trusion, whereas the Pannonian basin formed by either twofold stretching accompanied by subcrustal attenuation or by attenuation and erosion of the subcrustal lithosphere.

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Foreland Fold and Thrust Belts—Review

Most foreland fold and thrust belts are linear or arcuate belts of folds and thrust faults that form a marginal part of an orogenic belt between an undeformed craton and a more intensely deformed inner zone. They are characterized by an assemblage of structures that include low-angle thrust faults, folds, tear faults, and ramped and folded thrust faults that deform a wedge-shaped sedimentary sequence. In some belts it can be proved, and in others it is suspected, that these structures have been detached along one or more decollement zones, producing a shortened structural cover and an unshortened structural basement. Vergence of thrusts and folds is predominantly toward the craton, and in many belts it can be shown that there is a general decreasing age of structural development toward the craton. An external foredeep filled with molassic sediments is an integral part of these belts, and the history of thrust movements can often be read from these rocks. Foreland fold and thrust belts are known in orogenic belts of early Proterozoic to recent age.

There is, however, great variation in the general geometry, composition, and evolution of these belts, as well as numerous exceptions to the characteristics outlined above. The sedimentary wedge may consist of rocks that range from continental margin to deep sea fan environments. Variation in rock sequence, particularly the variation in thickness of ductile units such as evaporites, greatly controls the geometry of structures. Some foreland belts involve crystalline basement rocks both locally or extensively, and in one belt (High Atlas, Morocco) basement shortening occurs directly beneath the belt.

Kinematic and dynamic evolution of foreland belts are diverse, but they are an integral part of orogenes and are related to convergent boundary dynamic systems coupled with varying amounts of transform motions. Foreland belts can be shown to have evolved from the following convergent settings: both synthetic and antithetic to B- and A-type subduction, continent and arc collisions, and convergence within transform systems or combinations of such systems. The dynamics of foreland belts has been related to crustal convergence, lateral spreading of plutonic and metamorphic rocks in orogene cores, and a variety of gravity-induced instabilities. Palinspastic reconstructions of foreland belts suggest that while all of these mechanisms may contribute in different degrees to the formation of foreland belts, crustal convergence is the dominant process.

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Coal Resource Data Processing, Old and New Techniques

The use of data-processing techniques in coal resource evaluation is characterized by a gradual adaptation of computer techniques rather than by any revolutionary breakthrough. The main thrust of the data-processing effort is the use of computers to store and retrieve the large volumes of data associated with core-hole analyses. The data are of two types: (1) assay data from coal seams; and (2) codified lithologic descriptions of the stratigraphic sequence of interest. The automatic contouring of assay isopleths is now a routinely accepted procedure; the limitations of the contouring algorithms have been offset by the ability to generate quickly large quantities of maps. The trend now is toward increasingly sophisticated use of available options such as trend analysis and the different geostatistical algorithms for interpretation, estimation, and classification.

In regard to stratigraphic data, the main emphasis is a graphic display of information to aid the geologist in interpreting the stratigraphic sequence. Some attempts have been made to automate the interpretation. In the near future, we expect to see the routine use of interactive graphic devices to aid the geologist in his work. The type of tool envisaged is analogous to the stratigraphic interpretation of seismic records by petroleum explorationists.

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Unconformities—Key to Major Oil Accumulations, North Slope, Alaska

The entrapment of oil and gas at an unconformity at Prudhoe Bay, North America's largest oil field, is well known. It now appears that other large oil and gas accumulations such as those in the Kuparuk River sandstones west of Prudhoe Bay are trapped at an unconformity.

Prudhoe Bay field is on a large anticline on which the reservoir rocks have been truncated by an unconformity. The unconformity places organically rich Cretaceous shales in juxtaposition with Sadlerochit reservoir rocks. Cretaceous shales above the unconformity also provide the updip seal for the oil accumulation.

Oil in the Jurassic Kuparuk River sandstones is trapped on a large structural nose by truncation of the reservoir rocks. The Cretaceous shales above the unconformity provide the seal and possibly the source for the oil.

Uplift of the Barrow arch in Late Jurassic and Early Cretaceous time resulted in a regional unconformity. The truncation of older rocks by this unconformity, and the seal provided by the overlying shales are key factors to exploration of this arch which extends for more than 300 mi (483 km) along the Beaufort Sea coast. The delicate relations of source, reservoir, and trap, which are commonly controlled by one or more unconformities, are important to exploring this rich petroleum province.

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Future Exploration for Geothermal Resources

Exploration for geothermal resources has been concentrated in those areas where hot springs and hydrothermal alteration and deposition at the surface directly indicate geothermal potential.

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 $\mu$) include byrozoans, clionid sponges, and some large unidentified branched algal(?) tubes. Most microborings cover the range of 1 to 100 $\mu$ 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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