thus our continental margin will become increasingly important as a source of supply for new oil and gas.

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APPLICATION OF INFORMATION THEORY TO PALEONTOLOGIC PROBLEMS: I. TAXONOMIC DIVERSITY

Information theory deals with the relative frequencies of nominal classes by treatment of average uncertainty,

$$H = \sum_{i=1}^{k} p_i \ln p_i,$$

where p_i is the relative frequency of the i^{th} class, connected with observation of the system. Applied directly to proportions of the taxa in a collection, the equation yields a diversity measure. One may then generate an equitability measure $E = s'/s$, where s' is the number of taxa necessary to yield the observed diversity if the proportions of taxa were random and s is the observed number of taxa. Applied to foraminifer data from Sabine Lake, La.-Tex., diversity/equitability parameters define salinity gradients more clearly than the presence of particular taxa. Similarly, where applied to invertebrate fossils from the Mississippian of Scotland, these parameters make it possible to subdivide a transgressive sequence in finer detail than an analysis of taxonomic composition. Interpretations in terms of community structure are not justified, but empirical treatment of contemporaneous and successional patterns appears to be a useful paleoecologic tool.

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GOLDEN LANE–POZA RICA TRENDS, MEXICO—AN ALTERNATE INTERPRETATION

Middle Cretaceous cores from the prolific oil fields of the Golden Lane and Poza Rica trends in eastern Mexico were studied to determine the environment of deposition of the reservoir and associated rocks and to compare these with similar middle Cretaceous carbonate rocks along the Gulf Coast.

The Golden Lane fields produce from the El Abra Limestone, which was deposited in a shallow shelf or lagoon with scattered rudistid patch reefs. The structurally lower Poza Rica trend fields are 5–8 mi west and southwest of the Golden Lane, and contain rocks of the Tamaulipas and Tamabra Formations. The Tamabra Formation is composed largely of shallow-water coral-rudistid reefs, debris derived from the reefs and deposited in shoal-water nearby, and forereef talus mixed with basinal carbonate mudstone of Tamaulipas facies. Production in the Poza Rica trend is mainly from the reef debris. No coral-rudistid reef was recognized in the small amount of core examined from the Golden Lane, and available data do not support the prevalent view that the materials comprising the Tamabra Formation were transported 5–8 mi from the Golden Lane.

The carbonate rocks of the Golden Lane and Poza Rica trends and of the "Deep Edwards" trend in south Texas are of approximately the same age and, broadly speaking, were deposited under similar environmental conditions on a shallow shelf and at the shelf edge, adjacent to a basin. The Golden Lane and Poza Rica trends are only 30–40 mi from the Sierra Madre Oriental, a major early Tertiary orogenic belt, whereas the "Deep Edwards" trend is hundreds of miles from the same belt. Thus, although depositional environments of the Lower Cretaceous in south Texas parallel those of eastern Mexico, the subsequent geologic histories of the two regions differ markedly.

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KUMMERFORM FORAMINIFERA AS CLUES TO OCEANIC ENVIRONMENTS

Most planktonic foraminiferal shells resemble strings of hollow spheres of increasing diameter. The strings are coiled in a plane or on the surface of a cone. Shells of this type are defined as "normalform." Of all the chambers making up such a string, generally the last one only may be smaller than or equal to the previous one. If a foraminifer builds such a chamber, it leaves the normalform stage and enters the "kummerform" stage (German *kümmerlich* = measly). Attainment of the kummerform stage probably indicates environmental stress, notably lack of food.

In many samples of calcareous deep-sea sediment, a large proportion of the planktonic Foraminifera are kummerforms. This contrasts with the living populations in the upper water column where kummerforms are rare. The enrichment of deep-sea sediment with kummerform Foraminifera may be caused by (1) a greater propensity for living kummerforms, than for normalforms, to deliver an empty shell and (2) selective destruction of normalforms on the ocean floor.

There is evidence that both mechanisms may be important, depending on the oceanic environment in the upper water and on the ocean floor. Vigorous oceanic circulation may increase the proportion of kummerforms. Changes in the stability of oceanic environments thus may be recorded in the amount of kummerform Foraminifera in older deep-sea deposits.

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CRITERIA FOR RECOGNIZING ANCIENT BARRIER COASTLINES[1]

Worldwide modern barrier coastlines constitute a minor part of the total coastlines of all the continents. The aggregate length of present barrier coastlines in the world is approximately 3,530 mi, distributed as follows: North America, 2,000 mi; Europe, 500 mi; South America, 350 mi; Africa, 300 mi; Australia, 200 mi; and Asia, 200 mi.

Barrier islands commonly border coastal plains adjacent to broad continental shelves. They form in areas of abundant sand accumulation where longshore currents are prominent. Sandstone lenses which represent ancient barrier islands would be expected in thick wedges of interfingering terrestrial and marine sandstone, siltstone, and mudstone. Barrier islands of Pleistocene age have been recognized inshore from present

[1] Publication authorized by the Director, U.S. Geol. Survey.

coastlines, and drowned Holocene barrier coastline features have been described on the continental shelves. Pre-Holocene linear sandstone bodies resembling barrier islands have been described in ancient rocks of Pennsylvanian, Cretaceous, and Tertiary ages.

Probable barrier island sandstone bodies in ancient rocks have been described by previous investigators on the basis of comparison with features of modern analogs: geometry, sedimentary structures within the sand lens, physical properties of the sand, and the nature of associated environments. Recognition criteria used in this report are based partly on previous work and partly on recent studies along the Texas and North Carolina coasts.

Barrier islands are linear, have a length to width ratio generally greater than 10:1 and commonly are less than 60 ft thick. Padre Island, Texas, consists of four morphological units that have characteristic sedimentary structures: beach, foredune, barrier flats, and wind tidal flats—though the development of the foredunes and wind tidal flats changes considerably from north to south. Along the North Carolina coast, wind tidal flats are absent, but accretionary beach ridges are locally prominent. Superimposed on the islands of both coasts are storm washovers of hurricane origin that breach the foredunes and channel inlets that cross the island and connect the sea with the lagoon behind the islands. Beaches contain laminae of different thicknesses that dip principally seaward; the sand is locally shelly and fine laminae of heavy minerals may be prominent. The foredunes are markedly cross-bedded in an oriented pattern that reflects strongly the predominant wind direction. Barrier flats are underlain by sand which ranges from structureless to highly laminated; vegetal remains are common. Wind tidal-flat sediments that border the lagoon are an interlayered mixture of sand beds containing some fine shell fragments, and laminae of clay and algal remains. Sand is fine grained throughout. However, shell fragments, locally abundant, exhibit greater variability in size, shape, and sorting. Sand which refills channel inlets ranges from horizontally bedded to structureless; this contrasts sharply with the cut-and-fill cross-bedded sand common in stream-channel deposits.

The associated lagoon sediments are organic and calcareous mud which interfingers with barrier-island sand; the fauna is less diverse than that of the open sea and unbroken shells are abundant. Tongues of sand—washover deltas and fans which are built by storm flood tides—are prominent local features of the lagoons. Marshes overlying peat are characteristic of the inshore side of the bays along the North Carolina coast.

The geometry and alignment of the barrier islands and the close association of the sand in the barrier island with the organic mud of the lagoon are the key factors for the recognition of a barrier coastline. Attendant washover deltas and fans, cross-cutting inlet fill, and associated biota are important supplementary aids.

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Dune Sediments: Characteristics, Recognition, and Importance

One of the most important criteria for recognizing wind-laid deposits is based on their sedimentary structure. Eolian sandstone generally has large- and medium-scale cross-beds of the tabular-planar and wedge-planar types. Trough-type cross-beds are less abundant. The cross-beds commonly are composed of steeply dipping laminae which normally are concave upward. In modern dunes the foreset beds near the top of the slip face have steep (29–34°) dips but, in paleodunes, this value is somewhat less (20–29°) because of erosion which precedes deposition of the overlying set.

Dune cross-beds are distinguished from other similar structures on the basis of their more homogenous grain size. The nature of the adjacent and/or intercalated beds may help to determine the environment of deposition. The attitude of the bounding surface also is a diagnostic feature.

In the absence of cross-beds, other criteria are used to identify dune environments. Textural and mineralogical characteristics are not sufficiently conclusive. The mean grain size seems to be of little use. Although dune sand is slightly better sorted than other sediments, sorting is not distinctive. Positive skewness has been considered as an indication of dune environment. However, negative skewness also has been reported for dune sediments. Dune sand usually is more rounded than beach sand.

Dune and beach sediments can be separated on the basis of the heavy-to-light mineral ratio, and the relation between the settling velocity of two or more minerals of different density values.

Several criteria, together with the stratigraphic relations of the deposit to adjacent beds, should be used to identify the dune-sand environment.

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New Type of Sediment-Distribution Map: Preliminary Result for Gulf of Mexico

Normal sediment-distribution maps present the lithologic characteristics of only the upper 4–6 in. of the sedimentary column.

Cores collected from any area commonly reveal considerable changes in lithologic character through the thickness of the beds which are cored. Such variations can be expressed in vertical sections or in fence diagrams. Information concerning the upper sediment column to a depth of at least 30 ft is important for studies on sediment transport and deposition, basin filling, geotechnical properties, placing of laboratories on the sea bottom, salvaging sunken objects, acoustical measurements, and interpretation of high-frequency, shallow-penetration, and continuous seismic-reflection profiling.

"Standard patterns" have been determined from samples collected in long piston cores which penetrated different lithologic units and successions. The new sediment-distribution map constructed on the basis of the 30-ft cores shows the distribution of these standard patterns and thus reveals the sedimentary characteristics of the upper 30 ft. The patterns can be portrayed by colors, shades, and symbols, or combinations.

Other properties, such as geotechnical characteristics, can be added to the standards of the map or can be superimposed on the standard presentation.

The main divisions of the sediment-distribution map correspond to the boundaries of the physiographic provinces of the Gulf of Mexico.

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