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BÉ, A. W. H., Lamont-Doherty Geol. Observ., Palisades, N.Y.

ZOOGEOGRAPHIC PROVINCES OF HOLOCENE PLANKTONIC FORAMINIFERIDA

Faunal provinces of planktonic Foraminiferida are delineated by oceanic water masses and available food supply. Species diversity decreases generally from tropical to polar waters, as well as from fertile to infertile areas. Productivity is probably higher and more continuous in tropical current systems than in subpolar regions. Test size and porosity decrease from low to high latitudes. These factors combine to yield higher accumulation rates of foraminiferal carbonate in tropical-subtropical than in subpolar-polar ocean basins (at depths above the $CaCO_3$ compensation depth).

The bipolar nature of the species distributions is evident from the reciprocal faunal zones in the northern and southern hemispheres. The Indo-Pacific fauna is richer than the Atlantic fauna. Most species (23) live in the warm-water region between approximately 40°N and 40°S lat. Tropical species, such as *Globigerinoides sacculifer* and *Globorotalia menardii*, inhabit the relatively eutrophic equatorial current systems and are transported to mid-latitudes by western boundary currents. Some subtropical species (*Globorotalia hirsuta, G. truncatulinoides, etc.*) live in the central oligotrophic areas of the oceans. Other species (*Globigerinoides ruber, Globoquadrina dutertrei, etc.*) are abundant in both tropical and subtropical latitudes, especially off continental margins. Salinity influences the distribution patterns of the 2 most successful species, *G. ruber* and *G. sacculifer.*

The northern and southern cold-water regions are inhabited by a total of only 8 species. The subpolar fauna is characterized by *Globigerina bulloides*, and left-coiling *G. pachyderma* is the sole representative of the polar provinces. Mixed assemblages of subpolar and subtropical species appear in convergence regions and areas of upwelling along eastern boundary currents.

Apparent species compositions and distribution patterns can be modified artificially by the mesh sizes of plankton net samplers.

BEARD, J. H., W. V. SLITER, and L. A. SMITH, Dept. Geol., Esso Production Research Co., Houston, Tex.

LATE NEOGENE STRATIGRAPHY (FORAMINIFERAL, COCCOLITH, AND PALEOMAGNETIC), UPPER COASTAL GROUP, JAMAICA, WEST INDIES

Late Neogene planktonic foraminiferal and calcareous nannofossil biostratigraphy of the Upper Coastal Group on the island of Jamaica is compared with the planktonic succession in the Gulf of Mexico and with the standard European stages and reference sections in Italy. Correlation of epoch boundaries and other paleontologic data from the Italian to the Caribbean and Gulf of Mexico regions utilizes restricted occurrences of planktonic foraminiferal and calcareous nannofossil species common to both regions. Species important for this intercontinental correlation and dating include: *Globorotalia acostaensis, Sphaeroidinellopsis sphaeroides, Discoaster challengeri,* and *D. extensus* in late Miocene; early Pliocene *Globorotalia margaritae* and *Discoaster quinqueramus;* middle and late Pliocene species of the *Globorotalia crassaformis* lineage, *Sphenolithus abies,* and *Reticulofenestra pseudoumbilica;* and appearance of *Globorotalia truncatulinoides, Helicopontosphaera* sp., and *Gephyrocapsa oceanica,* and faunal evidence for onset of climatic deterioration in early Pleistocene.

Climatic criteria obtained by analyses of the planktonic fauna provide a basis for recognition of the Pliocene-Pleistocene boundary within the most continuous and fossiliferous exposures of late Neogene marine sediments in the Gulf of Mexico and Caribbean region. On the basis of these data a sequence of planktonic foraminiferal zones and subzones is compared with the polarity reversal stratigraphy within the Gilbert, Gauss, and Matuyama geomagnetic epochs.

BEBOUT, D. G., Esso Production Research Co., Houston, Tex., and C. PENDEXTER, Esso Standard Libya, Tripoli, Libya

CARBONATE POROSITY RELATED TO DEPOSITIONAL FABRIC —ZELTEN FIELD, LIBYA

Production from the Zelten field, Libya, is from the highly porous shelf carbonates of the Zelten Member (main pay) of the Paleocene and lower Eocene Ruaga Limestone. Fifteen facies are easily recognized, mapped, and predicted. In the Zelten field, primary and secondary porosities, recorded as high as 40%, are related to the original depositional fabric of the sediment and are, therefore, facies controlled. Porosity is best developed in the coralgal wackestone and packstone and *Discocyclina*-foraminiferal packstone and grainstone, which together form a northwest-southeast trend across the northern part of the field. Porosity is lowest in the miliolid-foraminiferal-wackestone and argillaceous bryozoan/echinoid-wackestone facies, both of which are blanketlike in distribution over the top of the field and form the cap for the reservoir. Porosity is also low in the argillaceous molluscan-wackestone facies south of and equivalent to the coralgal and *Discocyclina*-foraminiferal facies.

It is concluded that early compaction of the soft carbonate sediments determined the amount of porosity preserved in the reservoir today. The grain-supported facies were not compacted and much of the original primary porosity is presumed to have been enlarged later by leaching. However, the mud-supported facies were compacted; the original porosity was lost early and consequently, later leaching was inhibited.

BERG, R. R., Texas A&M Univ., College Station, Tex., and S. TEFLIAN, Inexco Oil Co., Denver, Colo.

HILIGHT MUDDY FIELD—LOWER CRETACEOUS CHENIER PLAIN DEPOSITS IN POWDER RIVER BASIN, WYOMING

Thin sandstones and shales of the Muddy Formation produce large amounts of oil at Hilight field. The Muddy section is generally tight, and the best reservoir sandstones have effective porosity of 17% and average permeability of only 115 md. High production rates are caused primarily by extensive fractures, and the reservoir will yield an ultimate recovery of more than 80 million bbl of oil.

Sedimentary structures and petrographic analyses show that Muddy sands were deposited in littoral marine, lagoonal, and fluvial environments. Porous sandstones average 10 ft and rarely attain 20 ft in thickness. Lower Muddy sandstones are fluvial, whereas upper Muddy sandstones are mostly littoral or lagoonal in origin. Fluvial sandstones are associated with shales and siltstones that are highly carbonaceous and were deposited in poorly drained marshes. Lagoonal sandstones and marsh deposits also occur lateral to the littoral sandstones.

The presence of thin, littoral marine sandstones with widespread marsh sediments suggests a depositional environment similar to the modern chenier plain of South Louisiana. The entire Muddy sequence is transgressive toward the east and southeast over a low-relief topography developed on the underlying Skull Creek Shale.

BERGER, W. H., Scripps Inst. Oceanogr., La Jolla, Calif.

CRETACEOUS AND TERTIARY DEEP-SEA SEDIMENTS FROM ATLANTIC OCEAN

The sediments drilled during Leg 14 of the Deep Sea Drilling Project off northwestern Africa and northeastern South America comprise a wide range of Cretaceous and Tertiary deep-sea facies. The major processes controlling the distribution of these facies are the changing patterns of supply and preservation of biogenous matter, terrigenous influx, and erosion and redeposition on the ocean floor. The sequence of mid-Tertiary to Quaternary sediments can be described as an evolution from a "north Pacific" to a typical "Atlantic" facies, contingent upon a change in deep-sea circulation from ascending (estuarine) to descending (lagoonal), and a decreasing orogenic influence. For older sediments, recent counterparts are not available in many cases, and the reconstruction of the ancient environments involves unfamiliar sets of geochemical, climatological, and geographic variables, in addition to diagenesis.

BISSELL, H. J., Brigham Young Univ., Provo, Utah

THREE-DIMENSIONAL STYLOLITES AND MIGRATORY ROUTES OF OIL AND GAS

Stylolite seams are mutually interpenetrating sutures, illustrated in the literature as cross sections resembling a stylus. Typical two-dimensional views are those of sutures shown on polished marble and limestone. Three-dimensional views of stylolites are provided by many limestones in the Virgin Member, Moenkopi Formation (Lower Triassic), of southern Nevada. They are well developed in outcrops at Blue Diamond Hill and southwest of Las Vegas. Essentially all seams display a columnar stylus fluted with striations resembling slickensides. In cross section, stylolites range in size from a few millimeters to as much as 15 cm. In plan view, they are polygonal, ranging from pentagonal to octagonal, to some with more sides. Many Virgin Limestone stylolites parallel the stratification, but others are oriented at various angles. Seams bifurcate, braid, regroup, and display diverse patterns of solution channels. Some stylolites parallel cross-stratification.

As interpreted, stylolites are solution-compaction phenomena, and the amplitude of sutures or length of fluted columns is a measurement of the amount of compaction resulting from removal of carbonate sediment. If interlocking columns are 15 cm high, this represents the thickness of bedding unit removed during solution-compaction. Stylolites, being postdepositional, early compaction features are avenues along which oil and gas migrate. Hydrocarbons migrate early during depositional history in depocenters. Stylolites studied in carbonates of the Virgin Member show migratory routes of hydrocarbons, including some which carried oil to fill bioherms.

BLAKEY, R. C., Univ. Iowa, Iowa City, Iowa

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF MOENKOPI FORMATION IN SOUTHEASTERN UTAH

In southeastern Utah the Triassic Moenkopi Formation is composed mainly of red and yellowish-gray siltstone, sandstone, mudstone, and limestone. Continuity of individual units in this formation provides a basis for regional correlation. Five members are recognized here: Hoskinnini Member, "lower slope-forming member," Sinbad Limestone Member, "ledge-forming member," and "upper slope-forming member."

The Moenkopi Formation was deposited on a fairly uniform and gentle west slope that was bordered and at times covered by an epicontinental sea. Prominently stratified mudstone and fine siltstone were deposited when the rate of subsidence slightly exceeded the rate of deposition. Mudstone or massive sandy siltstone was deposited from a suspension load or by gravity flow. Ripple-marked and platy siltstone was deposited when subsidence and deposition were nearly equal and currents distributed thin layers of sediment over tidal flats, floodplains, and sea bottom. Horizontally stratified or low-angle cross-stratified sandstone is indicative of beach, bar, or shallow-marine environment. Prominently cross-stratified sandstone was deposited by restrictive currents such as those found in fluvial and tidal channels and some offshore bars. Fossiliferous carbonate was deposited in shallow marine waters.

Using these data, the following conclusions can be drawn. The Hoskinnini Member was deposited in a quiet body of water but was disturbed after deposition. The "lower slope-forming member" was deposited on a large tidal flat and in shallow marine waters; the sea transgressed farther east and deposited the Sinbad Limestone Member. As the sea retreated, a large delta spread across much of the basin of deposition and the complex "ledge-forming member" was deposited. Lithology of the "upper slope-forming member" indicates a widespread low-energy tidal, sabkha, and shallow marine environment.

BOOTHROYD, J. C., Coastal Research Ctr., Geol. Dept., Univ. Massachusetts, and G. M. ASHLEY, Geol. Dept., Univ. Massachusetts, Amherst, Mass.

CONTINENTAL SEDIMENTATION IN TECTONICALLY ACTIVE GEOSYNCLINAL BASIN, GLACIAL OUTWASH PLAIN OF NORTHEASTERN GULF OF ALASKA

Active stream systems on the glacial outwash plain of southeastern Alaska are building individual fans that exhibit a systematic variation in gradient, morphology, and suites of sedimentary structures from glacier terminus to ocean. The upper fan is characterized by a single, incised stream channel. The central fan, delta-shaped in plan view and occupied by braided streams, is the locus of most active deposition. It is subdivided into a gravel-depositional (upper) area and a sand-depositional (lower) area. A marsh or swamp area, with both braided and meandering streams, may be present at the fan terminus.

Bar morphology changes downstream from sheet bars to longitudinal bars to a complex of longitudinal and linguoid bars. Side and point bars are found in meandering streams. Mega-ripples are common in channels on the lower fan and the sand-depositional central fan, but are rare elsewhere.

A downstream succession of sedimentary structures is (1) well-imbricated, poorly sorted, coarse gravel