sure and by as much as 1,900 psi below the outcrop-controlled systems. This system is interpreted to be a sandstone lens completely enclosed in shale; its pressures were developed by geo-osmosis, as indicated by facies relations, shale analyses, and salinity maps.

The osmotic cell in this system consists of the low-salinity Viking sandstone and the deeper, high-salinity, Mannville sandstone and shale; the semipermeable membrane of the system is the intervening Joli Fou shale. Because the Viking sandstone system is isolated from the outcrop by shale and shaly rocks of very low permeability, the osmotic process produced a marked pressure anomaly.

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Lower Tertiary Deltas and Petroleum, Rocky Mountain Region

Paleocene and Eocene lacustrine deltas are present in several Rocky Mountain intermontane basins. Deltaic deposits of the Eocene Green River Formation in the Red Wash-Raven Ridge area, northeastern Utah, have been studied intensively. Recognition of the Red Wash delta is based on distribution of (1) fluviatile red and green shale facies (Wasatch Formation), distributary and nearshore sandstone facies, and lacustrine oolitic, ostracodal limestone facies (Green River Formation); (2) geographic orientation and spatial dimensions of thick sandstone bodies projecting into the lake beds, indicating positions of entry into Lake Uinta of south-flowing streams; and (3) sedimentary structures that are in accord with a deltaic environmental interpretation (although they are present also in other environments).

An estimated 100 million bbl of oil reserves (ultimate production) is trapped in a series of discrete sandstone bodies within the Red Wash delta. Variations in petroleum chemistry from pool to pool indicate local source beds and short-distance migration. Several billion bbl of oil in Wasatch-Green River outcrops (not including oil shale) attest to the almost incredible petroleum-generating power of Eocene lake deposits.

In the Piceance Creek basin, northwestern Colorado, Douglas Creek sandstones (basal member of the Green River Formation) were deposited at the mouth of a southwestward-flowing river, and facies associations similar to those of the Red Wash area are present. The lobate shape of sandstone deposition is not as distinctively developed as in Red Wash. An estimated 250 billion cu ft of gas is trapped at the up-dip edge of porous intervals on Piceance Creek anticline. Oil saturation is common in outcrops and is present in the subsurface although high wax content and low reservoir temperature prevent commercial production.

A similar facies association in the Wasatch-Green River section is present in the Washakie basin, southern Wyoming. A river flowing northwestward deposited thick sandstone beds that interfinger with lake beds in the vicinity of the basin axis and along the west flank of the basin. Oil and gas shows have been reported in these beds, but no commercial production has been developed.

Paleocene lakes in several basins have shoreline deposits, in part deltaic, that contain oil and gas fields and are targets for future exploration. Examples are the Fort Union Formation in the Big Piney-La Barge area, Waltman Shale lake beds in the Wind River basin, and Fort Union lake deposits in the Big Horn basin. The lobate configuration of Fort Union coarse clastics on the west flank of the Big Horn basin is very suggestive of deltaic deposits.

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Diagnostic Primary Structures of Estuarine Sand Bodies

Estuarine sand bodies assume complex morphologic characteristics in response to multidirectional tidal currents and wave action. Studies in 8 New England estuaries show, however, that the major forms are repetitive from estuary to estuary and that they display diagnostic suites of primary structures.

Sand accumulation around the seaward margin of the major inlets takes the form of ridge-and-runnel systems and recurved spits attached to the barrier beaches, large swash bars offshore, and submerged ebb-dominated sand sheets. Wave-generated flow over the intertidal bars creates an abundance of large-scale (up to 20 ft thick) planar cross-beds oriented landward.

Tidal deltas inside the inlets consist mainly of sand flats covered with flood-oriented sand waves—$>$20-ft wave lengths (λ). Margins of the deltas (ebb shields and ebb spits) contain predominantly ebb-oriented megaripples ($\lambda = 2$–20 ft) which produce festoon cross-bedding. In places, the deltas are cut by spillover lobes formed by ebb currents. Thus, zones of flood dominance are differentiated from zones of ebb dominance by distinct differences in scale and type of cross-bedding formed.

Major tidal channels are floored with large sand waves that may be ebb or flood oriented or bidirectional, depending on relation of bottom topography to current flow.

With respect to primary structures, a preserved regressive sequence of estuarine sand bodies would begin with large-scale, bimodal cross-bedding at the base that would grade upward into broad zones of flood-oriented, planar cross-beds interfingering with linear zones of small-scale, ebb-oriented festoon cross-beds. The sequence would be capped by burrowed sand (clam flats), mud (mud flats), and peat (salt marsh).

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Organic Carbonate Buildups in Epeiric Seas: Some Theoretical Aspects

Organic carbonate buildups form where conditions are favorable for calcareous organisms to flourish and to secrete enough calcium carbonate to build up the substrate locally. Advantages from buildup include inducing better water-circulation patterns and providing firm substrate for organisms not suited to live elsewhere. Perhaps most importantly, buildup involves simply production of enough sediment for the substrate to remain continually in the optimum zone for proliferation of the organisms.

R. J. Dunham's distinction between "ecologic reefs" in which organisms provide rigid framework and bind sediment, and "geologic reefs" in which the restricted area of thickened carbonate is due to localized organic proliferation without necessity of framework or sediment binding, resolves much of the nomenclatural controversy concerning organic carbonate buildups. Perhaps distinction also can be made between geologic "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-