

mopolitan aspect and more intense provincialism. The biogeographic changes appear related to changing ocean basin configuration and initiation of the breakup of the circum-equatorial Tethys.

In the present preliminary phase of investigation firm conclusions cannot be drawn, but the convergence of such diverse approaches encourages the interpretation that ridge activity caused mid-Cretaceous biogeographic changes.

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APPLICATION OF OIL CORRELATION AND SOURCE-ROCK DATA TO EXPLORATION IN WILLISTON BASIN

Most Williston basin oils belong to one of two basic types: (1) a lower Paleozoic type believed to have originated in Winnipeg shales and found predominantly in Ordovician and Silurian reservoirs, and (2) a Mississippian type expelled primarily from Bakken shales and produced mostly from Madison reservoirs. The two types are isolated vertically by evaporites but commonly are mixed beyond the evaporite limits in basin margin areas.

Both oil types can be related to their source facies. Lithofacies maps of these source sequences, when combined with diagenesis determinations, provide source-area definition. The time of expulsion and volume of expelled oil from each source can be calculated. Paleostucture maps and carrier-bed isopachs indicate the direction and extent of secondary migration, both horizontally and vertically from the source area. Ultimately, the subsurface distribution of each oil type is predicted, to define high-grade areas in which to concentrate exploration activity.

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DISCRIMINATION FUNCTION ANALYSIS AND BAYESIAN CLASSIFICATION APPROACH TO MUDDY SANDSTONE EXPLORATION, WYOMING

Stratigraphically trapped petroleum deposits occurring in the Muddy Formation of Campbell County, Wyoming, were studied by using discriminant function analysis followed by Bayesian classification analysis. The data used in this study were obtained from over 600 productive and nonproductive wells in a 720-sq mi area.

A total of 15 quantitative measures (variables) of lithology, porosity, and salinity were computed from the S.P., gamma ray, and density logs from each well. Discriminant and Bayesian classification analyses were used to compute discriminant and probability maps. Discriminant-scores maps were made by two methods: (1) using the total data set of both productive and nonproductive wells, and (2) using only the nonproductive wells. The second type of map more closely simulates the exploration situation.

A map showing probability of oil occurrence was constructed by first partitioning the study area into 64 cells of 9 sq mi each, and then establishing a control area and a test area. In the control area the cells were divided into productive and nonproductive subsets; a discriminant function then was computed. The discriminant function derived from the control area was used as the input for a Bayesian classification procedure to compute probabilities of petroleum occurrence in the test area. The predictions made by the statistical analyses are compared to the actual production in the test area.

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NORTH SEA BASINAL AREA, EUROPE—IMPORTANT OIL AND GAS PROVINCE

The North Sea covers the offshore part of a major sedimentary basin which extends from Norway, Scotland, and Denmark across northern Germany and the Netherlands into eastern England.

Information gained from exploration efforts over the last 10 years shows that the North Sea covers several smaller sedimentary and structural basins of different geologic ages, but for descriptive purposes these can be divided into southern and northern areas. The rocks range in age from Paleozoic to Tertiary and consist of sandstone, shale, carbonate rock, and evaporite. The most important reservoir rocks are the Lower Permian sandstones of the Rotliegendes Formation, the Upper Permian dolomites of the Zechstein Formation, the Triassic sandstone of the Bunter Formation, the Maestrichtian-Danian chalk, and Paleocene and Eocene sandstones. Significant shows of hydrocarbons have been found in 9 formations. The main source rocks are Carboniferous coal measures, Mesozoic shale and carbonates, and Tertiary shale and carbonates. The significant traps are folds and fault blocks associated with salt movement and basement faulting.

Exploration activity received its initial impetus in 1959 from the discovery of a major gas field, Schlochteren, onshore in northern Netherlands. In the early 1960s the passing of legislation favorable for the acquisition of exploration acreage offshore added further stimulus to the exploration pace. The majority of this activity was concentrated initially in the southern area, and resulted in the discovery of the first offshore commercial gas field at West Sole in 1965. This discovery was followed rapidly by other gas discoveries in the United Kingdom and the Netherlands culminating in the Leman Bank field, a major gas field by world standards. Interest and activity lagged, however, in the northern area despite reported small oil and gas discoveries in Denmark, and the discovery in 1968 of the Cod gas-condensate field in Norway. In late 1969, oil production was established at the Ekofisk field in Norway. With this discovery and subsequent confirmation as a major field, exploratory interest has shifted to the north.

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BIOMERIZATION: ECOLOGIC THEORY OF PROVINCIAL DIFFERENTIATION WITH EXAMPLES FROM MODERN AND FOSSIL BIOTAS

Modern biotic provinces are centers of endemism surrounded by zones of coincidence of broad-ranged species. Provinces form coherent units of association above the community level. Superimposed ranges are used to construct a surface contoured for provincial diversity. Provincial boundaries overlap. Frequencies of provincial components along boundaries vary from season to season. Relict provinces survive in these zones.

Biomeres, as chronologic provincial units, are transgressive and regressive, and exhibit complex intertonguing in boundary regions. Faunal and floral zonal sequences are replicable within the biomere, but are complicated by inversion and recurrence along boundaries. These anomalies are useful in locating boundary zones.

Provinciality is due to homeostasis of the ecosystem and is proportional to diversity. Terrestrial biota is more provincial than marine biota.

A biomere appears as a pioneer biota under new conditions. It differentiates about centers of habitat di-

versity, matures through increase in interdependence, and wanes to extinction under changing environment. Different styles of diversity are used to distinguish degree of provincial maturity.

In Pennsylvanian and Lower Permian rocks, several terrestrial biomes, based on insect-faunal and on floral ranges, are present across North America and Europe. One boundary is correlated with paleolatitude, another boundary is meridional. These biotically leaky boundaries are not associated with physiographic barriers.

Zonation of terrestrial biomes shows promise for fine-correlation of coal areas remote from standard and type stratigraphic sections.

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TINTINNIDS IN SHELF SEDIMENTS FROM ALASKA, OREGON, AND CALIFORNIA

The distribution of neritic, agglutinated tintinnids on the sea floor has been examined using approximately 530 samples from the Arctic Ocean between 115°E and 165°W long., the northern Bering Sea, and the eastern North Pacific between 37°N and 46°N lat. *Tintinopsis fimbriata* dominates the observed fauna in the Arctic Ocean and Bering Sea, whereas *Stenosemella ventricosa* is dominant in the sublittoral region off northern California and Oregon. Species <63 μ in diameter and without firmly agglutinated loricas are not likely to have been recovered with sample processing techniques used in this study.

Tintinopsis fimbriata occurs in low frequencies in nearly all samples from the Arctic Ocean and Bering Sea. It is most common, however, in samples from off the mouths of the largest rivers, particularly the Lena River. It may be a diagnostic brackish-water species. An unidentified *Tintinopsis* appears to have a similar relation to the Columbia River and the Yaquina River of the Oregon-Washington area. Other distributional patterns appear to be the result of dispersal by either surface currents or bottom currents. This pattern is particularly noticeable in the southeastern Chukchi Sea and off the coast of Oregon and Washington.

A sharp decrease in the number of tintinnid loricas with depth in a core from the southeastern Chukchi Sea suggests that they are less likely to be preserved in the fossil record than are the remains of other common marine microorganisms.

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MARINE GEOLOGY OF CARIBBEAN SEA COMPARED WITH MEDITERRANEAN SEA

The Caribbean basins, surrounded by lands and islands marked by a history of tectonic and volcanic activity, have remained remarkably stable throughout the Cenozoic. Sedimentation has been characterized by pelagic biogenic material and volcanic ash typical of a deep marine environment. Acoustic basement, reached at 5 sites by the Deep Sea Drilling Project, is composed of Late Cretaceous dolerites and basalts considerably younger than the surrounding lands.

The Mediterranean Sea may be divided into eastern and western basins. The eastern basin is dominated by the Hellenic arc, an island-arc structure, and the Mediterranean Ridge, a low ridge characterized by thick folded and faulted sediments. The western basin has more features in common with the Gulf of Mexico,

such as thick terrigenous sediments and salt diapirs. Drilling has revealed buried evaporites in association with shallow water sediment and fossil indicators that led the scientific team to the conclusion that the Mediterranean desiccated during the late Miocene.

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RADIOGRAPHIC AND SEDIMENTOLOGIC EXAMINATION OF HOLOCENE SALT MARSH, GEORGIA

Seven subenvironments of a coastal Georgia Holocene salt marsh vary conspicuously in grass types and topography. However, preliminary examination has revealed few basic differences in sedimentary structures and grain-size distribution of the sediments, from these various parts of the marsh. Samples from these subenvironments are classed as either clays or silty clays, and any primary sedimentary structures in these habitats have been reworked biogenically by burrowing organisms and/or disturbed by plant activity. Noticeable variations do occur in subenvironments in which silt and sand predominate over clay-size materials. Tidal creek banks show laminations, crossbedding, slump structures, and filled-in burrows. Levees bordering major drainage tributaries and barrens adjacent to the Pleistocene barrier island show no distinct structures but have a distinctive grain-size distribution in the silty sand to fine-grained sand range. Minerals present include quartz, feldspar, montmorillonite, kaolinite, chlorite, and illite at all sampled stations, with only slight variation in relative proportions.

The widespread uniformity of the normal marsh and the grain-size variation on and adjacent to tidal levees suggest that the topography and grass types delimiting subenvironments are controlled chiefly by the tidal and freshwater hydrography of the marsh.

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MAGNETIC SUSCEPTIBILITY STUDIES OF SHALES FROM NORTHERN ANTHRACITE FIELD OF PENNSYLVANIA

Magnetic susceptibility measurements, using the Gouy method, were carried out on 70 pulverized shale samples from the Wyoming-Lackawanna Valley in northeastern Pennsylvania. The samples also were chemically analyzed for the elements Fe, Mn, Cr, Ni, and Co. The study showed that variations in the susceptibility values follow very closely variations in the concentration of the trace elements Cr, Ni, and Co. The susceptibility values varied from 1.682186 $\times 10^{-6}$ to 29.938439 $\times 10^{-6}$ per gram using a magnetic field of 2.25 Kilogauss. These values correspond to concentrations of Cr = 11 to 420, Ni = 30 to 160, and Co = 2 to 7.5 ppm respectively. The magnetic susceptibility was found to be field-dependent particularly in samples with high trace-element concentrations. The susceptibility also was measured using the Faraday method and similar results were obtained.

By both methods the variations in Fe concentration did not correlate with the susceptibility values measured, although Mn showed a minor degree of correlation. The contribution to the susceptibility values by free pyrite present in some samples was very small.

Trace-element concentrations were found to be low in the north and to increase southward. Black shales showed higher concentrations than greenish or grayish shales. Samples containing appreciable amounts of coal gave very low or negative susceptibility. Pure