plane parallel with bedding plane and the minimum reflectance axis is perpendicular to the bedding plane. If maximum reflectance is achieved prior to folding, the minimum reflectance is always perpendicular to the bedding regardless of the subsequent folding and the attitudes of the coal beds. Thus, the attitude of the minimum reflectance is a good parameter for evaluating whether maximum thermal maturation is achieved prior or after folding or other structural changes. Twenty-five samples were collected from coal-bearing strata from Monkman's Pass north to Sparwood, British Columbia, in the Canadian Rockies. Most of the coal beds sampled were highly disturbed by folding and faulting with dips ranging from a few degrees to overturned. Analysis results indicate distinctive groupings of the samples with the minimum reflectance deviating a few degrees to more than 30° from the normal of the bedding. This suggests a varied thermal history for the coal fields studied. The technique can be applied not only to the investigation of coal-bearing strata but also to the study of source rocks of petroleum as to whether thermal maturation occurs before or after a trap has been developed.

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Depositional History of Strawn Group (Pennsylvanian), Fort Worth Foreland Basin, Colorado River Valley, Central Texas

In the Colorado River Valley of central Texas about 1,200 ft (366 m) of Pennsylvanian (Desmoinesian) terrigenous clastic and carbonate facies were deposited in the Fort Worth basin. Paleocurrent and petrographic data indicate that the clastic provenance, to the west and northwest, was the rising Ouachita orogenic foldbelt.

Surface study suggests that the Strawn Group includes two main stratigraphic divisions: (1) a lower sequence representing basin and submarine fan sediments deposited as active tectonic subsidence substantially increased water depths in the Fort Worth basin; and, (2) an upper progradational sequence of fluvial-deltaic and carbonate plaform sediments deposited as passive isostatic subsidence or regional uplift to the east accompanied progressive shoaling of the sediment surface. The lower Strawn is characterized by sediment gravity flows suggestive of submarine fan deposition. It is subdivided into four facies (from proximal to distal): (1) massive channeled sandstone; (2) massive amalgamated sandstone; (3) turbidite; and (4) shale facies. The upper Strawn constitutes a delta-platform assemblage that includes: (1) delta facies including channel-mouth-bar sands, delta-front sands, delta-slope shales, and interdistributary fine clastics; and (2) carbonate platform facies that includes phylloid algal mounds and perideltaic bioclastic limestones.

The lower Strawn basinal shale and submarine fan sequence is gradational with the underlying basinal Smithwick Shale (Atokan) and records foreland basin subsidence synchronous with orogenesis in the Ouachita foldbelt. In contrast, the basal contact of the upper Strawn is variable. Generally, the upper Strawn is gradational with the lower Strawn but locally it rests disconformably on the Marble Falls Formation (Morrowan-Atokan). This stratigraphic relationship suggests that regional compressive forces from the Ouachitas were depositionally more important than previously supposed.

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Resource Appraisal and Environmental Problems Associated with Oil-Shale Deposits in Morocco

The best-known oil-shale deposit in Morocco occurs in the Middle Atlas region at an elevation of 5,000 ft (1,525 m), and contains total estimated reserves of 3.5 billion bbl. Approximately 1 billion bbl is amenable to open-pit mining techniques, having an overburden ratio of 0.8. Yields from this deposit reach maximum values of 45 gal/ton and average more than 20 gal/ton. Questionable infrastructure and extreme climatic conditions are important considerations, but do not represent major obstacles to development. Run-off of precipitation is very important in this region because the water is used for field irrigation. Major changes from the present hydrologic pattern could easily destroy the dominantly cedar vegetation and adversely affect the most important inland recreational area in the region.

Conditions are much more favorable for developing the 100 billion bbl deposit situated near Tarfaya. This oil shale averges 19 gal/ton and approximately 60% of the deposit has an overburden ratio of 0.8 and thus could be mined in an open pit. Suitable infrastructure conditions exist in this area, including a harbor, an airport, and asphalt roads. Proximity to the Atlantic Ocean, stable climate, and low precipitation conditions help resolve problems which exist for other oil-shale deposits worldwide. Under these conditions, this particular deposit could be exploited by above-ground retort technology.

Development of these two deposits would be in contrast to current United States operations which tend to favor in-situ processing because of environmental considerations.

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Utopia Algal-Bank Complex and Its Potential in Shallow Gas Exploration in South-Central Kansas

The Utopia Limestone (Upper Pennsylvanian) was deposited as a series of algal banks forming a narrow arcuate band approximately 25 mi (40 km) long on the shelf margin of Sedgwick basin in south-central Kansas. Utopia banks may attain a maximum thickness of 70 ft (21 m) and are encased in a dark gray shale, creating excellent reservoirs for hydrocarbon accumulation. Having porosities of up to 22%, the Utopia produces economic quantities of gas from depths of 2,000 to 2,500 ft (610 to 762 m).

The Utopia contains three distinct facies: (1) biomicrite, the "core" facies; (2) calcilutite, an *Osagia*-coated biosparite, the mound facies; and (3) an oolitic facies associated with the mound. The facies distribution was controlled by basin geometry and the variations in the subtidal and intertidal environments of the shelf. Sedimentation rate approximately equaled subsidence rate, maintaining the position of the bank tops within the shallow intertidal range. The banks are slightly asymmetrical and thicken basinward. The initial mound accumulation began with the deposition of a biomicritic mound "core," in a quiet-water environment. The major constituents of the calcilutite facies are green algae (*Osagia* and *Epimastopora*), along with a wide assortment of shallow-water biota. The oolite shoal facies formed contemporaneously beside the mound facies.

Subaerial exposure and subsequence leaching of the banks during successive marine transgressions created the intraparticle and oomoldic porosity. Locally, dolomitization of the algal fragments occurred.

Results of this study indicate that further exploration in this area and basinward should prove profitable.

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Hydrocarbon Migration and Accumulation as Influenced by Growth-Fault Building Mechanism

It is generally believed that growth faults act as primary conduit to the migration of hyrocarbon from the source to the reservoir rock. These faults and their associated structures often provide closures for hydrocarbon traps as exemplified in the Niger delta and Gulf Coast region. However, the relation of the growth-fault building mechanism to the migration and entrapment of hydrocarbon has not been fully understood.

A model of the influence of growth-fault building mechanism on the distribution and accumulation of hydrocarbon is presented. Fundamental to the model is a quantitative analysis of the criteria for failure. This failure is shown to occur in the so-called "plane of weakness" of the rock. When sliding accompanies the failure, the plane is commonly referred to as the slip plane. The criteria for failure in the presence of pore pressure and cracks have been studied and used to model the source rock. Hydrocarbon, which is "squeezed" out from the source rock as a result of the failure criteria, follows the plane of weakness in migrating to the reservoir region.

Therefore, an understanding of these directions and a knowledge of the geology of the reservoir region will be helpful in identifying new possible targets within a growth-fault zone and in reexamining areas within the zone that were thought to be barren.

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Petroleum Trap Associations: a Basis for Systematic Exploration

A strategy that considers "all possible" trap types in each volume of potentially petroliferous rocks becomes increasingly attractive as the remaining petroleum prospects become more elusive. This approach calls for cataloguing systematically the numerous lithologic configurations possessing trap-forming potential that may result from the basic processes of erosion, deposition, diagenesis, and deformation, as experienced by the particular strata.

These varied lithologic configurations are then considered in terms of their areal and time-stratigraphic associations. A wide variety of oil and gas entrapments is commonly related to one or more large-scale trap-forming features, such as a paleodrainage system or a salt dome. Traps associated with such features commonly develop during intervals of exceptionally rapid change, certain of which may be regarded as distinct trap-forming events. Some changes, like river avulsion, may be caused by internal processes, whereas others, like particular (series of) changes in sea level, originate outside the local systems and so may affect extensive regions. The objective is to predict "all" the potentially trap-forming lithologic configurations that might occur on each feature at the stratigraphic position of each event.

However, the accumulation-forming potential of these configurations and events must also be considered. This is revealed most directly by studies of existing production, which may then be used to guide exploration for related accumulations and to predict "new" types and locations of entrapment. Since the trap-forming features and events are frequently related to the other prerequisites for petroleum accumulation, consideration of accumulations provides some integration of all the prerequisites.

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Dolomitization of Brassfield Formation

The Brassfield Formation (Lower Silurian), which crops out in southwestern Ohio, through parts of Indiana and Kentucky, to western Tennessee, is a transgressive sequence consisting of interbedded shales, limestones, and dolostones. Shales dominate the eastern edge of the outcrop, whereas carbonate sediments are characteristic of the western and southern exposures. A detailed study of outcrops in southwestern Ohio shows that two separate dolomitizing processes have altered the rocks. Elsewhere, the Brassfield Formation appears to be dolomitized by a single process. In southwestern Ohio, initial dolomitization was restricted to the basal Belfast Member and probably occurred penecontemporaneously in a supratidal environment similar to a modern sabkha. Dolomite in the Belfast member occurs as small (10 to 40 μm), cloudy, anhedral crystals. Thinly laminated sediments with a few gypsym casts are characteristic of this unit.

Regional dolomitization was a later diagenetic event related to the formation of a freshwater and seawater mixing zone beneath a landmass created by upwarping of the Cincinnati arch and Nashville and Ozark domes. Intensity of dolomitization in the outcrop belt is controlled by the proximity of the original carbonate sediments to the source of dolomitizing fluids in the mixing zone. The Brassfield is undolomitized away from these structural highs. Dolomite from this portion of the formation is typically large ($>10\mu$m), limpid, euhedral rhombs replacing bioclasts and sparry calcite cement.

This "Dorag" type of dolomitization suggests the presence of landmasses in the areas of the Cincinnati arch and the Ozark and Nashville domes during the time of dolomitization of the Brassfield Formation.

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Zoning in Chesapeake Bay Dredge Piles

Chesapeake Bay economics requires channel dredging to maximize its potential in trade. Because of environmentalists' objections, aspects of dredge spoil disposal have received much attention and have held up dredging operations. The effects of heavy metals is an important factor in these environmental concerns.

The most recent and popular method of disposal involves the dumping of a sediment slurry, via conveyor, into a contained, nearshore or onshore dumpsite. This creates piles of sediment above water, incident to the bay. This method of dumping provides a model for some basic sedimentary and geochemical principles: sorting by grain size owing to differing settling rates, and resultant sorting of metals owing to affinities of these metals to a specific grain fraction. Vertical zoning of metals with depth is also possible, due to supergene enrichment. These three processes are investigated by this project with the intention of providing information to help in structuring the long term use and development of the bay.

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Facies-Controlled Diagenesis and Reservoir Character, Entrada Sandstone (Late Jurassic), Durango, Colorado

The Entrada was deposited as part of a Late Jurassic erg that covered much of the western United States. Depositional environments of the Entrada include: (1) small-scale, coarse-grained eolian dunes, (2) eolian sand sheet, (3) large-scale eolian dunes, and (4) water-laid sands. Quartz and potassium feldspar overgrowths are the most abundant cements, followed by dolomite, calcite, and kaolinite.

Current reservoir models for eolian depositional environments suggest that well-sorted dune sands should have higher permeability than the finer grained and poorly sorted sand sheets. However, in the Entrada, no difference in permeability was