Future exploration for geothermal resources must depend on effective use of geology and geophysics to discover geothermal fields with no surface expression. An effective program must begin with an understanding of the geologic and geophysical processes that interact to create regions of high potential. Further exploration in these high-potential regions must then confirm that specific geologic and geophysical factors associated with good geothermal fields are present or indicated.

The present stage of geothermal exploration is a return to basic geology and geophysics to guide future programs to discover geothermal fields with no surface expression.

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Depositional Environments in Upper Cambrian Jordan Sandstone in Wisconsin

The Upper Cambrian sandstone formations of the Upper Midwest are superficially uniform over broad areas. Individual formations are homogeneous in texture and mineralogy, and several of the sandstone units in the sequence are nearly identical in terms of these parameters. However, texture and composition have been shown to be environmentally ambiguous, whereas sedimentary structures and trace fossils provide definite criteria for interpreting depositional settings and for distinguishing between apparently similar quartzarenites. Major differences exist among the formations in mode of deposition (subtidal marine, eolian, tidal flat, and possibly fluvial environments have been recognized). One formation, the Jordan Sandstone, is an example of marine depth zonation. The Jordan contains two major facies, based primarily on bedding style: (1) high-angle, trough cross-stratification; and (2) low-angle cross-stratification (hummocky cross-stratification). The high-angle facies is interpreted as shallow subtidal (shoreface depth) in origin, produced by constantly moving dune bed forms in a current-dominated regime. The following criteria suggest this interpretation: festoon bedding, well-defined trough axis modes, and presence of *Skolithos* without strong bioturbation. The low-angle facies is interpreted as a shoreface to offshore deposit, representing episodic deposition by storm surges—on the basis of dominant hummocky cross-stratification, wide dispersion of trough axis orientations, presence of laterally extensive bedding planes and shale seams, dominance of *Planolites*-type burrows, and localization of intense bioturbation on tops of cross-sets. Generally, the high-angle facies overlies the low-angle facies, indicating shallowing upward (progradation). However, the facies are intertongued and even lenticular in places; this stratigraphic variability and the lack of beach or nonmarine deposits suggest that no shoreline was present.

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Bioturbation as Factor in Hydrocarbon Generation—Example from Mowry Shale

The Lower Cretaceous Mowry Shale of the Western Interior has long been recognized as an oil source rock. Previous workers have shown that the Mowry displays distinct lateral changes in organic carbon content. Such variations have been ascribed to a dilution effect—siliciclastic swamping of the planktonic component in areas of rapid deposition. Examination of Mowry Shale fabric shows that sediment bioturbation was negligible in eastern Wyoming (central part of Albian seaway), but that the muds in western Wyoming (margin of seaway) were thoroughly bioturbated. Bioturbation was produced by deposit-feeding infauna; thus organic carbon was actively consumed and depleted in bioturbated muds. True source rock lithologies in the Mowry, as determined geochemically by Nixon, are localized in areas where bioturbation of the sediment was minimal or absent.

Bioturbation in the Mowry appears to reflect the degree of oxygenation, and hence the water depth, in the Albian seaway. Systematic decrease in bioturbation indicates the direction of the paleoslope. In initial basin reconnaissance, it should be possible to anticipate where the largest concentrations of organic carbon accumulated—downslope in deeper-water, less oxygenated, less bioturbated sediments.

The undisturbed shale fabric characteristic of anaerobic environments may also influence the primary migration of oil. Fine-silt laminations, common in the Mowry Shale and other black shales, could serve as preferential avenues for migration; bioturbation obliterates these laminae and could inhibit migration. The distribution of oil fields in eastern Wyoming and southeastern Montana, within the laminated Mowry facies, supports this hypothesis.

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Microbial and Invertebrate Endolithic Assemblages from Late Cretaceous Belemnite Rostra

Thick-shelled oysters, belemnoids, and terebratuloids from the Upper Cretaceous Navesink and Mt. Laurel Formations of the New Jersey Coastal Plain show an abundant, diverse, and well-preserved assemblage of microbial and invertebrate borings. Macroscopic examination of invertebrate skeletons reveals large sponge, bivalve, gastropod, and annelid worm borings. Smaller borings in *Belemnitella americana* were resin-embedded and studied by SEM after acid dissolution of the rostrum skeleton.

On the basis of morphology, size, and distribution patterns of the resin casts, at least a dozen borehole types can be recognized. The largest borings revealed by SEM (small microborings > 1 mm) include acrothoracian barnacles, clionid sponges, and phoronids(?). Mesoborings (100 to 1,000 μ) include byrozoans, clionid sponges, and some large unidentified branched algal(?) tubes. Most microborings cover the range of 1 to 100 μ and include branched tubes and bags of algal and fungal origin. The microborings are the most common and uniformly distributed members of the assemblage.

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