ABSTRACTS OF A.A.P.G.-S.E.P.M.-N.A.G.T. PAPERS

LOS ANGELES, CALIFORNIA, APRIL 10–13, 1967

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PETROGRAPHY OF A REEF COMPLEX IN LOWER CRETACEOUS JAMES LIMESTONE, FAIRWAY FIELD, TEXAS

The James Limestone at Fairway field and vicinity is an elongate, northwest-trending, atoll-like reef complex about 9 miles wide, 36 miles long, and 200 feet in maximum thickness. Along the northeast, southeast, and southwest margins of the reef complex, reef calcarenite interfingers with and grades laterally into clayey calcisiltite and calcareous shale of open-marine origin. Toward the northwest, reef calcarenite passes rather abruptly into oölitic calcarenite.

The development of the complex is characterized by a main reef phase followed by a lagoonal phase. During the main reef phase, two parallel-trending contemporaneous reef cores were constructed on a muddy, calcareous foundation unit. Both cores are marked by a distinct vertical zonation of bio-constructed limestones which from top to bottom include: (a) rudistid limestone, (b) *Chondrodonta* (pelecypod) limestone, and (c) algal-spongiomorph limestone. As the reef cores grew, considerable reef-derived calcarenite accumulated peripherally to the reef cores and far exceeded the reef cores in areal extent.

Near the end of the main reef phase, a shallow depression created between the reef cores became the site of a lagoon in which was deposited an interbedded sequence of foraminiferal-pelletal calcarenite, algal nodule-bearing calcilutite and biostromes of rudistid and *Chondrodonta* limestone. With the exception of additional minor growth of reef cores, lagoonal limestone deposition prevailed through a limited area and climaxed the development of the reef complex.

The sequence of diagenetic processes operative on the reef complex is summarized as follows:

1. Skeletal breakdown and grain diminution caused by boring organisms at the time of reef growth.
2. Post-depositional leaching of the reef complex, resulting in the development of skeletal modic porosity and sparry calcite cementation of reef calcarenite.
3. Impregnation of certain parts of the reef complex by a hard, brittle, bituminous (?) substance causing local reduction of porosity and permeability.

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LATE PLEISTOCENE AND RECENT SEDIMENTATION IN STRAIT OF JUAN DE FUCA

During part of the late Pleistocene (at least 14,000 years B.P.), the Strait of Juan de Fuca was occupied by a lobe of the continental ice sheet that extended from the Cascade Mountains of Washington and British Columbia on the east, to the nearshore waters of the Pacific Ocean on the west.

As the front retreated, marine waters were able to re-invade the lower region, changing the type and character of sedimentation, and permitting benthic Foraminifera to migrate into the strait. The sediments of this time appear to be glacio-marine, and indicate that the fauna was able to adapt to a sedimentary environment of cold brackish waters containing vast amounts of sediment, with a few coarser sediments and cobbles supplied by berg or shelf ice. As the ice front retreated farther toward the east and north, the Strait of Juan de Fuca waters became progressively less brackish and supported a more marine fauna.

Later, almost catastrophically, the environment changed from one of primary deposition to one of non-deposition or erosion. The upper part of the section and the surface sediments today are primarily coarse sand and gravel. This upper sand layer appears to lie disconformably on the underlying glacio-marine section. Measurements of the currents in the strait suggest that it is presently an area of non-deposition for fine sediments. Whether the upper sand layer in the strait represents a lag deposit after the removal of the finer fraction, or sediments added from coastal erosion, has not been determined. There is some seismic evidence, however, that Recent sediments are being shed into the strait from both sides.

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ORIGIN OF DIAPIRIC SHALE STRUCTURES OF SOUTH LOUISIANA

The intrusive diapiric shale structures of south Louisiana are related to the undercompacted shales that occur in normal stratigraphic sequence. These undercompacted shales, characterized by low density, low velocity, low resistivity, high porosity, and high formation pressure, are derived from the outer-neritic shale facies deposited on the continental shelf. The critical prerequisite of their occurrence is the absence of porous and permeable interbedded sandstone members that are pressure-connected with the atmosphere. Where present in the section, these undercompacted shales provide the mother or source bed for the diapiric shale structures, which may or may not be associated with diapiric salt derived from the much more deeply buried mother bed, the Louann Salt.

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DESIGNING AN EXPLORATION PROGRAM FOR MAXIMUM PROFIT

The concept of an exploration system designed to yield maximum profit recently has been successfully applied to exploration for metallic ore deposits. Similar methods using estimation of the probability of different exploration outcomes may be useful in the search for petroleum. The design of such a mineral exploration system involves the analysis of ownership, production, geological, geochemical, and geophysical data to produce maps showing regional and local probability values of mineral occurrence. These probability maps can be used in a general sequence to evaluate large land areas for minimum cost while limiting the use of more costly methods to smaller areas of progressively higher discovery potential.

Maps showing the distribution of mineral value in production and reserves covering areas as large as 100,000 square miles are of particular use. These maps guide the selection of smaller areas of 25,000 square miles where patterns of basic mining activity and ownership can be related to regional geologic features. In turn, they may be used to outline smaller areas of higher mineral potential where geochemical and geophysical methods may be applied in the field to pinpoint the location of specific deposits and give quantitative estimates of profitable outcome.

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Depositional Environment of White Rim Sandstone (Permian), Canyonlands National Park, Utah

The White Rim Sandstone of Leonardian age forms prominent topographic benches west of the Colorado River in Canyonlands National Park. Its origin has been interpreted as eolian or marginal marine by various authors without specific evidence other than the large-scale cross-stratification which is generally conspicuous.

A detailed study of the gross geometry, cross-stratification, ripple marks, trace fossils, and facies relations of the sandstone revealed a subaqueous environment of deposition which was probably sub-littoral marine. The formation contains numerous offshore bars that were constructed by surf and longshore currents moving from the northwest as shown by bar trends and cross-stratification analyses. Numerous small bars with 10–20 feet of relief occur in a northwesterly trending swarm northeast of Elaterite basin near the Green River. A larger elongate bar with 200 feet of relief extends in an arcuate northwesterly direction for about 10 miles through Elaterite basin. Excellent exposures of sedimentary structures reveal that the original geometric configuration of the bar is preserved. The sandstone grades abruptly into fine-grained lagoonal redbeds just east of the Elaterite bar, forming a stratigraphic oil trap that has been exposed by Recent erosion. The shallow-water bar apparently was constructed on the nose of the Monument upwarp which was mildly positive, providing shoal conditions at the time of sedimentation.

Pre-Triassic (Hoskinnini?) redbeds were deposited across the White Rim Sandstone, draping over the bars preserved at its upper surface. Subsequent erosion prior to Moenkopi (Triassic) sedimentation produced local angular unconformities along the margins of the bars.

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Paleontological Guides to Depositional Environments

Foraminiferal-environmental relations provide criteria for (1) the reconstruction of marine basins of the geologic past, (2) the determination of structural trends based on differential subsidence rates, and (3) the identification of important producing trends within the sediment and environmental framework.

One of the primary guides to depositional environments is the patent foraminiferal zonation from marsh to deep-sea environments. This may be summarized for southern California as follows: (1) marsh, *Jadammina-Miliammina* fauna; (2) euryhaline lagoon, *Ammonia beccarii tepida* fauna; (3) intertidal zone, *Rotorbinella* fauna; (4) open ocean 0–20 m., *Buliminella elegantissima* type of fauna; (5) 20–100 m., *Florilus-Nonionella* fauna; (6) 100 m. upper depth limit, *Bolivina acuminata-Uvigerina peregrina* fauna; (7) 400 m. upper depth limit, *Bolivina argentea-Bolivina spissa* fauna; (8) 700 m. upper depth limit, *Bulimina striata mexicana* fauna; (9) 1,000 m. upper depth limit, *Uvigerina hispida* fauna; and (10) 2,400 m. upper depth limit, *Melonis pompilioides-Uvigerina senticosa* fauna. Bathyal species such as *Uvigerina peregrina, hispida, senticosa,* and *Melonis pompilioides* are essentially isobathyal showing little if any evidence of temperature control in their distribution patterns in different oceanic areas.

Other guides to depositional environments include the bathyal bolivine trend within the general oxygen-minimum zone (0.3–0.7 ml./l.); specimens of this group become larger and more abundant with increasing organic content and depth. Oxygen values of about 0.1 ml./l. or less result in an absence of larger invertebrates and a concentration of depositional laminae with very fragile hyaline bolivines and other Foraminifera. The largest benthic bathyal Foraminifera (measuring several millimeters in length) require oxygen values of more than 1.5 ml./l. and nitrogen values of more than 0.15 per cent; these occur in homogeneous or disturbed sediments, characteristics resulting from the activities of larger invertebrates. Displacement processes may produce intercalations of these various facies; variations in water masses may result in somewhat similar fluctuations of facies.

Planktonic foraminiferal abundance and diversity increase seaward into the bathyal zone. Although most planktonic Foraminifera live in the photic zone, some such as *Globigerina pachyderma* (typical form) and *"Sphaeroidinella"* are characteristic of the bathyal zone when they are fully developed. Many planktonic Foraminifera add a crystalline crust to their test as they descend into deeper waters of the bathyal zone. Radiolarians are of primary importance in middle bathyal-to-abyssal depths.

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Neogene Planktonic Events and Radiometric Scale, California*

More than seven significant events are recorded by planktonic microfossils of the Neogene for the eastern Pacific and the Pacific Coast of North America, correlated with provincial microfaunal stages and a radiometric scale based on available K-Ar dates. (1) There was a significant evolution from *Globigerina concinna* to *Globigerina bulloides* about 17 m. y. ago marking the approximate Relizian-Luisian boundary of California. (2) The youngest known dextral specimens of *Globoquadrina altispira* occur about 12 m. y. ago correlating with part of the upper lower Mohnian. (3) The youngest known sinistral specimens of *Globorotalia mayeri* occur about 12 m. y. ago, correlating with part of the lower Mohnian. (4) The radiolarian, *Prunopyle titan*, spans the interval of about 15–10 m. y. B.P., becoming extinct before the end of the Miocene (Delmontian). (5) The transition from *Sphaeroidinellopsis* to *Sphaeroidinella*, the SPHAEROIDINELLA DEHISCENS DATUM, and the introduction of *Globorotalia inflata* marks the Miocene-Pliocene boundary (approximate Delmontian-Repetto boundary) and is about 9 m. y. B.P. (6) *Globorotalia* (*Truncorotalia*) *truncatulinoides* ranges from basal Pliocene to Recent; however, it is most characteristic

* Grateful acknowledgment is made to the U.S. National Science Foundation (Grant GF-195) for support.