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

spurs and grooves are expressions of lapies. These karst-induced differences in relief are perpetuated, and indeed accentuated, by reef growth, but reef growth per se has little to do with the resulting configuration.

It follows from this hypothesis that similar events should be recorded in the geologic record, and it is therefore interesting to note that facies relations among some supposed fossil reefs are depositionally incompatible unless an intervening period of subaerial exposure is assumed.

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GEOLOGIC OCCURRENCE OF OIL AND GAS IN MIOCENE OF GULF COAST OF UNITED STATES

Miocene sands have produced, through 1967, approximately 6.76 billion bbl of oil and 35 Tcf of gas in about 650 fields in coastal and offshore Louisiana and Texas. More than 80% of the production has come from fields in the Louisiana segment, where all 19 giant Miocene oil fields are located.

The Miocene sediments of coastal and offshore Louisiana and Texas form a seaward-dipping and thickening wedge of interbedded marginal-marine sandstone and shallow-marine shale with maximum thickness at any locality of about 25,000 ft. A composite section in the Gulf Coast geosyncline is at least 45,000 ft thick.

Rapid sedimentation in large deltas, where there were prolific organic production and accumulation and where the organic material was preserved by rapid burial, made possible the many large Miocene petroleum accumulations. These favorable conditions were confined mainly to the Louisiana coastal and adjacent offshore areas that subsided at a faster rate than the coastal interdeltaic regions on the east and west, and confined the Miocene Mississippi River to that part of the northern Gulf basin. Downward movement along faults that bound the deeply buried salt-filled grabens also took place as the major deltas prograded, causing diapiric structures and "rollover" anticlines to form where organic-rich deltaic mud, silt, and sand were deposited.

The tectonic-sedimentation history of the Gulf Coast Miocene clearly demonstrates the close relation between depositional environments and petroleum occurrence.

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DISCONTINUITY SURFACES IN BEAVERHILL LAKE GROUP (DEVONIAN) LIMESTONES, ALBERTA

More than 300 individual occurrences of discontinuity surfaces were examined in well cores of limestone of the Beaverhill Lake Group in the Swan Hills area of central Alberta. Planar to bumpy surfaces with truncated shells, organic borings, and associated pyrite, glauconite, and intraclasts grade morphologically into bedding planes. Irregular reentrants, up to 15 cm deep and infilled with sediments lithologically similar to the overlying rocks, can be interpreted as burrows and/or solution cavities. Many of the discontinuity surfaces are present within burrowed carbonate mudstone of the Waterways Formation, which contains a brachiopod-gastropod-echinoderm-ostracod fauna typical of normal-marine, subtidal environments. Although only few Waterways surfaces can be correlated in adjacent wells, 2 extensive surfaces are significant in that they form the upper and lower boundaries of the House Mountain–Deer Mountain reef complex (Swan Hills Formation).

The presence of discontinuity surfaces within subtidal, sub-wave-base limestone beds suggests that they are products of submarine lithification and erosion (mechanical, chemical, and biologic). These processes must have acted periodically to form hard clean areas of tens to hundreds of square miles of sea floor. Change in the normal circulation pattern of currents possibly triggered these processes and led to formation of discontinuity surfaces. A discontinuity surface at the upper contact of the reef complex indicates that rapid submergence, rather than emergence, probably terminated reef growth in the House Mountain–Deer Mountain area. The discontinuity surface just below the reef complex shows that reef growth was initiated from a hard surface.

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CHARACTERISTICS OF SHOREFACE SEDIMENTS

Sedimentary structures in shoreface deposits are in marked contrast with those of laterally equivalent facies. Whereas sediments of the beach and offshore areas consist of clean sands inhabited by relatively few species of burrowing organisms, the shoreface is characterized by an abundant and diverse fauna inhabiting detritus-rich, muddy sand. Principal sedimentary structures of shoreface deposits are those produced by biogenic reworking, whereas in the laterally equivalent beach and offshore sediments, structures which reflect physical energy are more abundantly represented. Examples of ancient nearshore sediments indicate that these characteristic features of the shoreface are valid facies indicators in the sedimentary record.

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A NEW LOOK AT OLD PROVINCES

The oil industry, like the historian, glorifies the pioneer exploring glamorous new frontiers. A new exploratory look at old or mature producing provinces may be equally challenging and even more rewarding. A successful search needs the same optimism, resourcefulness, and skill, and even more tenacity than required to conquer virgin basins.

Obvious advantages of mature producing provinces are commonly overlooked. Mature provinces supply explorationists sufficient data to truly delineate significant causal geologic relations of oil production. Available data allow an intelligent focus of meaningful exploration effort. Ready markets furnish immediate return from oil and gas discoveries that would be uneconomic in new frontiers.

Numerous facets of old provinces merit new looks. Units a few hundred feet below commonly accepted pay zones are as unexplored as many new frontiers. Multitudinous subsurface controls, and even potentially productive wells, which were abandoned as dry holes, may provide evidence for the presence of prolific shallower zones. Careful analysis of productive trends can indicate major new projections. Extending old trends can be especially rewarding if they were terminated at well-known geographic boundaries, such as rivers, county, and province or state lines. Reanalysis may reveal near-similar parallel trends or similar unexplored geologic environments. Subsurface data from structural