tion has destroyed most primary bedding features except the southwest-dipping master bedding. Dielectric anisotropy data indicate long-grain axis orientations toward the southwest, perpendicular to the length of the sandstone body and regional depositional strike. The 2 parallel limestone bodies consist almost entirely of coarse, well-sorted bryozoan-crinoidal biosparites. These limestones contain a minor percentage of terrigenous quartz; silicification of skeletal fossil debris is common. Directional properties in the 2 limestone bodies indicate a southwesterly transport direction.

The coarsening-upward sequence of highly bioturbated sandstone with an increase in carbonate downdip indicates a littoral to infralittoral barrier separating a gently shallowing sea on the southwest from its shoreline on the northeast.

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LATE PLEISTOCENE BIOSTRATIGRAPHY AND PALEOCLIMATE OF GULF OF MEXICO DEEP-SEA CORES

Studies carried out on 25 of 55 piston cores collected during *Kane* surveys in the Gulf of Mexico show that detailed paleoclimatic curves can be determined for the late Pleistocene based on change in frequency of planktonic Foraminifera. Three carbonate-rich cores from the southwestern Gulf of Mexico have been examined in detail and show that most of the 28 species or forms distinguished in these cores show quantitative trends in response to paleoclimatic change. During warm intervals the *Globorotalia menardii* complex, *Pulleniatina obliquiloculata,* and *Globorotaloides hexagona* (interglacial) are characteristic whereas *Globorotalia inflata* and *Globigerina falconensis* indicate cool intervals.

A total of 3 major warmings and 2 major coolings are recorded; these probably correlate with zones Z to V of Ericson and Wollin. In addition faunal changes of less magnitude reflect secondary temperature oscillations superimposed on the more marked (glacial-interglacial) climatic oscillations. The climatic oscillations are remarkably uniform in some cores if fairly constant sedimentation rates are assumed.

Volcanic ash zones in 2 cores approximately correspond to the lowermost and uppermost boundaries of the last interglacial period. In one core a large increase in *Orbulina universa* coinciding with these ash zones may be due to temporary environmental changes associated with extensive ash deposition.

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DEPOSITIONAL ENVIRONMENT OF WIDESPREAD PENNSYLVANIAN BLACK SHALE (EXCELLO)

The Excello Shale covers an area of almost 200,000 sq mi in the Mid-Continent and the Illinois basin, and is the most widespread lithologic unit of the Summum cyclothem. It overlies both marine carbonates and coals, and is overlain by marine carbonates and deltaic clastics. The typically carbonaceous Excello grades laterally into more oxidized greenish-gray facies as it onlaps and crosses structural highs.

It is difficult to explain the great lateral extent of the thinly-laminated, fine-grained, organic-rich Excello Shale by a nearshore or lagoonal origin. The stratigraphic relations and lithologic characteristics of the Excello Shale are indicative of deeper water sedimentation in a stratified anoxic water system.

The accumulation of organic-rich bottom sediments resulted from the growth of a widespread density gradient (thermocline) which inhibited circulation of bottom waters of the epicontinental Excello sea to such an extent that anoxic water conditions arose as a result of the subsequent processes of deoxygenation, denitrification, and sulphate reduction. The distribution of the sulfide-bearing bottom waters, and hence the distribution of the organic-rich bottom sediments, was controlled by submarine topographic highs and basinal depressions. Sedimentation was restricted to the slow influx of clay minerals (probably clad with organic films) and detrital plant and animal remains. Return to the normal marine environment and clastic deposition was brought about as the Excello sea became shallow, thus breaking up the thermocline and destroying the anoxic bottom waters.

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HOLOCENE AND PLEISTOCENE SUBAERIAL CRUSTS AND PISOLITES, NORTHERN BARBADOS, WEST INDIES

Laminated calcareous crusts are present on most surface outcrops of Pleistocene limestone on northern Barbados and are similar to the caliche so common in areas with semiarid climate and a source of $CaCO_3$. Crust development is most intense at the surface of relatively young, poorly lithified, commonly little diagenetically altered carbonates. The complete zone of alteration (irregular, hard calcareous bands alternating with soft, chalky carbonate) may extend to depths of 6 ft or more. Large amounts of salt spray, either wind blown or direct splash, also contribute $CaCO_3$ to the system, resulting in the formation of thick crusts.

When developed on poorly indurated carbonates, crusts are usually interbedded with pisolites. These pisolites are either laminated microcrystalline grains, formed in the process of limestone alteration or, where salt spray is heavy, coated skeletal grains.

The Pleistocene section on northern Barbados includes a succession of transgressive reef complexes, unlike the generally regressive sequence on the rest of the island. Each episode of reef building is considered to represent a separate high stand of sea level during the late Pleistocene. Occurrence of fossil calcareous crusts and pisolites (similar to those forming on the surface today) between overlapping reef complexes in the transgressive sequence suggests a period of subaerial exposure and diagenesis between the formation of each successive reef complex.

The presence of comparable calcareous crusts and pisolites, both Holocene and fossil, in other Pleistocene and some Paleozoic limestone successions indicates they are useful criteria for subaerial exposure.

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NEW ASPECTS OF QUANTITATIVE INTERPRETATION OF VELOCITY DATA AND THEIR IMPACT ON GEOLOGIC EVALUATION OF EXPLORATION PROSPECTS

Studies on elastic wave velocities in rocks have proved increasingly useful in the geologic investigation of sedimentary basins. Velocities of sediments are

closely interrelated with their lithology, structure, and fabric, and strongly reflect their alteration through diagenetic processes. Perhaps the most important of these processes, the compaction of clastics, causes progressive and unilateral reduction of pore space and expulsion of fluids. Compaction status—especially of shales—can be measured by interval velocities which increase irreversibly up to the maximum burial depth. In any specific basin, therefore, shale velocities indicate later uplift and thus aid in recalculating the thickness of eroded sediments. Shale velocities, when observed vertically and parallel with the bedding plane, exhibit an anisotropy which probably decreases with growing lateral tectonic stress. Rapidly deposited shales and shales embedded in evaporites, show retarded compaction and consequently delay in velocity increase. Psammites and carbonates have more complicated velocity patterns due to the complexity of their diagenesis. Evaporites show little compaction because of their primary lack of porosity.

All these phenomena are reflected in velocities and have been studied in basins where numerous well-velocity data were available (*e.g.,* NW German basin). Seismic velocity data, collected through advanced modern techniques, serve the same purpose. Although their accuracy is still comparatively limited, an almost quantitative interpretation may be reached with the aid of mathematical and statistical treatment of sedimentation models.

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USE OF RIDGE REGRESSION ANALYSIS IN GEOLOGY

Multiple linear regression may be used to describe the relation of one geologic variable to several other (independent) variables, and may also be used to fit a trend surface to geographically distributed variables. The least-squares estimates of the regression coefficients commonly differ from the true coefficients if the independent variables are correlated. The estimates can be too large in absolute value, and may even have the wrong sign. Also, the least-squares solution may be unstable; replicate samples are likely to give widely differing values of the regression coefficients.

Ridge regression analysis, described by Hoerl and Kennard, is a technique for removing the effect of correlations from the regression analysis. The regression coefficients obtained are biased but have smaller sums of squared deviations between the coefficients and their estimates.

Correlations between geologic variables are common, and multiple regression coefficients based on these data may be suspect. For example, in trend surface analysis correlations between the geographic coordinates may range from zero (gridded data) to different from zero (clustered data) in a linear trend. In addition, when higher order terms are used in the trend the various powers of the geographic coordinates are highly correlated.

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BIOCLASTIC SEDIMENT DISPERSION OFF BERMUDAN PATCH REEFS

Skeletal debris, shed from the top of patch reefs, forms a wedge of reef-flank sediment which angularly onlaps the reef mass at the uppermost reef flank and grades into lagoonal sediments in deeper water. Major avenues of sediment transport are reef-face channels, which connect sand channels of the reef top with upper sections of the reef flank. Maximum distance of sediment transport off the reef top is less than 100 m.

The understanding of compositional and textural trends across patch reefs is enhanced by use of a working model based on substrate type, biofacies development, particle breakdown, and sediment transport by wave action. Sediment composition provides the basis for recognition of the following microfacies: sediment pockets, sand channels, reef-face channels, reef flank, interreef lagoon, and open lagoon. These microfacies are transitional and, in the preceding order, display the following trends: from the reef top lagoonward, the abundance of *Homotrema,* coral, and red algae in the sediment decreases and the abundance of *Halimeda* and Foraminifera (excluding *Homotrema*) increases. Interreef lagoons are distinguished from open lagoons by a lower molluscan content in the sediment.

Because of the effects of irregular particle shapes and variable particle densities, textural trends are secondary in delineating patch reef facies. Sand-size particles dominate each facies from the reef top to the lagoon. The absence of silt and clay is characteristic of the reef top. Gravel is nearly evenly distributed, in part because of the large *Halimeda* content of the sediment (25–60%). Generally, mean grain size decreases from the reef top lagoonward, whereas sorting progresses from poor to very poor.

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PRUDHOE BAY—GREATEST GEOLOGIC EXPLOSION OF OUR TIME

Prudhoe Bay field, potentially the largest oil discovery on the North American continent, is on the flat-lying arctic coastal plain of Alaska.

The structure of the field resulted from 2 periods of deformation. The Lisburne and Sadlerochit (Carboniferous-Triassic) productive structure is a westward-plunging anticline superimposed on a stable ancestral shelf. The anticline broadens eastward until it is progressively truncated by a major unconformity. The geologic structure is complicated by 2 fault patterns cutting rocks of pre-Cretaceous age: (1) normal, NW-SE-trending faults on the south flank, and (2) high angle stair-step faults parallel with the axial plane of the fold on the north flank. The structure of the field, contoured with the top of the Kuparuk River (Cretaceous) as datum, is a pronounced eastward-plunging structural nose.

Two major depositional sequences have been recognized in northern Alaska: (1) an upper sequence composed of orogenic rocks with poor reservoir characteristics, and (2) a lower sequence ranging in age from Mississippian to Early Cretaceous which contains most of the Lisburne Group. Accumulation was controlled by structure and porosity-permeability variations. The middle and main producing zones are sandstones of Permian to Triassic age which compose a gigantic stratigraphic trap abruptly truncated and overlapped by impervious Cretaceous shales. The upper producing zones are confined to the western part of the field and consist of discontinuous lenticular sandstones of Late Jurassic and Early Cretaceous ages.

A model concept of field-wide unitization will be in effect before production commences in the mid-1970s.