semblages in middle Miocene through Holocene sediments exposed along the Pacific Coast north of Lat. 28°N. Therefore, the sequence of tropical planktonic species commonly used to zone Tertiary sediments is difficult to utilize at the leading edge of the northern East Pacific. Nevertheless, variations in percentages and coiling directions of temperate and cool-water species, together with restricted occurrences of tropical species, allow paleo-oceanographic definition of that part of the stratigraphic record currently accepted as the Pliocene-Miocene boundary, specifically the interval from $13\text{–}10 \times 10^6$ yrs. ago.

Bathyal upper Miocene sediments exposed north of Lat. 30°N. are characterized by a subarctic to cool-temperate planktonic fauna marked by a zone of sinistral-coiling specimens of *Globigerina pachyderma*. A warm-temperate to subtropical fauna characterized by *Globigerina eggeri, G. conglomerata, Globorotalia inflata, G. menardi tumida, G. crassaformis, G. hirsuta, Globigerinoides ruber, G. triloba, G. conglobatus,* and *Sphaeroidinella dehiscens* occurs in sediments deposited at Lat. 34°N. (Repetto Formation of southern California) approximately $10\text{–}9 \times 10^6$ yrs. ago. This tropical to warm-temperate facies can be traced within a wedge of bathyal marine sediments extending north from Lat. 8°N. (Charco Azul Formation of Panama) to Lat. 47°N. (Quinault Formation of Washington). North from the equator the number of subtropical and tropical species characterizing the biofacies decreases; *Pulleniatina obliquiloculata* is absent within the biofacies north of Lat. 25°N.; *Sphaeroidinella dehiscens, Globigerina conglomerata, Globigerinoides triloba, G. conglobatus,* and *Globorotalia menardi tumida* are not present north of Lat. 35°N. At Lat. 47°N. the biofacies is marked only by dextral-coiling specimens of *Globigerina pachyderma* and rare occurrences of *Globorotalia crassaformis* and *G. hirsuta.*

The initial appearances of *Globorotalia crassaformis, G. inflata,* and *Sphaeroidinella dehiscens* are currently used to mark the Pliocene-Miocene boundary in tropical latitudes. Consequently, their first appearance possibly can be used as a correlative Pliocene-Miocene boundary in the temperate eastern Pacific. However, expansion of warm isotherms from the equatorial region during the early Pliocene can not be considered instantaneous. Indices of the tropical to warm-temperate biofacies appeared later at progressively higher latitudes. A choice must be made between utilization of a time-transgressive biologic datum or a radiometric datum for an epoch boundary. Given a framework of absolute dates, appearance and oscillation of planktonic foraminiferal faunas can be evaluated in terms of paleo-oceanographic parameters rather than emphasized as criteria for establishing highly controversial epoch boundaries.

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PORE GEOMETRY OF CARBONATE ROCKS

In most clastic rocks a relatively simple relation exists among producibility, porosity, and permeability, depending on the degree to which size and shape of framework particles influence these factors.

Carbonate rocks do not exhibit such a simple relation. In addition to porosity between framework particles, the particles themselves may be porous. Carbonate rocks are subject to leaching, replacement, and recrystallization to a vastly greater degree than are clastic rocks. During the course of diagenesis of carbonate rocks, type and degree of porosity and permeability may be so altered that they no longer offer a satisfactory measure of the producibility of the rock. Two carbonate rocks may have identical porosities and permeabilities, with one forming a good reservoir rock whereas the other is incapable of storing or producing oil or gas. A study of the pore geometry of a carbonate rock commonly is necessary to determine whether it is capable of producing hydrocarbons.

By relating previously devised systems of classification of carbonate-rock particles, grain-size, porosity, and texture to mercury capillary-pressure measurements, a petrophysical classification has been devised which classifies carbonate rocks by producibility. Families of capillary-pressure curves are related to families of carbonate-rock types. Once such a classification has been made for a carbonate rock in a given area, it is possible to predict the shape and amplitude of its capillary-pressure curve from a visual examination of the rock.

By relating rock characteristics to depositional environments, maps may be made that predict what the producibility of rocks in an area may be. Such maps can help reduce the number of dry holes drilled in areas where anticipated closure is less than that dictated by the pore geometry required for the rocks to produce hydrocarbons.

The pore geometry of dolomitized rocks differs greatly from that of limestone. Work done in the past has led to the conclusion that dolomitization creates and then destroys porosity and permeability. In the field, rocks commonly are found which appear to invalidate this conclusion. Pore-geometry studies indicate that the time during diagenesis at which dolomitization occurs and the original petrographic characteristics are the critical factors that determine whether dolomites will develop into reservoir rocks capable of hydrocarbon production.

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SIGNIFICANCE OF DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN EQUATORIAL ATLANTIC UNDERCURRENT

The relation between distribution of living planktonic Foraminifera species and selected elements of the equatorial Atlantic current system has been investigated through the use of depth-controlled, opening-closing net, quasi-synoptic plankton samples, as well as hydro-casts, S-T-D lowerings, and direct current measurements. Physico-chemical data collected with the biologic samples were used to define major biotopes within the current system. They showed salinity variation to be one of the most important factors affecting foraminiferal distribution and temperature variation to be of lesser importance; variations in salinity as small as 0.5 ppt. appear to exert strong influence on population variation within the planktonic Foraminifera. Because of such sensitivity, planktonic Foraminifera may be very useful as water-mass indicators in studies of oceanic-current and circulation patterns.

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SOME ASPECTS OF SEDIMENTATION AND PALEOECOLOGY OF MIDDLE DEVONIAN WINNIPEGOSIS FORMATION OF SASKATCHEWAN, CANADA

The Middle Devonian Winnipegosis Formation of Saskatchewan is divisible into upper and lower mem-

bers on the basis of a regionally developed, argillaceous interval which forms the uppermost part of the lower member.

The lower member consists of regionally dolomitized marine carbonate rock of relatively consistent thickness and lithology, and has a maximum observed thickness of 54 feet. The upper member is a varied marine carbonate sequence, with three major facies. In the southwest, a wedge of lithologically relatively consistent carbonate rocks has a maximum thickness of about 130 feet along a northwestward-trending axis extending through the Weyburn district in the southeast and the Elbow district in the northwest. This wedge thins somewhat irregularly, though gradually, to a depositional edge in the extreme southwestern part of the area. North and east of the basin, finely laminated carbonate rocks are regionally developed, together with numerous interspersed biofragmental-pelletoidal carbonate banks with biohermal zones. The former have a maximum observed thickness of about 70 feet; the latter may be as thick as 345 feet.

Data indicate that the lower member was deposited as a whole in a broad epicontinental sea. The relatively shallow, open-marine conditions culminated at two different times in basin-wide, reducing, lagoonal conditions, as evidenced by the upper and medial bituminous, argillaceous intervals containing impoverished faunas.

The upper member appears to have been deposited in a shallow sea which deepened toward the northeast. Using a regionally developed, vertically restricted *Amphipora* zone as a datum, three pre-*Amphipora* tectonic provinces are discernible. In the southwest, the Elbow-Weyburn basin subsided relatively rapidly as thick shallow-water carbonate sediments accumulated. In the north and east, the comparatively stable Saskatoon shelf was the site of deposition of thin, laminated carbonate sediments and basal bank-carbonate sediments. Flanking the shelf on the north, the Meadow Lake-Sayese basin complex was a depositional site for similar sediments, except that bank sedimentation was further advanced, in response to more rapid, or more prolonged, subsidence.

In post-*Amphipora* time, subsidence continued in the north and was accelerated in the shelf area which received thick bank accumulations, whereas, in the southwestern basin, carbonate deposition was almost complete.

The consistently developed carbonate wedge occupying the Elbow-Weyburn basin would seem to offer the better prospects for large hydrocarbon accumulations. The abundance of localized carbonate build-ups north and east of this basin presents opportunities for multiple, if comparatively small-scale, accumulations of hydrocarbons.

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EXPLORATION PROGRESS IN NORTH SEA

The general structure and the type of prospects which have resulted from aerial magnetometer surveys and seismic work, including the location of the major evaporite basins of Permo-Triassic age, are now known. The expanded sedimentary column in the north and east, which probably includes a thick Tertiary sequence, and the occurrence of major unconformities may now be evaluated.

The general stratigraphic sequence is illustrated by reference to some of the first holes drilled in the western (British) sector of the North Sea.

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SUPRATIDAL DIAGENESIS OF CARBONATE AND NON-CARBONATE SEDIMENTS IN ARID REGIONS

A supratidal sediment surface is the common end-product of shallow-marine and intertidal sedimentation. Such surfaces normally increase in area as sedimentation proceeds, and may have a variety of geometric shapes. Furthermore, they may be either attached to a coastline or be unattached. The sediments deposited may range from almost entirely carbonate to non-carbonate and may be fine- or coarse-grained. The original mineralogy of the sediments represents a relatively stable assemblage for the temperature and solution conditions of the marine environment. When in the supratidal position, under a different physical and chemical regime, diagenetic changes may occur.

Many of the climatic variables which affect the marine environment affect the supratidal environment in a more severe manner. Solution compositions normally show small fluctuations in the marine environment, but pore solutions may undergo substantial dilution or concentration in supratidal areas. Solution changes depend largely on the balance between rainfall and rates of evaporation and evapotranspiration. The addition of land-derived waters may occur in inner parts of attached supratidal areas.

In areas of diluted pore waters, the probable diagenetic trend in carbonate sediments will be toward formation of low-magnesium calcite. Where pore-water concentration occurs, dolomitization of the original carbonate sediments takes place. The dolomitization of coarse-grained skeletal carbonate sediments is slower than that of finer-grained materials. Dolomitization normally is preceded by a fairly large calcium loss from the pore solution as a result of interstitial precipitation of aragonite or gypsum, the latter occurring under more extreme conditions of evaporation. Gypsum may be formed seasonally, being leached during the wet season, and is likely to be preserved only under conditions of net evaporation. Under high net-evaporation conditions, anhydrite, typically of the nodular type, is a possible development. Under an extreme net-evaporation regime, halite is formed, but higher salts are unlikely. In non-carbonate environments the evaporite mineral developments will be similar. In carbonate sequences larger amounts of calcium sulfate minerals are commonly present as a direct result of dolomitization.

The chemical evolution of the pore fluids in carbonate and non-carbonate sediments under net-evaporation conditions will vary greatly. In the carbonate sequence, a large magnesium loss results from dolomitization; sulfate can be removed almost completely because of the excessive amounts of calcium available, and the final solution is essentially a calcium chloride-type brine. In non-carbonate sediments there is little or no magnesium loss, but almost complete loss of calcium, largely as carbonate and sulfate minerals; less than 40 per cent of the available sulfate is removed, and the final solution is essentially a magnesium sulfate-type brine. An important variable which may have a critical effect on brine evolution is the bacterial reduction of sulfate.

Early diagenetic changes which may occur in supratidal environments are controlled largely by original sediment characteristics and climatic variables. The variation in possible diagenetic developments is large. Overprinting of different diagenetic facies commonly