

tion for the distribution and compositional variations of the petroleum across the platform. In addition, material balance calculations of oil-in-place *versus* indigenous sediment hydrocarbons provide a quantitative insight into petroleum migration problems.

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IMPORTANCE OF STORM ACTIVITY IN DEPOSITIONAL HISTORY OF WESTPHALIA (PENNSYLVANIAN) LIMESTONE MEMBER OF NORTHERN MID-CONTINENT EXPOSURES

The Westphalia Limestone Member (Stranger Formation, Douglas Group, Virgilian, Pennsylvanian) crops out from northern Osage Co., Oklahoma, on the south to southern Buchanan Co., Missouri, on the north. In most Kansas outcrops, the Westphalia is essentially continuous. South of east-central Chautauqua Co., Kansas, and north of southernmost Franklin Co., Kansas, discontinuous lenses comprise Westphalia outcrops.

Two very different rock types, a fusulinid, calcareous packstone and an ostracod, coaly, calcareous mudstone, are believed to represent the effects of storm deposition. These facies form most northern Mid-Continent Westphalia outcrops. Inner parts of the intertidal zone are postulated as the depositional site of the sediment that now forms the fusulinid calcareous packstone. Either a marsh or a supratidal tract was the probable site of the ostracod, coaly, calcareous mud deposition.

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IDENTIFICATION OF *Catapsydrax stainforthi* ZONE IN UPPER PART OF LOWER SAUCESIAN STAGE, CALIFORNIA

Samples from the upper part of the lower Saucesian Stage represented in Reliz Canyon, California, reveal populations of *Catapsydrax stainforthi* Bolli, Loeblich, and Tappan together with specimens of *Turborotalia opima nana* (Bolli) and *Globorotalia scitula praescitula* Blow. The concurrence of these planktonic foraminiferal indices suggests a correlation of the upper part of the lower Saucesian of Reliz Canyon with the *Catapsydrax stainforthi* Zone of tropical areas and with the fossil fauna exposed on Erben Guyot, Pacific Ocean. Associated planktonic species include *Globigerina angustumbilicata* Bolli, *Globigerina woodi woodi* Jenkins, *Globigerina praebulloides* Blow, *Turborotalia mayeri* (Cushman and Ellisor), and *Turborotalia opima continuosa* (Blow). Critical benthonic species include *Planulina appressa* Kleinpell and *Rectuvigerina kleinpelli* (Cushman).

Equation of the *Catapsydrax stainforthi* Zone with the upper part of the lower Saucesian indicates that the underlying *Catapsydrax dissimilis* Zone of the tropics probably is equivalent in large part to the lowermost Saucesian; the superjacent *Globigerinatella insueta* Zone of the tropics is equivalent to the upper Saucesian and perhaps to the lowermost part of the Relizian Stage of California.

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YATES (PERMIAN) CARBONATE RESERVOIR, WINKLER COUNTY, TEXAS

Backreef Yates (Permian) carbonate stringers in producing wells of the Hendrick field area, Winkler County, Texas, have lithologic and environmental characteristics which are very similar to equivalent-age outcrops in the Guadalupe Mountains of New Mexico.

Extensive dolomitization of the pay zones has not destroyed the original carbonate textures which appear to reflect oscillations of intertidal to supratidal environment in a narrow, relatively sheltered lagoon of predominantly carbonate deposition. These discrete carbonate units merge basinward with the massive Capitan reef complex and interfinger shelfward with quartz sandstone.

Stylolitic algal material alternates repeatedly with calcareous mudstone pellets, aggregate grains or "lumps," pisolites, and calcarenite beach deposits. Selective leaching of pellets, aggregate grains, and pisolitic textures accounts for most of the effective porosity development. Shelfward termination of this facies and consequent termination of porosity aid in the entrapment of hydrocarbons across a low-relief anticlinal trend.

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SUMMARY OF OFFSHORE EXPLORATION AND PRODUCTION

During the last decade, the continental offshore has emerged as a major petroleum-producing province and the leading area for future growth. The petroleum industry has invested more than \$7 billion in exploration of the shelves of the continental United States. Major offshore areas produce approximately 1 MM b/d of oil, more than 10% of U.S. production. Spurred by increased demands, gas production will assume a more important role in future offshore operations. In 1968, gas gatherers filed six major pipeline applications for 1969 construction of 800 mi of big-inch pipeline that will cost \$290 million.

Early offshore activity adapted onshore techniques to shallow-water installations. Gradual evolution to greater water depths and more hostile environments followed. Industry has developed designs for offshore structures and spent more than \$5 million to gather oceanographic data; several major programs currently are active.

Exploration technology has been sharpened because of intense competition and high costs. New sources of seismic energy for marine exploration have almost supplanted dynamite. To improve exploratory drilling, many types of mobile rigs have been developed, the first of which became operational in 1950. Industry continually has extended its capability and in 1968 drilled in 1,300 ft of water.

Although production facilities take many forms, including single-well templates, the most common is the large multiwell platform. During 1967, a 12-well platform was installed in 340 ft of water. Current designs suggest that platform construction is feasible to depths of 1,000 ft. Through continued development, underwater completions may evolve as a major producing method.

The large amount of bidding at 1968 offshore sales emphasized industry's need to develop new reserves. This need will continue into the foreseeable future;

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 *kümmertlich* = 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 COASTLINES¹

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

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