reef core, others extend into the laterally contiguous deposits and a few are regional in extent.

Typically, rudist reefs in this region record a history of short periods of organically controlled growth in shallow water alternating with brief periods of subaerial exposure and early diagenesis. These processes result in the formation of laterally restricted but internally complex limestone bodies 10–2,000 ft thick and a few hundreds of square feet to tens of square miles in areal extent.

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TERTIARY MICROFAUNA, MACKENZIE DELTA AREA

A lower Tertiary foraminiferal assemblage from the Arctic Coast of Canada contains 18 species. Two species are new, *Cyclammina arctica* and *Cyclammina borealis*. The fauna was recovered from a core of the Reindeer well drilled in the Mackenzie delta area. The faunal assemblage suggests a correlation with an outcrop section near Coal Mine Lake (lat. 68°40′46″N; long. 130°20′11″W).

The age assigned to the microfauna is Oligocene-Miocene, and the assemblage has an affinity with Tertiary faunas of the circum-Pacific area. The depositional environment suggested is deep, cold, marine water.

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REEFS AND WAVE ACTION

Wave resistance is used in many definitions as a criterion for "reef." It is therefore important to clarify what wave resistance means, whether it can be recognized in ancient reefs, and what effect the use of this criterion has on our thinking. For present purposes the noun "buildup" is used for all organically constructed mounds, including reefs, mudbanks, and algal stromatolites, irrespective of wave activity.

Wave resistance has several legitimate meanings, but none can be used as a reef criterion unless a definite degree of wave action is specified. Reefs would then be arbitrarily and undesirably separated from other buildups, whatever their biologic relations. Wave resistance as a criterion is therefore rejected, but as a variable characteristic, differing from one buildup to the next, it allows each to be placed in a unified wave-resistance hierarchy.

The degree of wave resistance required in a buildup depends on the wave environment, defined by the depth of water over the buildup, wave dimensions, and the relative frequency of waves of various dimensions. Wave energy increases rapidly upward, so that small depth changes involve large energy differences. Wave action (water-particle velocity) diminishes downward through the wave zone to 4% of its surface value at a depth equal to half the wavelength. Turbulence in the lower part of the wave zone requires no special adaptation by organisms; other forms of current may have more influence. Increase in wave size lowers the depth to which wave action is effective and increases turbulence at all depths in the wave zone. If large waves damage the buildup, their relative frequency becomes important, because wave resistance depends on a balance between wave damage and repair by organisms. The critical size of damaging waves depends on the "wave-resistance efficiency" of the constructing organisms, a function of growth form and strength. Organism growth rate contributes indirectly to the wave-resistant capacity of a buildup through its role in repairing damage.

Diagnosis of the wave-resistant capacity of ancient buildups is difficult. The geologic history of modern turbulence-indicative species (such as *Acropora palmata*) is short. Growth forms, distinctive in strong surf, become less diagnostic with decreasing wave action. Current action must be distinguished from wave action. Erosional debris, such as detached blocks, may be the product of slumping or boring organisms rather than turbulence. Storm damage may leave a record which gives a false impression of prevailing wave conditions.

Wave-resistance as a variable characteristic must, despite difficulties, become increasingly important in the study of buildups through geologic time. Organic evolution made possible the development of increasingly wave-resistant buildups and culminated in modern coral-algal reefs.

As a wider variety of constructing organisms became available and a correspondingly greater range of wave environments was colonized, the range of buildups that could exist at any one time increased. Thus, if one considers wave-resistance as a variable characteristic instead of an absolute value, arbitrary definitions are less important than environments and evolutionary relations.

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SHELF-EDGE CARBONATE-REDBED TRANSITIONS, RED PEAK AND THAYNES FORMATIONS (TRIASSIC), WESTERN WYOMING AND ADJACENT IDAHO

Stratigraphic correlations between the shallow, generally open-marine deposits (dominantly limestone) of the Triassic miogeosyncline in eastern Idaho (Thaynes Formation) and shelf redbeds in west-central Wyoming (Red Peak and Crow Mountain Formations) have been uncertain. The principal, most widely recognized marker bed in the Wyoming sequence—the Alcova Limestone Member—has been correlated variously with many different parts of the Thaynes, as well as with beds considered younger than the Thaynes. Our studies indicate that the Alcova is a marine tongue extending eastward from the sandstone and limestone unit of the upper part of the Thaynes. Carbonate tongues of the Thaynes below the sandstone and limestone unit also extend eastward into redbeds and evaporites in western Wyoming, but none of them extends as far as the sandstone and limestone unit.

Red Peak–Thaynes correlations lead to the reconstruction of an average paleogeography for western Wyoming and adjacent Idaho. In eastern Idaho and westernmost Wyoming, carbonate mounds and oolite shoals composed of bivalves, algae, and oolites lined the shelf edge. Shallow, agitated water is indicated by the carbonate associations. Restricted, shallow-marine conditions, characterized by gypsum and early diagenetic dolomite, extended eastward from the banks into western Wyoming. Throughout west-central and central Wyoming, shallow-marine and paralic conditions prevailed during deposition of the redbeds (dominantly siltstone) of most of the Red Peak Formation.

Despite differences in age and tectonic setting, the facies relations and the reconstructed paleogeography resemble the Permian shelf-basin sequence of West Texas. This similarity suggests the possibility that oil and

gas accumulations are present along the shelf edge although deformation may have allowed hydrocarbons to escape.

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DEEP-SEA DRILLING IN NORTHWEST PACIFIC AND PHILIPPINE SEA: LITHOLOGY AND PHYSICAL PROPERTIES

Seventeen sites were drilled on Leg VI of the Deep Sea Drilling Project in 5 contrasting areas of the Pacific: (1) Pacific basin floor, (2) Shatsky Rise, (3) Horizon Ridge, (4) Caroline Ridge, and (5) Philippine Sea.

Sediments of the Pacific basin floor are characteristically Tertiary brown clays overlying Cretaceous nannoplankton oozes containing chert and lithified ash. Tertiary chert-bearing nannoplankton oozes were found on Horizon Ridge. On the Shatsky Rise, Neogene nannoplankton oozes unconformably overlie Eocene and Upper Cretaceous nannoplankton oozes; Lower Cretaceous and Jurassic(?) carbonate oozes there have abundant chert. These Jurassic(?) to Lower Cretaceous sediments are the oldest reported from the Pacific. The sequence on the Caroline Ridge is Pleistocene to Oligocene nannoplankton ooze and volcanic ash lying on a very smooth "basement" of olivine dolerite. In the Philippine Sea, Miocene to Oligocene brown clay, thick volcanic ash, and red metamorphosed limestone lie on an irregular "basement" of olivine basalt.

Shipboard measurements of 6 physical properties were made on the sediments recovered: natural gamma radiation, sound velocity, wet-bulk density, porosity, thermal conductivity, and penetrability. These correlate chiefly with lithology and show no systematic variation with age or depth of burial. Gamma radiation is typically highest in zeolitic clays, intermediate in ash and brown clay, and low in microfossil ooze. Clayey sediments and microfossil ooze have low sound velocities (about 1.5 km/sec), sand-silt size ashes and microfossil ooze intermediate values (about 1.6–2.2 km/sec), and limestone and basalt the highest values (3.19–6.02 km/sec).

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PETROLOGY OF PERMIAN WEISSLIEGENDES SANDSTONES IN NORTH SEA BASIN

The contact between the continental redbeds of the Early Permian Rotliegendes and the marine sediments of the Late Permian Zechstein is a widespread and significant stratigraphic interface in the western European North Sea basin. It is at this boundary that the economically important Weissliegendes reservoir sandstone beds are present. Petrologic examination of the Weissliegendes sandstone and adjacent units, in the outcrop belts of eastern England and western Germany and in the subsurface in the southern North Sea and in the Netherlands, gives indications of their origins and suggests possible distribution patterns for the Weissliegendes reservoir sandstone bodies in the North Sea basin. The Weissliegendes sandstones, whose compositional aspects are controlled by local conditions, range from orthoquartzites, to subarkoses, to subgraywackes, to graywackes. The sandstones are multicycle deposits, largely derived from the local marine reworking of Rotliegendes sandstone, mudstone, and conglomerate. Interpretations of the textural and bedding characteristics of the Weissliegendes sandstone bodies indicate that they are of a subaqueous origin (*e.g.*, submarine sand ridges and banks), rather than of the eolian dune origin that has been long postulated for them. The distribution of the sandstone bodies is irregular with some having elongate shapes several kilometers wide, up to 40 m thick, and several tens of kilometers long. These sandstone bodies are most prevalent on the flanks of pre-Permian structural highs, in places overlapping the Rotliegendes and extending onto the Variscan basement.

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REEF CONFIGURATIONS: SOME CAUSES AND EFFECTS

It has been assumed that the deep borings on Pacific atolls have confirmed Darwin's theory of coral-reef development which holds that continued subsidence results in the successive appearance of fringing reefs, barrier reefs, and atolls. It is true that the considerable thicknesses of shallow-water carbonates found in these core holes necessitates subsidence; however, it does not necessarily follow that this subsidence has resulted in the genetic succession of reef types advocated by Darwin. The author enlarges on an alternate theory (first presented by MacNeil) and demonstrates that many, if not most, of the shape attributes of modern reefs are fundamentally karst induced rather than growth induced.

There is little doubt that the carbonate platforms beneath most modern reefs have suffered some degree of subaerial exposure. This general inference is warranted by the apparent thinness of recent shallow-water carbonate deposits in conjunction with the low stand of sea level during Wisconsin glaciation. Thus it seems logical to conclude that most modern reefs have developed on a karst substrate. The presence of drowned sink holes a few hundred feet deep on several modern carbonate platforms supports this conclusion and, more importantly, suggests a potential for the development of considerable solution relief.

Experiments with limestone blocks indicate the feasibility of solution development of the diagnostic cross-section morphology of both barrier reefs and atolls. Tropical karst land forms are suggestive of the same conclusion. All that is required apparently is a large surface area of gently dipping beds bordered on 1 or more sides by a relatively steep slope. The dissolving action of meteoric water differentially lowers the central area relative to that adjacent to the steep slopes and results in a partly or completely rimmed solution basin. Subsequent rise in sea level permits coral colonization of both the solution rim and the residual karst prominences within the basin. The resulting barrier reef or atoll, with its satellite lagoon reefs, is thus formed without recourse to a prior history of reef development.

The attributes of the reefs themselves support this interpretation, and all seem related to the development of a karst solution basin. Thus drowned "atolls" reflect drowned karst topography; reef passes originate as drainage breaches in the solution rim; faros are a karst product of breaching; peripheral limestone islands are exposures of the fossil drainage divide; and