that vegetation was the source of soil hydrocarbon anomalies.

Studies have been made on grasses and roots which show that, aside from methane, only unsaturated hydrocarbons in relatively large amounts are present in or produced by vegetation. However, soils in the vicin-

ity of oil or gas fields contain significant quantities of saturated hydrocarbons ranging from methane through the pentanes.

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EXAMINATION OF GEORGIA COASTAL SEDIMENTS WITH N.E.L. SPADE CORER

For 2 years samples have been obtained with an N.E.L. spade corer from the nearshore waters of the Georgia coast. During the past year, work has been concentrated on sampling in the coastal rivers, sounds, and estuaries of the Sea Island section of Georgia. Approximately 300 spade cores have been collected at 150 stations in 12 rivers and estuaries.

A tremendous variety of sediments and substrates are indicated by the sampling results. Sediment textures in the estuaries and rivers range from clay to gravel. Rivers such as the Satilla, Altamaha, and Ogeechee, which have their sources far inland, are characterized by clean, well-sorted sand, whereas closed sounds such as Doboy and Sapelo Sounds appear to be the sites of silt and mud accumulation. Exposures of Miocene bedrock, indicating the absence of any Holocene sediment accumulation, are found at several locations in the St. Marys and Turtle Rivers. All the samples reflect the mixing, to some extent, of Pleistocene and Holocene sediments. Mixed assemblages of Miocene, Pleistocene, and Holocene macroinvertebrate fossils have been found.

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OCCURRENCE AND SIGNIFICANCE OF RIBBING VARIATIONS IN LATE ORDOVICIAN BRACHIOPODS

Brachiopods are among the most common elements of marine Paleozoic faunas. Many species are suitable for study of widely separated basins.

Costate specimens representing 11 species were obtained from Upper Ordovician (Richmondian) strata in the Ohio Valley, Illinois, Iowa, Minnesota, Missouri, Oklahoma, Tennessee, and Texas in order to examine geographic patterns in costation and to determine whether observed variations were uniform within each sedimentary province. Regardless of wide variations in costae between different species, most species showed some tendency toward geographic variation in costation. In the Ohio Valley, the variations generally followed a trend toward lower costation. Specimens of *Lepidocyclus capax* (Conrad), *Austinella sooyellei* (Miller), *Plaesiomys subquadrata* Hall, *Zygospira kentuckiensis* James, and *Z. modesta* (Hall) are typically less costate than related members in adjacent basins. These relations support earlier observations of provincialism in the type Richmond fauna. Exceptions to this general pattern were noted in *Glyptorthis insculpta* (Hall) and *Rhynchotrema dentatum* (Hall), both of which exhibited little geographic variation in their costation. Observations for the widespread species, *Lepidocyclus capax*, are somewhat contradictory. Representatives from the Ohio Valley generally are less costate than those observed in Tennessee, Iowa, and Minnesota, but are somewhat more costate than the "Fernvale" variant in Oklahoma. The latter may be an older form.

Preliminary results suggest that ecologic factors, operating within a sedimentary basin, did affect costation but not uniformly for all species. Studies are continuing to determine more precisely the degree of uniformity of costation patterns and whether such patterns are related to variations in lithology.

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SOLITARY CORAL GROWTH FORMS AND DISTRIBUTION PATTERNS AS INDEX OF SEDIMENT-ACCUMULATION RATES

The characteristic feature of a 300-m-thick shelf sequence of alternating limestone and shale (lower Carboniferous, Northwest Ireland) is the presence of extensive solitary coral-strewn bedding planes. These shale-overlain, prone, coral death assemblages from particle-supported beds 5–15 cm thick alternating with 6–75-cm beds of skeletal carbonaceous silt, sand, or mud. The death assemblages consist of randomly oriented adult corals averaging 50–100 cm in length in concentrations of 4–11/sq m; they are laterally extensive (>30 m) with rare discontinuities. Locally upward-facing surfaces of prone individuals are breached and infested with boring bryozoans and sponges, or encrusted with auloporid corals. Coral growth forms and internal structures in the death assemblage commonly are aberrant; the cylindrical form is irregularly coiled and constricted; the intertabular space is highly variable (0.50–4.0 mm); the tabulae are thin in places and accompanied by a suppressed dissepimentarium. In the malformed parts of the corals the intertabular space commonly is infilled completely with silty biomicrite, whereas normally developed axial structures are spar filled. A few free-living upward-growing corals are present in life position in intervening units.

The coincidence of silty biomicrite axial infill and aberration in growth form and internal structures suggests that rapid local accumulation of fine sediment about the calyx forced upward growth and concomitant skeletal reduction. The coral death assemblages are lag deposits probably produced by unusually intense storm wave action which alternated with prolonged periods of quiet-water accumulation. The thickness of the quiet-water deposits (>75 cm) implies a long duration between storms, *e.g.*, "once-in-a-hundred-years."

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GEOCHEMICAL PROSPECTING AT SEA

An underwater seep-detector system was placed in operation in November 1967 as one of the research and development programs on the M/V *Gulfrex*. From thousands of miles of traverse, the results of the hydrocarbon analyses of seawater have shown the tremendous potential of this system for locating petroleum and natural gas seepages in offshore areas. The seepages, in turn, indicate prospective areas of buried hydrocarbon deposits.

The *Gulfrex* seep detector is capable of analyzing seawater for saturated and unsaturated hydrocarbons up to butane. The analyses have yielded surprisingly consistent data on the background hydrocarbon assemblage in the seas. From this knowledge, we now can recognize true petroleum and natural gas seepages, even in areas where prolific life activity may give abnormally high hydrocarbon backgrounds. The specific signature of hydrocarbon distributions in the sea also has the potential of distinguishing the types of hydro-