areas of numerous large anticlines with multiple unconformities and complex growth and fault histories; areas of small, gentle, low-relief anticlines and areas where the Tertiary sediments onlap older volcanic rocks with little or no folding of the strata. Both oil and gas shows have been detected, but no commercial accumulations have yet been found.

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ANTIDUNE CROSS-STRATIFICATION IN TURBIDITE SEQUENCE, CLORIDORME FORMATION, GASPÉ, QUEBEC

Large-scale, single set cross-stratification, considered to have been produced by the upstream migration of antidunes, is present in the basal division of turbidite beds 2–3 m thick in the β_1 member of the Cloridorme Formation (Ordovician), Gaspé, Quebec. The local westward paleocurrent direction is approximately parallel with the east-west strike of the vertical beds, which crop out on the wave-cut platform.

The beds generally show 3 broad divisions. The basal division (2–15 cm) consists of very coarse-grained sand with a smooth or fluted base and sinusoid top (wave length from 45 to 100 cm and amplitude from 3 to 7 cm) and internal laminae inclined at a shallow angle (less than 15°) toward the east. Where flutes occur they give a paleocurrent direction toward the west. A second division consists of spindle or globular-shaped nodules ("pseudonodules") in an argillaceous matrix and commonly occurs above the basal division. In 1 bed, which occurs in a sequence with beds exhibiting ripple-drift cross-lamination, a ripple-drifted horizon is developed between the basal and pseudonodule divisions, the ripple-drift produced by a paleocurrent toward the west. The upper division consists of fine-grained siltstone or shale.

Because the basal very coarse sandstone is a small percentage of the total thickness of any bed, it appears that the settling velocity of the coarser grains probably was reduced by a high concentration of fine suspended material which increased the viscosity and reduced the density difference between the coarse grains and the suspension; the result was a high transport rate and the formation and preservation of antidunes, because of a delicate balance between traction and suspension in the current. Calculations suggest that the current moved at velocities of approximately 1 m/sec.

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PHYSIOGRAPHY, ECOLOGY, AND SEDIMENTS OF TWO BERMUDAN LAGOON REEFS

To provide a possible Holocene analogue for some ancient reefs, we studied the physiography, ecology, and sediments of two small reefs in Bermuda's north lagoon. Both are rough-topped "mesas" rising 18 m from the relatively featureless lagoon floor to within 1–2 m of sea level. On the reef top, irregular coral- and algae-covered knobs are separated by sediment-filled valleys and hollows. The central area of 1 reef, believed to be in a more advanced stage of development, is an atoll-like sandy plain with only scattered knobs.

Scleractinian corals, principally *Montastrea annularis* and *Diploria strigosa*, are the most important reef-framework builders, as revealed in sections artifically constructed by blasting with dynamite. Coral growth is thought to be the major factor influencing the shape of reef cavities that are common throughout the reef mass. The walls of these cavities are covered with distinctive wall growths built by the skeletons of shade-loving organisms, principally encrusting red algae, pelecypods, a foraminifer, and ectoprocts.

Sediments on the reef top are generally coarse to very coarse sand with good to moderate sorting. The particles, dominated by *Halimeda*, which is also common in lagoonal sediments, are derived entirely from the breakdown of reef-top organisms. These same reef-top sands are washed down the reef face to build a steep reef-sediment slope. Fine sediments are winnowed from the reef-top and settle from suspension to the near-reef lagoon floor, where they form a "halo" of fines around the reef.

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MICROSTRUCTURE OF RUGOSAN SKELETON (COELENTERATA)

Scanning electron and petrographic studies of *Thamnophyllum, Pachyphyllum, Tabulophyllum,* and *Charactophyllum* indicate that the Rugosa have much in common with the Scleractinia in terms of formation and structure of their exoskeleton. Possibly all rugosan septa are trabecular in construction, as lamellar structures are secondary, and fibro-normal structures are at least partly the result of modification of trabecular septa by diagenetic processes. There is no difficulty in applying the scleractinian model of biocrystallization to the rugosans. The question of original skeletal mineralogy remains unanswered, with some evidence of occurrence and microarchitecture suggesting that it was calcitic. However, recent study of aragonite inversion or recrystallization to calcite in scleractinians shows that structures produced by these processes are close to those noted in the Rugosa.

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STUDIES ON ORIGIN OF CRUDE OIL: STATISTICAL ANALYSES OF CRUDE OIL DATA

Multivariate statistical methods, including factor analysis and generalized analysis of variance and covariance, were used for interpretation of molecular and isotopic data obtained on 92 crude oils from the Western Canada basin. The data used in this study were obtained through gas-chromatographic and mass-spectrometric analyses of the oils.

Interpretations made through statistical analysis of the data are: (1) the 92 oils fall into natural groups that correspond to major variations in stratigraphy and geography; (2) a major part of the differences that exist among these groups is not due to regional temperature and pressure variations but rather to source differences; (3) all of the crudes are derived from an original primary petroleum which consists predominantly of high-ring naphthenes, high-ring aromatics, resins, and asphaltenes; and (4) more than 70% of the present variance in the oil data can be explained by low-temperature chemical reactions in the reservoir.

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CRETACEOUS DELTAS, ALBERTA

Tectonic divisions of the Precambrian basement of Alberta seem to have exerted geographic control on the emplacement of major deltas of the late Mesozoic. The greater thicknesses of the Albian lower Blairmore delta coincide with the site (in Devonian time) of the west Alberta ridge and the Peace River "high." The thick parts of the latest Cretaceous Belly River and Edmonton deltas show similar disposition. The Dunvegan delta (Cenomanian) pinches out abruptly south of the Peace River arch. The Milk River delta (Campanian) is a feature of the Sweetgrass arch and the lower Edmonton tongue is limited to an area west of the same arch.

Hydrocarbon pools within these deltas are controlled by pre-Cretaceous erosion features and/or by shoreline facies.

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GEOMETRY OF INYO-WHITE MOUNTAINS ALLOCHTHON, EASTERN CALIFORNIA

Approximately 750 sq mi of the northern Inyo and southern White Mountains, eastern California, are cut from a relatively simple, well-exposed, allochthonous mass consisting primarily of late Precambrian and Cambrian rocks. The thrust surface is exposed on both the eastern and western flanks of the Inyo Mountains where mainly Mississippian rocks underlie the allochthon. Although igneous rocks along the north and southeast have intruded the thrust zone, its position can be inferred from great differences in the stratigraphy (on the north) and structure (on the southeast) across the interpreted thrust. On the southwest, however, the allochthon is structurally continuous with the southern autochthon. The entire eastern and southern margins of the allochthon are folded down and under, suggesting eastward and southward movement. Apparently rotation occurred, probably in the Late Triassic, east of Independence, California, in the vicinity of the connection between the allochthon and autochthon. Movement northeast of Independence in the latitude of Tinemaha Reservoir has been a minimum of 15 mi. A large N-S-trending anticline and an adjacent syncline (which parallel most of the small folds) are the major structures within the allochthon. Superimposed on these north-south folds are E-W-trending warps involving the thrust plane.

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SEDIMENTARY AND FAUNAL ASSOCIATIONS OF PROTECTED CARBONATE SHELVES AND PLATFORMS

Protected carbonate shelves and platforms exhibit faunal and lithologic uniformity through time and space. Organic reefs of varied origin (stromatoporoid, rudist, coral) have sedimentologically and faunally similar backreef and lagoonal deposits. Backreef deposits, by definition, are dependent on organic reefs for their origin. Lagoonal deposits, however, primarily reflect restriction of circulation and are independent of the type of circulation barrier (reefs, islands, shoaling water). Thus, backreef deposits indicate presence of reefs, but lagoonal deposits reveal only the environmental character of the shelf or platform.

Backreef deposits—skeletal sands and gravels originating through breakdown and transport of reef organisms—reflect relatively high-energy nearreef environments. Though generally characterized simply as debris deposits, these materials form well-defined sedimentary bodies. Transport by sheet flow across the reef or by tidal currents in interreef channels results in formation of skeletal sand banks, islands, downwind offreef drape, coarse rubble piles, and tidal deltas. Reef migration and lagoonward expansion of the reef flat may incorporate these deposits in the reef mass, accounting in part for the large amount of loose debris in reefs. More detailed investigation of lateral and vertical relations in modern environments should lead to recognition of these sedimentary bodies in ancient rocks.

Lagoonal deposits reflect restriction of circulation, and lagoons commonly are characterized as sediment traps for fine-grained carbonates. Geometry, lithology, and faunal content of lagoonal deposits reflect depth, lagoonal circulation, and ecology of lagoonal organisms. Facies belts paralleling bathymetric contours in atoll lagoons, and paralleling strike of carbonate-shelf lagoons reflect the effect of depth. The generally simple pattern of lagoonal deposition is modified by sedimentary accumulations such as mud mounds, islands, and their intertidal and supratidal facies, tidal deltas, and oolite bars. Climate and tectonics influence relative abundance of different types of lagoonal sediments. Increased restriction, arid climate, and low coastal relief lead to formation of vast supratidal sabkhas, lagoonal evaporites, and reflux dolomitization. Exchange with the open sea promotes organic productivity and formation of skeletal sediments. Terrigenous influx results in complex terrigenous-carbonate facies.

Sparse paleontologic data reveal consistent faunal associations in lagoonal and backreef deposits of diverse origins and ages. Foraminifera, mollusks, and algae dominate these faunas. Ostracods also are characteristic. Devonian reefs are unique in that lagoonal deposits are dominated by abundant fragile branching stromatoporoids. The striking similarity of lagoonal faunas through time should provide a superb framework for ecologic and evolutionary studies.

Detailed resolution of carbonate subenvironments has been attempted most commonly in relatively thin, shelf-carbonate sequences. More detailed resolution of backreef and lagoonal subenvironments and sediment bodies is obtainable by more thorough definition and by application of available recent models.

Investigation of vertical and lateral variation in lagoonal carbonates should provide useful data on shelf history. Effects of sea-level change, climatic variation, growth and destruction of barriers, and variation of sediment sources may be revealed more explicitly in these relatively uncomplicated sediments than they would in the complexly varying facies of the shelf or platform edge. Consideration of recent models suggests possible reinterpretation of development in several ancient carbonate complexes.

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TECTONIC HISTORY OF NORTHERN ALASKA

(No abstract submitted)

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PETROLOGY OF PENNSYLVANIAN CARBONATE BANK AND ASSOCIATED ENVIRONMENTS, AZALEA FIELD, MIDLAND COUNTY, TEXAS

The Azalea carbonate biogenic bank developed on a broad shallow shelf during early Strawn deposition.