structures in cover rocks, and in part may be a cause of polyphase, break-back thrust development.

Basement faults are of three types: (1) normal faults of Precambrian and Cambrian age that are related to Precambrian continental rifting, (2) normal faults that were reactivated or initiated during Late Mississippian, and (3) Alleghanian thrust faults.

A basement fault system that moved during Cambrian and Mississippian-Pennsylvanian defines the northwest border of a basement low referred to as the Birmingham trough. The trough is a narrow, northeast-trending structure as much as 135 mi (215 km) long, up to 25 mi (40 km) wide, and has more than 7,000 ft (2,100 m) of displacement along the faulted northwest border. The southeast edge of the trough is bounded by Alleghanian basement thrust faults that exhibit as much as 2 mi (3 km) of shortening. The southwest-plunging trough loses relief to the southwest beneath the Gulf Coastal Plain onlap. On the northeast in northwestern Georgia, the trough is bordered by shallow basement.

The basement normal faults exerted significant control on the configuration of Alleghanian structures as well as on sedimentation during the Paleozoic. Basement faults control the magnitude of duplexes, thrust ramps, and associated ramp anticlines to varying degrees, depending upon local basement structural relief. Break-back thrusts in the Alabama Appalachians may be a result of buttressing of large-scale thrust sheets against the high-relief basement fault system at the northwest border of the Birmingham trough.

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Thermal History of Otway Basin, Australia—Case Study of Fission-Track Analysis in Petroleum Exploration

Annealing of fission tracks in minerals, like the generation and maturation of hydrocarbons, is a function of temperature and time, the temperature zone of fission track annealing in apatite (70-125°C, 158-257°F, for heating times of 10^6-10^8 years) coinciding closely with the oil-generation window. Patterns of fission-track age, track length, and length distribution can thus give an important record of the thermal evolution of a sedimentary basin.

The early Cretaceous Otway Formation in southeastern Australia is a 3-km (10,000-ft) thick sequence of volcanogenic sediments in the late Jurassic-Tertiary Otway basin. Fission-track ages on detrital apatite, sphene, and zircon in outcropping sandstones from this formation are concordant, indicating a contemporaneous volcanic source. This concordance also indicates that the outcrop samples have not been heated above about 70°C (158°F) since deposition.

Apparent apatite ages from deep wells in the subsurface section of the Otway Formation decrease with depth, reaching zero at subsurface temperatures of about 125°C (257°F). Wells in different parts of the basin show a variety of thermal histories. In some wells, the rocks are experiencing their maximum temperatures now, whereas others show evidence of higher temperatures in the past. The extreme example, at the eastern end of the basin, experienced maximum temperatures prior to a period of rapid uplift about 95 Ma. The apatite data show that hydrocarbon generation in this area occurred less than 30 m.y. after deposition and prior to this structuring event. The fission-track evidence also requires that the early Cretaceous geothermal gradient was substantially higher than at present.

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Methods for Evaluating Occurrence and Origin of Radionuclide Concentrations in Texas Lignites

The association of tuffaceous formations with radionuclide-bearing lignites is well established in Texas and elsewhere in the United States. Radionuclides in or near minable lignite horizons are important due to public and governmental concern over the human and environmental effect of low-level radioactivity.

The primary lignite-bearing formations of Texas include the Eocene Calvert Bluff, Yegua, and Manning Formations. A study of the formations adjacent to these lignite formations reveals that the Manning Formation is the likeliest to contain radionuclide zones in or near the lignite horizons. The overlying tuffaceous Catahoula and Whitsett Formations are the probable source of the radionuclides. The reduced carbonaceous zones of the Manning Formation provided a favorable environment for radionuclide precipitation.

The occurrence of radionuclide zones within oxidized carbonaceous horizons are modeled for the Manning Formation using geophysical logs, cross sections and areal occurrence maps. In-situ borehole assays confirmed a wide range of gamma radiation log responses, and quantification of them revealed the concentrations and specific types of radionuclides present.

Specific exploration techniques are used to model this phenomenon during lignite exploration activities. These techniques include calibrated gamma probes, in-situ borehole assays using advanced high-resolution gamma-ray spectroscopy logging tools, mapping of lignite weathering profiles using close-spaced drilling techniques, geologic interpretation using cross sections, and mapping of the radionuclide zones and sands. The resulting geologic model can be used for environmental impact studies and mine planning.

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Paleohydraulic Analysis of Hummocky Cross-Stratified Sands Indicates Equivalence with Wave-Formed Flat Bed: Pleistocene Lake Bonneville Deposits, Northern Utah

Hummocky cross-stratification (HCS) has been reported from over 100 ancient units, but has never been unequivocally recognized in recent sediments. Consequently, little is known about hydraulic conditions under which HCS forms.

In Pleistocene lacustrine deposits of Lake Bonneville, both depth of formation and parameters of inferred generative waves may be defined accurately. HCS was formed in fine to medium-grained sand in water depths of 1.2-2.2 m (3.9-7.2 ft). The site of formation was exposed to a maximum fetch of 15 km (9 mi). Depths were great over this fetch, permitting calculation of conditions under which this example formed, assuming: (1) HCS is purely wave-formed; (2) HCS formed under maximum storm conditions; (3) maximum storm-generated wind speeds over Lake Bonneville were similar to speeds generated by continental storms today. Inferred wind-speed range is 16 m/sec (52 ft/sec, moderate gale force) to 34 m/sec (112 ft/sec, threshold hurricane force).

Resulting calculations indicate that HCS formed under waves with periods (T) of 3.8-5.7 sec and maximum orbital speeds (U_m) of 0.9-2.5 to ~2-4 m/sec (3.0-8.2 to 6.6-13.1 ft/sec), respectively. This range falls within the wave-formed flat-bed field for fine to medium-grained sand. Independent corroboration is provided by the equivalence of wavelength of hummocky laminae in outcrop and calculated wave-orbital diameter (d_o). HCS has wavelengths of 3.1-4.2 m (10.1-13.8 ft) in this example; the 3-m and 4-m (10-ft and 13-ft) isograds of d_o run directly through the middle of the U_m-T field calculated above.

It is generally agreed that HCS probably is formed by oscillatory flow or oscillatory-dominant combined flow. Consequently, this analysis serves at least as a guide to conditions of formation of HCS and suggests that HCS and wave-formed flat bed are at least partly equivalent bed configurations.

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Abandoned Oil Fields of Texas Gulf Coast

One nonconventional oil target in Texas is the oil that remains in abandoned fields, defined as those fields that had no oil or gas production in 1977 and 1982. This target includes oil that has not been tapped by conventional field development because of reservoir heterogeneity and oil in reservoirs that have not been subjected to any secondary or tertiary recovery efforts. A total of 138 abandoned oil fields having individual cumulative production greater than 500,000 bbl are located in the Texas Gulf Coast (Railroad Commission of Texas Districts 2, 3, and 4). These 138 onshore fields produced 276 million barrels of oil before being abandoned. Nongiant fields in the Texas Gulf Coast average about 40% ultimate recovery, so these fields probably originally contained about 700 million bbl of oil in place. Therefore, about 424 million bbl of oil remain unrecovered.