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TERRESTRIAL TO MARINE TRANSITION OF HEAVY MINERALS

Heavy-mineral analyses show that the main supply of sand for the beaches and sea floor off Southern California is provided directly by the adjacent land areas. The longshore movement of sand is only of local importance because obstacles along the coast, such as submarine canyons and points of land, limit the longshore movement of sand to small segments along the coast. A close examination of a coastal segment shows marked differences between Recent marine and nonmarine sediments, and suggests that longshore drift of sand within a segment is prominent. The concept of time, as used in correlation of heavy-mineral samples, should include consideration of source rocks and drainage patterns, and should not be based solely on depositional features.

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CALIFORNIA OFFSHORE GEOLOGY AND EXPLORATION

During the years 1948 to 1961 the oil industry spent more than $150,000,000 exploring the submerged oil potential of offshore California. Seven oil or gas accumulations were discovered, but none appears to be of sufficient size to yield a significant profit to the operator. Prior to 1948 four giant California offshore oil fields (Elwood, Rincon, Wilmington, and Huntington Beach) had been developed with total estimated ultimate reserves exceeding 1,500,000,000 barrels. Published reports had outlined unexplored offshore basins with vast volumes of sediments. Producing fields onshore but close to the ocean are estimated to yield ultimate recoveries ranging from 150,000 to 550,000 barrels per acre.

Hypothetical offshore extensions of these producing trends led to enthusiastic multi-million-barrel estimates of the offshore potential. In 1953 the "Tide and Submerged Land Act" triggered a hectic exploration campaign. Sophisticated, costly tools were developed. Estimates indicate that 40,000 miles of seismic lines were shot. Several hundred coreholes were drilled. Bonus bids at State offshore sales reached new highs in 1958 when approximately $55,000,000 was paid for five parcels of land at prices ranging up to $6,175 per acre. Drilling during the following year resulted in four discoveries. From the oil finders' view, 1959 was a very successful year in California exploration history but from the economic viewpoint the results do not appear impressive.

Many major companies continue the offshore campaign with improved methods and tools, yet the California offshore potential remains largely unexplored. Economic development of this oil to serve our companies and the exploding West Coast population requires reassessment of exploration methods, more advancements in technology, less expensive drilling and completion techniques, a better understanding of offshore economics, and more realistic appraisals of individual prospects.

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CENOZOIC FORAMINIFERAL ZONATION AND BASINAL DEVELOPMENT FOR PART OF PHILIPPINES[1]

Foraminiferal analyses of Cenozoic strata of Central Valley, Luzon and southern Iloilo, Panay, indicate a general planktonic zonation for the middle and later Cenozoic which is similar to that recognized in equivalent strata of other tropical areas of the world.

There is generally parallel basinal development in Central Valley and Iloilo beginning in the Late Oligocene-Early Miocene interval. The cycle commenced with shelf conditions and orbitoidal facies giving way upward and with time to increasingly deeper-water facies of the bathyal zone. Maximum water depths of at least 1,000–2,000 meters were attained during the Miocene as indicated by *Pullenia bulloides*, *Osangularia bengalensis*, *Laticarinina pauperata*, and others. The parallel history in the two areas stops in the Late Miocene when Central Valley experienced prominent basin-filling and a transition to shallow-water paralic facies. In Iloilo, deep basinal conditions prevailed into the Middle Pliocene before basin-filling occurred.

The more complete planktonic sequence is that of Iloilo. Late Oligocene time is suggested by *Globigerina ciperoensis* in at least one part of the basin. Early Miocene is represented by a lower *Globigerina dissimilis* zone and an upper *Globoquadrina rohri* zone. Middle Miocene time is indicated by a lower *Globorotalia fohsi fohsi* left-coiling zone giving way upward to the right-coiling populations of *Globorotalia fohsi robusta* and *Globorotalia menardii* (primitive form). From bottom to top, the Late Miocene zones include a basal *Globoquadrina dehiscens advena* zone, a *Globoquadrina altispira altispira* zone (top of occurrence), a *Globigerina nepenthes* zone (top of occurrence), and at the top a *Globoquadrina altispira globosa-Globoquadrina dehiscens dehiscens* zone.

Early Pliocene populations are characterized by *Sphaeroidinella dehiscens dehiscens* and *Globigerina eggeri*. Middle Pliocene populations lack these but include an abundance of *Globorotalia truncatulinoides* and *Globorotalia menardii*. *Pulleniatina obliquiloculata* is common to abundant in the Middle and Early Pliocene and rare in the Late Miocene. It is dominantly right-coiling in the Middle and most of the Early Pliocene, left-coiling at the base of the Pliocene, right-coiling and rare in the latest Miocene, and mostly left-coiling and very rare below.

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PHYLOGENETIC TRENDS IN MISSISSIPPIAN *Pentremites*

Recognition of thecal modifications in the Mississippian blastoid *Pentremites* through geologic time has expanded its stratigraphic usefulness. Of particular stratigraphic significance are changes in the exterior shape, in the cross-sectional outline of the ambulacra, and in the number of hydrospire folds beneath each ambulacral side. *Pentremites* of Osage and early Meramec age have nearly flat bases, slightly convex ambulacra, and a low number of hydrospire folds per ambulacral side (normally three). In the late Meramec two divergent phylogenetic lines occur: *Pentremites* with flat or nearly flat bases and those with pyriform exterior shape. Both lineages persist to the end of the Mississippian. The lineage characterized by species with flat-based thecas have flat to slightly convex ambulacra from the late Meramec to the early Chester, and have progressive concavity of the ambulacra from the middle to late Chester. The number of hydrospire folds per ambulacral side in flat-based species changes from three in the late Meramec to four or five in the middle Chester; surprisingly, late Chester forms have a reduced number of folds (commonly three to four). The

[1] Publication authorized by San Jose Oil Company, Manila, Philippines.

lineage with pyriform thecas have flat to convex ambulacra from the late Meramec to the early Chester; nearly flat or concave ambulacra occur in middle and late Chester specimens. The number of hydrospire folds per hydrospire group is four to five in early Chester pyriform species; five to seven in the middle Chester, and four to five in some late Chester forms.

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LATE CRETACEOUS BIOSTRATIGRAPHY IN LOS BAÑOS CREEK AREA, CALIFORNIA

Facies studies present a narrowing of the continental shelf during the Cretaceous-Paleocene transition in central California. Response to this changing environment was attended by accelerated evolution and proliferation of individuals prior to the extinction of many previous well adapted animal stocks, especially the ammonoids and the larger reptiles.

Evidence is lacking for the presumed unconformity between the Cretaceous and Tertiary sediments, and the often quoted Paleocene transgression is actually more regressive in character, with a considerable increase in red oxidized sandstones and associated tidal marsh leaf-bearing clastics.

The Late Cretaceous stratigraphic nomenclature is compromised with the increasingly continental trend of the Late Cretaceous deposits north of Los Baños Creek. For example, the Volta Member of the Garzas Formation northward grades from the medium-depth neritic foraminiferal marl of the Marca shale through the littoral calcareous sandstones of the "Mercy" Sandstone lentil to the brackish-water anauxitic sandstone member of the lower "Martinez" Formation.

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PERMIAN FUSULINIDS IN EASTERN NEVADA—PALEOECOLOGIC IMPLICATIONS

Field and laboratory studies of fusulinids from exposed Permian strata in no fewer than 15 mountain ranges in eastern Nevada, and six similar sections in western Utah have progressed to the point that the following conclusions can be drawn concerning paleoecology of these Foraminifera: (1) they were most abundant in the infraneritic to epineritic benthos; (2) areas of optima were below wave-base for many schwagerinids, although some of these along with numerous parafusulinids seemingly thrived in areas of high energy; (3) most species of all fusulinids occur in areas where clean calcarenitic limestones and clean carbonate muds accumulated; (4) pseudoschwagerinids and paraschwagerinids lived in environments of agitation as well as under circumstances of slightly foul bottoms; (5) triticitids and pseudofusulinids occurred where silty, sandy, and calcarenitic materials were accumulating under moderate- to high-energy conditions; (6) most species of fusulinids can be found in the reef-tract; some in fact contributed notably to this biotope.

Throughout most places in eastern Nevada (and western Utah) strata of Wolfcampian age are limestones of criquinitic, calcarenitic, and high-energy patch-reef types. These contain pseudofusulinellids, schwagerinids, and pseudoschwagerinids in abundance. Strata of Leonardian age consist of silty, sandy, calcarenitic and reef materials, all more or less rich in robust to elongated schwagerinids and parafusulinids; pseudoschwagerinids occur abundantly in reef-rocks. Strata of late Leonardian, and Wordian to early Capitanian age locally are gritty, sandy, conglomeratic, and coarsely bioclastic; diagnostic species of parafusulinids and schwagerinids preferred the environment typifying these sedimentary realms.

It should be emphasized that possibly all these Foraminifera at times and under optimum environmental conditions formed veritable slimes and oozes of protoplasm. Some of this material may have contributed to oil source beds for strong hydrocarbon odors now characterize most fusulinid-bearing strata of the Permian of eastern Nevada and western Utah.

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LATE DEVONIAN—EARLY MISSISSIPPIAN CORRELATIONS CENTRAL WASATCH MOUNTAINS, UTAH

Strata of Late Devonian age have been recognized west of the Wasatch Front (Pinyon Peak Limestone and "City Creek Limestone") and a few miles east of the Wasatch Mountains in the western Uinta Mountains (Pinyon Peak Limestone?). These consist commonly of a basal sandstone or shale a few feet thick which grades upward to a dolomite sequence that ranges in thickness from 50 to 300 feet. This succession is in turn overlain by the Madison Limestone (Mississippian). On the west this contact is conformable but on the east it is unconformable. In the Wasatch Mountains, sandstone or shale a few feet thick rests on older rocks (mostly of Cambrian age) and changes upward through about a 3-foot interval into medium to dark gray dolomite about 50–150 feet thick, which in turn is overlain conformably by the Madison Limestone. These pre-Madison rocks were tentatively correlated with the Jefferson Formation (Devonian) by earlier workers on the basis of stratigraphic position and lithologic character. Subsequent workers of the U. S. Geological Survey have reported corals of Mississippian affinity from the exposures in American Fork Canyon and have thus assigned a Mississippian age to these strata.

Restudy of several of the Wasatch Front exposures disclosed well preserved molds of the brachiopod *Cyrtospirifer whitneyi* (?) in the basal sandstone in the Big Cottonwood Canyon area. This fossil is generally considered to be of Late Devonian age and has been collected from the Pinyon Peak Limestone in the western Uintas and in the areas west of the Wasatch. Thus the Mississippian age assigned to these rocks on the basis of corals is questionable. Moreover, a Late Devonian age is more consistent with a regional stratigraphic correlation on the basis of physical evidence. Therefore the "Jefferson (?)" of the Wasatch is here correlated with the Pinyon Peak Limestone of the areas east and west.

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THE EXPLORATION TEAM

Advancements in petroleum technology during the past 40 years have been so extensive that the science of finding oil has rendered obsolete dependence on one man or one method. Exploration success must now rely on the close cooperation of many people and utilization of all applicable methods.

Since the surface and seismic refraction programs of the 1920s and 1930s, new and highly specialized tools have contributed substantially to the complexity of the oil explorer's task in the 1960s.

It is no longer sufficient for the geologist, as the