from the coastline to a depth of about 2,500 m, covers an area of about 1.4 million sq mi, approximately a third as large as the land area of the United States. However, knowledge of the geologic framework of this vast area is rudimentary, to say the least.

In broadest terms we know of a great prism of relatively undisturbed sedimentary rocks off the Atlantic and Gulf of Mexico coasts in contrast to a group of narrow basins of sedimentary rocks off the Pacific coast of California and Alaska. The Bering Sea and Arctic coast of Alaska also are underlain by thick accumulations of sedimentary rocks. With a total volume of about 2.5 million cu mi, these sedimentary provinces have a geologic composition, regional geologic framework, and tectonic setting that leave little doubt of a recoverable resource in excess of 100 billion bbl of petroleum liquids and 300 trillion cu ft of gas; and perhaps even in excess of 200 billion bbl of petroleum and 1,000 trillion cu ft of gas. Resources in place are many times greater than these recoverable estimates. Other known resources are salt dome sulfur on the order of several million tons, sand and gravel, shell, phosphorite, and a variety of placer deposits.

To develop these resources to the outer limit of the continental margin for the benefit of the economy of the United States will involve resolution of the worldwide problem of the seaward extent of the jurisdiction of maritime nations. It also will require geologic studies of the offshore areas infinitely more intensive than the studies of the past and the application of continually advancing techniques, both for exploration and ultimate development of the resources. Vision and bold action will be the guidelines.

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Lacustrine Criteria

Although among the least abundant of depositional environments represented in the geologic record, lakes exceed their limited occurrence in interpretive significance. Lacustrine rocks yield important information concerning paleogeography, paleoclimatology, and tectonics. Therefore geologists should seek to expand their ability to identify and interpret lacustrine environments.

Modern lakes are present in a variety of geologic settings, but most lakes are too small and ephemeral to be geologically significant. Only large, long-lived lakes, such as those in structural basins with interior drainage, can accumulate major lacustrine sedimentary sequences. The recognition of lacustrine rocks requires a variety of techniques. Inasmuch as unique criteria generally are lacking, the geologist must infer origin from scattered, commonly unrelated, and often contradictory data.

Lakes closely resemble shallow, epicontinental seas in physical properties. Large differences, therefore, in lithologic characteristics, sequences, facies relations, sedimentary structures, paleocurrent patterns, and other physical aspects should not be expected. Comparisons of these features from lacustrine and epicontinental rocks indicate the scarcity of significant diagnostic differences.

Large lakes and epicontinental seas differ mainly in size and chemistry. Size differences are evident; few lakes exceed 10,000 sq mi in area. Thus, regional stratigraphic and paleogeographic relations can be used to differentiate lakes and seas. Geochemical differences, however, are more definitive. Normal seawater has been relatively constant in composition for most of geologic history and changes related to evaporation, precipitation, or dilution are predictable. On the other hand, the chemistry of lacustrine water is not uniform, but is determined partly by lithology and climate in upland source areas. The geochemical balance of lakes, therefore, varies widely in different areas and rarely approximates that of seawater. Accordingly, lakes and seas can differ in authigenic and early diagenetic minerals. Especially useful are evaporite cycles.

Marine and nonmarine environments commonly are distinguished readily by their fauna. Paleontologic differentiation of nonmarine environments is uncertain, however, and requires further study.

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Studies on Sedimentology of Shell Beds on Bermudian Patch Reefs

The upper surfaces of two patch reefs on the northern edge of the Bermuda platform were observed to consist of coral-coralline algal rock mounds amid a complex system of low-lying channels containing coarse- to fine-grained calcareous detritus. The rock mounds on the larger of the two reefs are noticeably concentrated toward the periphery. Detailed mapping of a part of one of these reefs indicates that the distribution of *Spondylus* valves and other coarse detritus bears a strong relation to the shape and width of the intermound channels. Oddly, 79% of the shells lay with the concave side up. The apparent preference for this generally unstable orientation is attributed to the lofting of shells during transport and the preferential burial of shells lying concave-side-downward.

The mode of the fine fractions of samples taken from shelly areas consistently is toward the right of the mode of samples taken from adjacent nonshelly areas. It thus appears that the shells act as baffles to permit the local deposition of fine sediment.

It is concluded that shell-bed sedimentology reflects the existence of two wave-energy regimes throughout the year. In winter, powerful storm waves determine the distribution of shell beds; calmer seas prevailing in summer months promote the preferential deposition of fines among the shelly material. Further, the rock-sand configuration on larger patch reefs suggests that the reefs may concentrate unimodal sand toward the center and bimodal sediments in the more narrow, circuitous, shell-rich channels toward the periphery.

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Intra-Permian Corrosion Breccias, Southern Canadian Rocky Mountains

An extremely widespread intra-Permian transgression eroded and successively truncated beds from Middle Permian (Guadalupian) to Mississippian (Meramecian) in age.

On this erosion surface are lag gravels in a phosphatic matrix, with associated corrosion breccias. The breccias are developed where planate beds of calcilutite, dololutite, and chert are infiltrated, corroded, and brecciated *in situ* by the phosphate and then partly or totally replaced by chalcedony. Fragments from the breccias may be incorporated in the overlying conglomerate, although every gradation may be seen from mosaic brecciation of bedrock to moderately well-rounded material in the lag gravels.

The breccias and conglomerates are unconformably and diachronously overlain by Middle or Upper Permian clastic sedimentary rocks that were deposited in an evaporitic environment.

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TIDAL FLATS

Tidal flats are built of marine sediments intersected by runnels and channels in a specific vertical sequence. Bidirectional current marks and subaerial features complete the environmental indicators.

Sediments in the intertidal zone lie between high- and low-water line across a vertical distance of 1-4 m or more, depending on the tidal range. The tidal range causes tidal currents which in turn form numerous gullies and channels. Currents of a high tidal range erode deeper channels than currents of low tidal ranges. The current velocity on the flats may reach 1 knot; therefore, on sandy bottoms small-scale current ripple marks are formed. The current velocity in gullies and channels is 3 knots or more, so that megaripples and underwater dunes are common in the channels. The tidal flats are sheltered by barrier islands or sand bars or they are in a sheltered bay. Though wave action is not too strong, it is nevertheless an important factor.

The whole wedge-shaped tidal flat body is elongate, parallel with the shoreline for many miles, but is intersected by channels or river estuaries.

The clastic sediments are mud (clay and silt), and sand, which is mostly fine grained. Gravel is scarce but clay pebbles and shells are commonn on channel bottoms. The mineral content of clay and silt is mainly clay minerals, quartz, iron minerals, garnet, mica, feldspar, some heavy minerals, dolomite, and carbonate. The mineral content of sand is mainly quartz, feldspar, mica, heavy minerals, fecal pellets, broken shells, and Foraminifera.

Near the high-water line (mud flats) the mud content is high, especially on wind- and wave-sheltered coastlines. The mud content decreases in the mixed flats and is low near the low-water line in the sand flats. The mud content increases near channels and below the low-water line, especially in the lateral channel deposits (except in the channel-bottom sediments). Even in the mudflats, the channel-bottom sediments are very muddy.

The tidal flats in The Netherlands are less muddy than the tidal flats in the German bay. Most tidal flats in Great Britain are very sandy. South of San Felipe, Gulf of California, the tidal flats are built of skin sand; north of San Felipe the mud content increases markedly toward the Colorado delta, whence the silt is derived.

Cross-bedding of megaripples is rare on the flats but common in the channels. On sand flats cross-beds of small-scale current ripples are very common. Locally the cross-beds shows herring-bone structures in sections normal to the ripple-crest axis and festoon bedding in sections parallel with the ripples. Laminated sand is not common. Climbing ripple structures are very rare. Flaser bedding, wavy bedding, lenticular bedding, interbedding, and interlamination of mud and sand are common bedding types in the mixed flats and in the lateral channel deposits. In mud flats there are thick mud layers with thin strips of sand. None of these bedding types is restricted to tidal flats. Salt-marsh deposits are characteristically interfused by roots and by uneven noduled lamination.

In the microstructure there is graded bedding in thin laminae, mostly less than 1 mm thick. Some beds are graded from coarse to fine, and some from fine to coarse. Small-scale erosional features are common.

The origin of these bedding types commonly is related to the alternation of tidal currents and tidal slack water. In a vertical column there are thicker sets changing in the bedding type from set to set, resulting from changes of wind and wave direction and force. Most of the layers are deposited in shallow morphological depressions as flat erosional patches (shallow runnels), but some are deposited laterally in channel deposits (point bars) and others on sheltered, gently inclined places. On the flats above the depressions and channels, overall (net) sedimentation is small because of alternating erosion and sedimentation.

Tidal flat faunas are plentiful, but only a few species are present. Most parts of the tidal-flat surface layers are strongly bioturbated by bottom-living animals. Where layers are deposited rapidly, bioturbation is not as common. This is especially true of the lateral channel deposits and the channel-bottom sediments.

In some places there are units with bottom-living invertebrates in living positions. In a few layers, fecal pellets are concentrated. Rolled algal mats develop on tidal flats in certain climates.

The most common surface-structure features on tidal flats are ripple marks, mostly of current ripples, but also symmetrical oscillation ripples. Subaerial marks are important; small runnels and erosional depressions are abundant. The flat depressions are commonly sculptured by oscillation ripples whereas the surrounding bottom is covered by current ripples. Tracks of birds and other land animals, raindrop and hail imprints, and desiccation cracks are on the surface. Groove casts also are common.

Transgressive sequence on tidal flats may develop as follows (from top to bottom): *e'*, sand (sand-flat deposits); *d'*, mixed sediment (mixed-flat deposits); *c'*, mud (mud-flat deposits); *b'*, brackish and freshwater clay; and *a'*, sphagnum peat. Regressive tidal-flat sequence, from top to bottom, consist of: *f*, peat; *e*, freshwater and brackish deposits; *d*, salt-marsh deposits; *c*, mud-flat deposits; *b*, mixed flat deposits; and *a*, sand flat deposits.

This sequence is common only if there is an abundant sediment supply. If the sediment supply is not plentiful, meandering channels rework the sediments and the thick channel sediments directly overlie the transgressive sequence. Even where channels are developed, a regressive sequence sand, mixed sediments, mud, and salt-marsh deposits can develop, though they are deeply dissected by runnels and channels. In many examples of fossil and recent tidal flats, the sequences given here may not be fully developed.

Seaward from tidal flats, and parallel with the coast, sandbars or barrier islands may develop. The landward side of the tidal flats is the line where land soils develop by older sediments are exposed.

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SEDIMENT CONTROL OF FAUNAL DISTRIBUTION PATTERNS IN LATE CRETACEOUS MARGINAL MARINE DEPOSITS OF SOUTH DAKOTA

The recessional history of the Late Cretaceous sea in