organic metamorphism; under ideal conditions, LOM is nearly linear with maximum burial depth. Comparison of reflectance data of vitrinite obtained from coal-bearing with other strata provides the most satisfactory method of describing the progression of organic metamorphism through a major segment of the coal-rank scale. Vitrinite reflectance studies in noncoal-bearing sequences are commonly complicated by the presence of higher reflectance vitrinite, which may result from the physical incorporation of vitrinite from older rocks or from oxidation caused by winnowing action or bioturbation. Interpretation of the reflectance data strongly hinges on a sequence of samples, a knowledge of the lithology, and knowledge of the depositional environment.

Geochemical maturity parameters, such as the *n*-paraffin ratio and the naphthene-ring index, indicate that the generation of petroleum is at a maximum for a source rock with a thermal history corresponding to a high-volatile *B* to medium-volatile bituminous coal rank (LOM 9 to 11.5), which falls within a vitrinite reflectance (*Ro*) of 0.72 to 1.20%. Studies in California and Alaska Tertiary basins show that the onset of geochemical maturity occurs at LOMs of 9-11. The depths to this zone range from 10,000 to 17,000 ft; the differences depend chiefly on variations in geothermal gradient.

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PROGRESS IN ARCTIC OCEAN SEDIMENT STUDIES

A few years ago the only information available on the deep Arctic Ocean sediments and history was based on a few short cores taken incidentally from floating ice islands by Americans and Russians. Summer work in the Beaufort, Chukchi, Laptev, Kara, and Barents Seas provided additional information but only for the marginal parts of the Arctic Ocean. Beginning in 1963, a systematic coring program was initiated from ice-island T-3 by Lachenbruch and Marshall of the U.S. Geological Survey. To date, 550 cores have been taken along the drift course of T-3, covering almost 1 million sq km of the central Arctic Ocean. Such coverage of an ocean from an iceberg is unique.

Because these cores represent the only record for such a large part of this important ocean, study has been designed to yield maximum data concerning mineralogy, petrology, paleontology, sedimentary structures, glacial erratics, paleomagnetism, and heat flow. Paleomagnetism has provided a stratigraphic framework for all of the studies. The objective of a paleoecologic interpretation of the Arctic Ocean has led to a variety of data, including information on the permanence of the ice pack and identification of the oldest sediment (Cretaceous) known in the central Arctic Ocean. Also, studies on paleomagnetism, sediments, silicoflagellates, and Foraminifera have combined in a unique manner to help establish a time reference for plate tectonics of the Arctic Ocean.

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GENERATION OF LIGHT HYDROCARBON GASES IN DEEP-SEA SEDIMENTS

Several hundred analyses have been made both on board the *Glomar Challenger* and in the laboratory on gas samples returned from the Deep-Sea Drilling Project (JOIDES). Methane was the dominant gas in all samples, commonly amounting to more than 99% of the total. Small quantities of ethane or propane were observed in areas of high heat flow, or over a possible petroleum reservoir.

Significant quantities (40 X 10^9 cu ft/cu km) of methane can be generated in the interstitial water of deep-ocean sediment where reducing conditions are initiated by rapid burial of organic matter. Comparison of carbon isotope (C^{13}/C^{12}) ratios of coexisting methane and dissolved carbonate indicates that the methane originates by bacterial CO_2 reduction. This mechanism does not involve the formation of ethane or higher hydrocarbons, or require the rupture of carbon-carbon bonds. Therefore, bacterial methane is chemically and (usually) isotopically distinct from hydrocarbon gases derived from thermocatalytic maturation of organic matter. Bacterial methane production generally begins when all sulfate is reduced, and continues with increasing depth of burial in the sediment, as long as symbiotic bacteria provide the required substrates, carbon dioxide, and hydrogen.

At some depth in the sediment column, depending on temperature and concentration, methane can exceed solubility in the interstitial water, migrate upward as a gas, and reach saturation at shallower depths. If the height of the overlying water column is greater than about 1.5 km, the gaseous methane may be converted to the solid clathrate hydrate within the uppermost (about 500 m thick) layer of sediment, where temperatures are below 20-25°C.

Stabilization of methane as a solid gas hydrate could be an important factor in the accumulation of natural gas deposits by (1) preventing loss of gaseous methane from the sediments; (2) allowing upward migration of gaseous methane at a pace controlled by the sedimentation rate; and (3) producing an enrichment of gaseous methane in the zone just below the lower limit of stability of the gas hydrate.

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SEDIMENTARY EVOLUTION OF NORTHERN APENNINES AS CONSEQUENCE OF EMBRYONIC TETHYAN SPREADING DURING LATE TRIASSIC-EARLY JURASSIC

Mesozoic Tethyan sedimentation may be explained tentatively by assuming a paleogeographic east-west-trending, narrow furrow dividing Europe from Africa. Along its northern margin are aligned the Carpathians, Northern Alps, Corsica-Sardinia, and Beticum; along the southern side are the Dinarides, Southern Alps, Apennines, Sicily, and the Atlas Mountains.

A slow transgression from Late Permian to early Lias is recognized from the Dolomites through Lombardy and Tuscany, and as far south as Sicily and the Atlas Mountains. The transgressive sequence overlying the continental facies is composed of clastic, shallow-marine deposits, evaporites, clayey or carbonate lagoon/tidal-flat deposits, shelf limestones, and cherty, pelagic limestones, or uninterrupted shelf sequences. The same facies sequence is recognized in the horizontal plane in two main directions along the main transgressive trend, and perpendicular to the isopach lines symmetrically disposed on both sides of the furrow. This situation is detected from Late Permian to Late Triassic, and is related to a slow downwarping. During early to middle Hettangian, a carbonate-shelf facies spread over the area, testifying to general marine conditons.

In late Hettangian time, a pelagic realm covered the region, and the facies distribution was controlled by faults parallel with or perpendicular to the main furrow. Thus, pelagic basins between small carbonate platforms were formed abruptly, attesting to the disintegration of the previous larger platform. However, tectonic control maintained the previous trend. In fact, the first pelagic facies are late Hettangian in Tuscany and Pliensbachian in Umbria. During Malm time, in the Ligurian region, continental crust broke up with extrusion of ophiolites which promoted jasper sedimentation, diminishing from Tuscany toward Umbria.

We conclude that the embryonic tectonic movements are detectable over great distances, through a slow shifting of facies in time and space. The rapid tectonic movements, instead,