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MOLLUSCAN BIOFACIES IN CALCAREOUS SEDIMENTS OF GULF OF BATABANO, CUBA

The Gulf of Batabano is a shallow embayment approximately 16,000 square miles in area on the south side of Cuba. It is covered with a veneer of carbonate sediments, and the water is generally no more than 25 or 30 feet deep. Reefs rim the Gulf on the southeast margin.

Calcareous sediments range in composition from clean oölitic sand, composite grain sand, and skeletal sand to a sediment consisting almost entirely of carbonate mud and skeletal debris. Some of these sediment types can be characterized by specific associations of mollusks.

The invertebrate fauna of the Gulf is principally molluscan, and comprises 194 named species and subspecies of gastropods, pelecypods, and scaphopods. Molluscan faunules were used from 119 gravity core and grab samples, which are more or less evenly spaced over the Gulf. Semi-quantitative methods were employed in analyzing the faunal data.

Mollusks are most abundant on areas of carbonate mud along the north margin of the Gulf, particularly in the northeastern part of the Gulf where brackish-water influences are greatest. They are least abundant in high-energy areas along the seaward Gulf margin.

The energy of the water mass and salinity appear to be the two most important environmental factors affecting the distribution of the mollusks. Accordingly, two major ecological molluscan assemblages may be recognized: (1) the Northern Gulf assemblage and (2) the Southeastern Gulf and Gulf Margin assemblage. The Northern Gulf assemblage is best developed in low-energy areas on grassy sediments that contain more than 50 per cent carbonate mud. The Southeastern Gulf and Gulf Margin assemblage is found on relatively clean sandy sediments along the seaward margin of the Gulf, and in the waters of higher energy found in the eastern part of the Gulf. Subordinate faunal associations are recognizable within each assemblage, but these reflect local variations in sediment type, salinity, and abundance of marine grasses.

Characteristic species of each of these major assemblages are: (1) Northern Gulf assemblage: *Anomalocardia brasilina*, *Corbula swiffliana*, *Brachidontes exustus*, *Alabina* sp., *Batillaria minima*, *Tegula fasciata*; (2) Southeastern Gulf and Gulf Margin assemblage: *Ercilia nitens*, *Divaricella quadrisulcata*, *Tellina candeana*, *Lucina pennsylvanica*, *Cerithium litteratum*, *Olivella nivea*.

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COMPARISON OF CONDITIONS AFFECTING EXPLORATION IN SOUTH AMERICA

South America is a land of contrasts. Within this variety of relief, climate, and cover are some countries blessed with oil resources and other countries denied this wealth. Exploration for oil and gas in three countries, namely, Brazil, Chile, and Uruguay is carried on by government oil monopolies and financed through State funds. In all other countries of South America exploration is either performed through the participation of private companies or through cooperation between State enterprise and private companies.

Venezuela is the most important oil-producing country of South America. Its daily rate of almost 3 million barrels of oil constitutes more than 80 per cent of

all South America's production. For several decades Venezuela served as a world model for a 50/50 sharing of profits between the government and private enterprise. Late in 1958 an increase in income-tax rates was instituted which resulted in a marked increase in the government's share of oil-company profits. One effect of this change, coupled with the government's announced policy of granting no more concessions, has been a reduction of exploration activities.

In Argentina a program called the "Battle for Petroleum" was invoked in July, 1958, by President Frondizi whereby private companies were invited to bid for contracts to help the government oil agency, Yacimientos Petroliferos Fiscales, develop known fields and to assist in the exploration for the finding of new reserves. This program in less than 4 years has brought Argentina self-sufficiency in oil production, greatly reduced the import requirements, and saved valuable foreign exchange.

The future of exploration in South America is intricately involved in the destiny of these peoples and could be affected seriously if communism or its Cuban variety, "Castroism," should make inroads into their political and economic life. Our government, through the "Alliance for Progress," a cooperative program, hopes to help the people of Latin America advance their economy and public welfare. Private enterprise also must challenge and defeat the charge of "imperialism" through accelerated public-relation programs and positive demonstrations of a working partnership or *sociedad* in the exploration for oil and gas.

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FACTOR ANALYSIS IN GEOLOGY

In geology, as in physical science in general, it is sometimes possible to approach complex problems by arranging observations or experiments so that selected variables are held constant. In many cases, however, such a simplification is either difficult to achieve, or unrewarding by reason of uncertainties and artificialities entailed in attempts to duplicate natural conditions in the laboratory. Advent of high-speed digital computers has made it possible to treat such problems by various multivariate statistical techniques. One of these techniques, factor analysis, can be applied to problems involving as many as 200 variables recorded quantitatively or qualitatively on any number of samples. By treating such a data array simultaneously, relationships that might otherwise be missed can be identified and objectively evaluated. One of the most useful features of this system is its ability to specify the number of independent casual influences at work in a given problem and to assess the relative importance of each variable at each locality. Applications to modern sediment data and ancient sedimentary rocks indicate that the scheme is a useful supplement to usual rational procedures of data analysis.

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SUBSURFACE PALYNOLOGY IN MADAGASCAR: PERMIAN, TRIASSIC, AND JURASSIC OF MORONDAVA BASIN

Palyнологical investigations are summarized for several hundred cores and cuttings samples from the Permian, Triassic, and Jurassic found in about 30 wells drilled by the Société des Pétroles de Madagascar in the Morondava Basin (southwest of Madagascar). The nature of the microflora, which includes about 300 forms of organic microfossils (numerous spores and

gymnospermic pollen grains, a few *Hystriospheres* and *Dinoflagellates*) is presented.

Evolutionary trends of the associations and lateral variations and environmental influences are discussed. Choice of stratigraphical characteristics and zonation of the series, which have an aggregate thickness of several thousand meters, are indicated. Correlation is made between wells at distances extending to as much as 600 kilometers and across various deposits of continental, brackish, and marine facies.

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#### SEDIMENTARY BASINS AND EXPLORATION FOR OIL AND GAS IN CALIFORNIA

California is one of the prolific oil and gas producing provinces of the United States. To date 12,350,000,000 barrels of oil and 17,122,000,000 MCF of gas have been produced. Estimated oil reserves are 3,550,000,000 barrels and estimated gas reserves 8,822,000,000 MCF.

The six important oil-producing sedimentary basins with estimated ultimate proved production are: (1) San Joaquin, 7,270,000,000 barrels; (2) Los Angeles, 6,070,000,000 barrels; (3) Ventura, 1,919,000,000 barrels; (4) Santa Maria, 684,000,000 barrels; (5) Cuyama, 375,000,000 barrels; (6) Salinas, 225,000,000 barrels. The most important dry gas producing basin, the Sacramento, has an estimated ultimate recovery of 4,800,000,000 MCF.

These basins are aligned in a general northwest-southeast trend paralleling the mountain systems of California. The San Joaquin basin with 10,000 square miles is the largest and the Los Angeles basin with 700 square miles is the smallest. The east-west-trending Ventura basin lays claim to being the narrowest and yet the deepest with approximately 60,000 feet of sediments in the synclinal trough. The sedimentary section in these basins ranges from Upper Cretaceous through Quaternary. Intensive folding, thrust faulting, and abrupt facies changes are common. Most of the oil fields are anticlinal and are characterized by high productivity per acre. Sandstones are the predominant reservoirs with Miocene (48%) and Pliocene (41.6%) accounting for most of California's oil.

California's first commercial oil field was discovered in 1898. The peak discovery years were the twenties when a plethora of new fields flooded the market and resulted in the first curtailment program. The advent of the seismograph in the thirties was followed by major discoveries. During the last 20 years, with the exception of 1948 and 1949, it has been a struggle to maintain reserves. Economic factors, including the increased cost of drilling to deeper objectives, higher royalties and land costs, expanding suburban development and the flood of foreign imports have become deterrents to many operators.

Despite this somewhat darkening picture there remain substantial parts of California's sedimentary basins that have not been adequately prospected and which should contain profitable oil and (or) gas accumulations. Provided with the opportunity, imaginative and aggressive geologists can keep California in the "prolific producing" category.

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#### APPLIED PALEOZOIC PALYNOLOGY

Delineation of specific segments of the Paleozoic geological column by palynological methods is based on the concept that plant composition throughout geological time underwent changes that are recorded in the

recoverable spores and pollen grains. These changes are largely the result of plant evolution and paleoecology.

The application of Paleozoic palynology originated 32 years ago with attempts to correlate economically important coals. In subsequent years, palynological data have been used in correlation studies of other strata, both non-marine and marine.

Separate thresholds of guide fossils are required when plant microfossils from different environments are compared in attempting to establish correlation lines. The coal-swamp environment, at a given point in time, has a particular set of fossils not necessarily duplicated in other non-marine environments elsewhere.

In recent years, palynological data have become available from many localities throughout the world. From these data it is possible to evaluate selected taxa potentially useful for correlation studies.

Palynology has certain limitations inherent to the science and others common to biological methods of correlation. Although palynology can not be used in every correlation problem, it has been useful and practical for parts of the geological column, in some cases after other biological methods have failed to be definitive.

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#### COMPUTER ANALYSIS OF STRATIGRAPHIC MAPS

Stratigraphic maps, such as structure, isopach, and facies maps, are commonly prepared as contour-type maps from measurement data obtained in wells and outcrops. In recent years geologists have experimented with methods for extracting additional information from these maps by application of various mathematical and statistical procedures. Most of the methods are very time-consuming and do not justify their cost as routine procedures without high-speed computers. The advent of computers has made possible a change in the entire framework of map preparation, analysis, and interpretation by furnishing quicker ways of assembling, storing, and processing the basic data. In this respect the computer and associated equipment act as a super-speed desk calculator and filing system that frees the geologist from much busy-work and gives him more time to interpret and use his final maps.

Among problems that can be examined conveniently with the aid of computers are similarities or differences among maps; the use of maps as predicting devices; and the more general question of setting up criteria for the selection of mappable variables that will give the most information per dollar in terms of the objectives of the map study.

Map comparison and the use of maps as predicting devices can be achieved at reasonable cost by trend surface analysis, by which the "observed" map data can be separated into two main parts—the trend surface that represents the broad areal changes in the mapped variable, and the deviations from the trend that represent small-scale local or anomalous variations. Sometimes the trend surface is of major importance in a study, but in some applications the deviations may rise to major importance. Selection of particular aspects for stratigraphic mapping can be approached in several ways—by regression procedures that "sort out" the important mappable variables; by multiple correlation procedures; or by use of factor analysis that identifies certain groups of variables as being of first-rank importance in the context of a map study.

Emphasis in this paper is on some principles that underlie map analysis, illustrated by sequential trend analysis of map data. The influence of open and closed number systems—rock thicknesses in contrast to per-