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LATE PLEISTOCENE PLANKTONIC FORAMINIFERAL TRENDS OFF OREGON

Oscillations in radiolarian-planktonic foraminiferal ratios with increasing depth in several deep-sea sediment cores from the southern Cascadia basin and the adjoining Blanco fracture zone off Oregon are thought to be the result of climatic fluctuations. Greater production of planktonic foraminifers compared with radiolarians seems to have occurred during glacial advances of the Pleistocene, whereas radiolarians predominated during glacial retreats. At least four intervals are evident in the deep-sea sediment record of the last 50,000–70,000 years. Based on radiocarbon dates, these intervals correspond approximately with late Wisconsin glacial advances and retreats as defined for the Puget lowlands of Washington.

Five species generally make up 90 per cent or more of the planktonic foraminiferal assemblage. *Globigerina pachyderma* and *Globigerina bulloides* together compose more than half of the assemblage. In grain-size fractions of less than 177 microns, *Globigerina quinqueloba* and *Globigerinita uvula* predominate. A few specimens of *Globoquadrina hexagona*, *Globigerina digitata*, and *Globigerinoides ruber* have been observed.

The species composition of planktonic Formaminifera does not appear to reflect the change from glacial to post-glacial climates. Neither do the coiling habits of *Globigerina pachyderma*. This species is dominantly left-handed throughout the sections examined. Right-handed forms reach a maximum of 13 per cent and average 2.7.

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NIGER DELTA OIL PROVINCE: RECENT DEVELOPMENTS ONSHORE AND OFFSHORE

The Niger delta oil province includes about 40,000 square miles underlain by thick Tertiary deltaic deposits. These have been subdivided into three formations: at the surface, the continental, sandy Benin Formation; the intermediate and transitional Agbada Formation of alternating sandstone and shale; and, at the base, the marine, shaly Akata Formation. The principal oil discoveries have been made in the Agbada Formation.

The accumulations are controlled largely by growth faults and rollover anticlines which are located primarily by seismic surveys. Exploration drilling on these structures has been highly successful. By mid-1966, there were 136 discoveries of 261 wildcats drilled for Tertiary objectives.

Subsequent development drilling has proved equally encouraging. The most productive onshore field, Bomu, and the first commercial offshore field, Okan, are described. Both fields have active water drives, production per well averaging about 3,000 BOPD. Production in Nigeria has increased from 5,100 BOPD in 1958 to 350,000 BOPD during the first half of 1966. It is expected that the daily rate will exceed 500,000 barrels before the end of 1966.

Parallel with this production buildup, exploration activities should continue at a high level, not only in the Niger delta oil province, but also in the area of possible Cretaceous objectives bordering the delta.

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TRACE ELEMENTS AS POSSIBLE ENVIRONMENTAL INDICATORS IN CARBONATE ROCKS

Carbonate sediments are composed chiefly of biogenic fragments. The biogeochemistry of the shells or skeletons of organisms contributing to the sediments reflects some of the variables in the chemistry of the water in which they lived. An important factor determining the composition of the trace-element biogeochemistry of the shells appears to be the availability of certain trace elements in the waters in which the organisms lived. The trace-element composition of fresh water differs from that of sea water. Three elements particularly showing differences in concentration between fresh and marine water are barium, iron, and manganese. The average amount of barium in marine water is about 0.05 ppm.; in fresh water the barium content may exceed that of marine water, be less, or be approximately the same. The average iron content in marine water is about 0.008 ppm. in contrast to 1.0 ppm. for river water. The average manganese content of marine water is about 0.003 ppm. and of river water is near 0.03 ppm. Lagoonal waters contain more iron and manganese for uptake by organisms than do waters of an open-marine environment.

A study of marine, lagoonal, and fresh-water gastropods and pelecypods shows that the shells of non-marine and lagoonal mollusks contain a greater abundance of barium, iron, and manganese than do those of marine mollusks. The difference between marine and non-marine is independent of taxonomic rank or mineralogy of the shells. Modern molluscan shells as well as Recent carbonate sediments from Florida show, as a rule, a greater abundance of iron and manganese than do those from a marine environment. Scatter plots of one against the other of these three trace elements, despite some overlap, show groupings which correlate with environment.

Could trace elements become a prospective tool in environmental recognition? Perhaps they could under some special circumstances. The problem is that, during diagenesis, the mineralogy and chemistry of carbonate sediments, including the trace element assemblage, are drastically changed.

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RECOGNITION OF DEEP-WATER LIMESTONE SEQUENCES, AUSTRIAN ALPS

Jurassic fine-grained limestone and radiolarian chert in the northern Limestone Alps of Austria contain evidence of bathyal to abyssal depositional sites. Evidence for a deep-water origin of the Alpine Jurassic sequence has been noted by a succession of European geologists including Fuchs (1887), Steinmann (1925), and Trümpy (1960), and has strongly influenced the European view of geosynclinal sedimentation. The major lines of evidence for deep-water deposition of this Jurassic section are:

1. *Fauna and rock composition.*—The fauna consists predominantly of planktonic and nektonic forms such as ammonites, radiolaria, and calpionellids. Electron microscopy reveals that much of the fine-grained limestone consists of nannoplankton.

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2. *Very slow sediment accumulation rates.*—This is apparent in several ways: occurrence of manganese nodules and crusts on bedding planes; very thin but complete stratigraphic sections representing long time intervals; and cosmic spherule abundances in the rocks. Average sediment accumulation rates on the order of 0.1 to 2.0 cm./10^3 years are suggested by rough calculations; however, it is evident that the actual rates changed considerably within the time intervals considered.

3. *Solution effect.*—Solution of all or nearly all calcium carbonate minerals produced the radiolarian chert as an insoluble residue; this is believed to be analogous with certain areas of the present deep-sea floor below the depth of complete $CaCO_3$ dissolution. In other parts of the Jurassic section, aragonitic skeletal parts (ammonite shells) were dissolved; calcitic parts (ammonite aptychi) are well preserved. The latter situation is believed to be analogous with certain present deep-sea areas where dissolution of aragonitic pteropods occurs at shallower depths than calcite dissolution.

4. *Subsidence rates.*—This can be fairly well established for the Triassic Period in the Austrian Alps because the total thickness of the shallow-water Triassic deposits (reefs, evaporites, *etc.*) is indicative of total subsidence. If projected unchanged into the Jurassic Period, this rate establishes at least minimum depths during the Jurassic and indicates that subsidence rates greatly exceeded sedimentation rates. Other evidence suggests that the subsidence rate actually increased during Jurassic time, at least in the beginning.

Together these criteria suggest maximum water depths of 4,500–5,500 meters in the northern Limestone Alps during Jurassic time.

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Floral Succession in a Pennsylvanian Coal Swamp as Indicated by Palynomorphs

Distribution of palynomorphs in segment samples taken in six outcrop sections of the Iron Post coal (Desmoinesian) of eastern Oklahoma shows prominent successional aspects. The variety of palynomorphs is small in the underclay and basal third of the coal, but is great in the top of the seam at all sections collected.

Underclay of the Iron Post coal contains a mircoflora dominated by *Calamospora*. Subordinate associations include *Lycospora* and *Laevigatosporites*. The spores *Lycospora* and *Calamospora* are dominant in the overlying basal third of the coal seam, everywhere except in the sections near the pinch-out of the coal. *Granulatisporites* and *Triquitrites* are locally important subdominants within this level.

The middle third of the coal seam is marked by a decline in *Lycospora* and the dominance of *Laevigatosporites*. A section located near the southern pinch-out of the coal is dominated at the same stratigraphic level by the saccate forms *Wilsonites* and *Florinites*. The upper third of the coal seam is everywhere characterized by a dominance of *Triquitrites* and *Verrucosisporites*.

Roof shale yields microfloras similar to those of the lower coal intervals except that there is a general decrease in most spore groups. This decrease is associated with a relative increase in saccate spores.

Palynomorph distributions within the Iron Post coal suggest that most spore groups were derived from plants indigenous to the swamp. However, palynomorph variety plotted with respect to position in the seam indicates that succession within the Iron Post coal swamp is somewhat irregular. A major decrease in microfloral variety at the base of the upper third portion of the seam indicates that some important event harmful to floral succession had occurred at the time represented by this level. It is suggested that relatively major fluctuations in palynomorph variety may be useful in stratigraphic correlation.

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Quantitative Analysis of Prospect to Determine Whether It Is Drillable

Thirty-one models were constructed in an attempt to represent all conceivable types of structural, stratigraphic, and structural-stratigraphic traps. Combinations of 52 parameters constitute these traps and define their proximity to hydrocarbon accumulation.

A trap is defined with 100 per cent certainty where all parameters necessary for its constitution can be demonstrated. Where only a part of the total parameters can be demonstrated, the per cent chance that a trap is present is reduced in a linear manner according to equations and graphs prepared by the writer. The same relation applies in defining the chance that a hydrocarbon accumulation exists, provided a trap is present.

The Composite Chance Factor (CCF) is the product of the Percentage Chance for a Trap and Percentage Chance for Hydrocarbon Accumulation. It is mathematically related to economics by the following formula:

Number of wells that must be drilled for any particular Composite Chance Factor, to eliminate statistically all but 1 per cent chance for failure as a result of bad luck, and find profitable amounts of hydrocarbons	×	{Absolute minimum desired return on investment}	=	{Profit to Risk Investment}

A graph was prepared showing the interrelations of the parameters in the above formula.

The statistical number of wells that must be drilled to find at least one economically successful prospect for a particular CCF, based on the minimum desired return, was calculated using probability equations and tables.

A summary sheet was designed to record all the data pertinent to the analysis of a prospect. A formula on this sheet yields a numerical prospect grade. These grades can then be used to select objectively the required number of drillable prospects commensurate with the allocated drilling budget.

By using the proposed system, the user can reduce considerably the monetary speculation when prospecting for oil, and he can invest, fully expecting to realize at least the desired minimum return on his investment.

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Sedimentary Facies and Their Importance in Oil Finding

In today's search for oil, industry has become increasingly aware of its need for information that will permit more accurate prediction of porous and permeable facies. Such information is important in exploring for both structural and stratigraphic accumulations.

To obtain the data desired, research geologists have directed their efforts to modern ocean basins and contiguous land areas where both sedimentary facies and the environments that produced them can be studied