with depth more so than identical normal faults active after deposition. The observed dip of a fault decreases as the velocity of the adjacent rock increases. For example, normal faults in rocks whose velocities increase with depth (e.g., most clastic sedimentary rocks) appear to flatten with depth more so than identical normal faults in rocks with more uniform velocities.

The appearance of secondary structures associated with normal faulting on our unmigrated seismic models depends on the position and size of the secondary structures. The increased thickness of low-velocity rock on the downthrown side of normal faults disrupts and bends the reflections on the upthrown side. Depth, fault displacement rock velocity distribution, and the angle between the fault surface and adjacent beds affect the severity of the distortion. This distortion obscures any secondary structures present on the upthrown side of faults (i.e., minor faults, anticlines produced by drag) and can erroneously be interpreted as secondary faulting and folding. Synclines produced by drag on the downthrown side of normal faults have small radii of curvature relative to their burial depths. This relationship makes these synclines difficult to identify on unmigrated seismic sections. Many forced folds in rifts are gentle shallow structures overlying normal faults. These folds are the most easily identifiable because they are unaffected by the distortion beneath faults and the synclines have large radii of curvature compared to their burial depths.

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Petroleum Geology of Bangladesh

The easternmost part of the Bengal foredeep or Surma basin is the most prospective area for finding additional gas because the degree of folding diminishes markedly in a westward direction. The foothills of the Tripura-Chittagong area and the Bengal basin (sometimes called Bengal foredeep or Surma basin) are locations of the gas fields in Bangladesh. These areas have sometimes been called the Outer Molasse basin. Folding occurred in four phases. Gas discoveries are in the Chittagong foothills. Similar structural features to those of the Chittagong foothills appear to be present in the extreme eastern part of the Bay of Bengal. Compressional folding did not affect the central and western part of the Bay of Bengal. However, by comparison with other areas of deltaic deposition, rollover structures associated with growth faults may be significant. The Oligocene to Holocene rock sequences were deposited in environments that range from abyssal marine prodelta to subaerial delta plain. In productive areas onshore and offshore, hydrocarbon traps include asymmetric, elongate, faulted anticlines. Strategic traps and sedimentary growth structures are found in the Bengal basin. Miocene sandstones constitute the gas reservoirs; Eocene, Paleocene, and Oligocene carbonaceous shales and Miocene shales are the source rocks. In the central and western part of the Bay of Bengal area, the major uncertainties are the development and thickness of sandstones and the possible size of structures.

Thirteen gas fields have been discovered: (1) Kutubdia, (2) Chhatak (8 mmcf/day), (3) Kailashtilla, (4) Habiganj (14 mmcf/day), (5) Bakhrabad, (6) Murdi, (7) Begumgoni, (8) Beanibazar, (9) Sylhet, (10) Rashidpur, (11) Titas, (12) Semutang, and (13) Jaldi. Chhatak, Habiganj, Sylhet, and Titas fields were on production during 1979.

The gas in these fields occurs in multi-sandstone reservoirs in anticlines that probably developed in late Miocene to Pliocene time. The gas reservoirs are the lower Miocene Bhuban Formation and lower to lower-middle Miocene Boka Bil Formation. Both formations are included in the Surma Group.

Total recoverable gas reserves are 7 to 7.8 tcf. Total estimated gas reserves in place are 9.33 to 10.39 tcf and possibly 10 to 20 tcf of gas resources yet to be discovered.

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Raton Basin, New Mexico—Exploration Frontier for Fracture Reservoirs in Cretaceous Shales

The Raton basin contains up to 3,000 ft (900 m) of marine shale and subordinate carbonate rocks of Cretaceous age, including (in ascending order) the Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Formation, and Pierre Shale. Clastic reservoir rocks are sparse in this part of the section and drilling for them in the Raton basin has led to disappointing results. However, brittle siltstone and carbonate-rich interbeds within the Cretaceous shale intervals are capable of providing fracture reservoirs under the right conditions.

Fracture reservoirs in other Rocky Mountain basins occur where there is maximum curvature of brittle interbeds within shale sequences at fairly shallow depths. Relatively low confining pressures found at shallow depth facilitate development of open fractures in the brittle interbeds. Anticlines, synclines, and monoclines can have favorable fracture systems. It should be kept in mind that if the axial surface of a fold is inclined, the hinge will migrate laterally with depth, and the hinge is generally the part of the fold having the maximum curvature. There are numerous folds in the Raton basin that could have excellent fracture systems. It is necessary to determine the areas of maximum curvature of the shale interval having brittle interbeds capable of fracturing.

Carbonate-rich beds of the Greenhorn Limestone and Niobrara Formation appear to be the most widespread and thickest intervals that might develop fracture reservoirs. Siltstone or orthoquartzitic interbeds in the Graneros, Carlile, and Pierre Shales may provide other zones with fracture systems. Hydrocarbon shows have been reported from the Graneros, Greenhorn, Niobrara, and Pierre Formations in the New Mexico parts of the Raton basin. Also, minor gas was produced from the Garcia field near Trinidad, Colorado. Fracturing appears to have enhanced the reservoir characteristics of the Wagon Mound Dakota gas field in the southern part of the basin.

Structure contour maps and lithofacies maps showing brittle interbeds in dominantly shaly sequences are the basic tools used in exploration for fracture reservoirs. These maps for the Raton basin indicate numerous exploration targets.

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Burial Cements in Lower Cretaceous Pearsall Formation and Lower Glen Rose Formation, South Texas

Lower Cretaceous platform carbonates and shales were buried to depths in excess of 2,000 ft (610 m) by the end of Eocene time, and were locally affected by late-stage cementation. Burial diagenetic cements include ferroan baroque dolomite, ferroan and nonferroan calcite, anhydrite, kaolinite, barytocelestite, galena, and sphalerite. The lack of these minerals in outcrop and their occurrence in fractures are evidence for a subsurface origin.

Carbonate cements are chemically and isotopically zoned; the $FeCO_3$ content in baroque dolomite cement varies by as much as 10 wt. % across a single crystal. Stratigraphic and regional distribution of iron in baroque dolomite indicates that the iron is derived from local sources. Good negative correlation between $\delta^{13}C$ values and iron contents of baroque dolomite suggests the simultaneous reduction of iron oxides and oxidation of organic material.

Some of the late subsurface carbonate cements with extremely depleted $\delta^{18}O$ values precipitated either from hot brine or from isotopically light water; both possibilities require the vertical movement of fluid along faults. Galena and sphalerite occur in small amounts in some cores; a single fluid inclusion homogenization temperature from sphalerite was 20° C (68°F) higher than the present formation temperature at that depth. Brines moving up faults after albitizing feldspars in more deeply buried formations could be the source of lead and zinc for these minerals. Strontium isotopic ratios for calcite cement in these rocks are similar to ratios for brines from the Stuart City reef trend that are believed to originate deep in the Gulf of Mexico basin.

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Jiuquan Basin—a Highly Explored (Mature) Area and Its Exploration Future

Jiuquan basin is one of the piedmont basins of the Qilian Mountain range in northwestern China. The basin has an area of about 2,700 km^2 (1,042 mi^2) and trends WNW-ESE. Cenozoic to Mesozoic deposits, with a total thickness of 4,500 m (14,764 ft) overlie lower Paleozoic rocks. Some Carboniferous, Permian, and Triassic outcrops are exposed near the margin of the basin.

Jurassic and Cretaceous formations, characterized mainly by marsh-lake sedimentary facies, are the source beds within this area. The thickness changes of these formations are related to the effect of crustal movement during deposition. On the uplifted parts of this area, Jurassic and Cretaceous deposits are very thin or absent; otherwise, they generally developed to a thickness of about 2,500 m (8,200 ft).

The Tertiary formations have a thickness of about 2,000 m (6,560 ft) and consist chiefly of river or lake to alluvial sediments deposited under arid climatic conditions. In the lower part of these formations, the river-delta sand bodies are the regional reservoir beds.

Between the Mesozoic and Cenozoic systems, a large depositional interruption exists. Upper Cretaceous to Paleocene deposits are all absent.

There are three structural belts in this area. From south to north, they are the southern anticline belt, the center depression belt, and the northern monocline belt.

The first field (Laojunmiao oil field) was discovered in 1939. Since the founding of the People's Republic about 33 years ago, six oil fields (comprising 14 oil pools) have been sequentially discovered within this basin.

The discovery history of the oil fields can be divided into three stages. During the first stage (1939-59), shallow reservoirs in the Tertiary were explored, based primarily on oil seepage and surface structure drilling. Fields discovered during this period were the Laojunmiao, Yarxia, Beiyanghe, and Shiyougou. From 1960 to 1974, the second exploration phase drilled to the deeper formations. As a result, a buried basement hill was discovered under the shallow Yarxia reservoir, and a new Cretaceous reservoir was found in the direction of the source area. After 1975, exploration entered a new stage with the search for pre-Tertiary nontectonic-type reservoirs. With improved seismic apparatus and data processing, the study of sedimentary facies using seismic stratigraphy is being applied to exploration efforts. The improved seismic and data processing, in combination with advances in drilling techniques, have led to the discovery of new nontectonic-type oil fields in places that had been previously drilled. The number of nontectonic reservoirs and their reserves are growing.

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Simulated Effect of Time of Satellite Overpass in Mapping Lineaments

Current lineament mapping from satellite imagery is possibly limited by the time of satellite overpass and the resultant sun azimuth and elevation angles. The use of plastic topographic raised-relief maps provides a method of lineament mapping using a wide selection of lighting positions. A comparison of lineaments mapped from the two media has been made, including general orientation, orientation relative to sun azimuth, and orientations in which length is maximized. It has been determined that the lineaments are sufficiently similar to permit the use of relief-map photos as a viable alternative to satellite imagery. These photos can then be used to study the effect of satellite overpass time in lineament mapping.

Simulated overpass times were represented in raised relief map photos. Overall, maximum lineament detection occurs at a relative sun azimuth range of 10 to 30°, and at sun elevation angles of 30 to 40°. In individual images, the maximization by relative azimuth is modified by the presence of a major lineament trend.

An effort to predict optimum overpass time indicates that no one specific overpass will provide adequate detection of an entire collection of lineaments in a region. However, if an operator is interested in lineaments trending at a specific orientation, an overpass time can be recommended that will provide the desired sun elevation and azimuth angles. Relief maps of the Appalachian Plateau of West Virginia were used in these analyses.

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Formation Model of a Giant Nonmarine Oil Field

Daqing oil field is one of the giant nonmarine oil fields. Taking Daqing oil field in the Songliao nonmarine sedimentary basin as an example, and on the basis of the study of organic geochemical and geologic conditions for the formation of the giant nonmarine oil field, the characteristics of formation of a giant oil field are discussed.

The formation of Daqing oil field, according to the analysis of depositional, structural, and geochemical conditions, can be characterized by the small area ratio of source rocks to reservoir rocks and the short distance of secondary migration of oil and gas. From three aspects of the reservoir characteristics of Daqing oil field—the geochemical conditions for generation, expulsion, migration, the accumulation of oil and gas; and the relationship between these conditions and structural growth—the process of formation of Daqing oil field is discussed by the writer.

It is considered that the kerogen in Daqing oil field is of "combined" sapropelic type. The source rocks in Daqing oil field have high efficiencies both in hydrocarbon generation and in hydrocarbon expulsion, thus forming good source rocks, indicating that even a relatively small hydrocarbon generation area can effect a giant oil field.

Because the sandy reservoir (parallel with the striplike oil source sags on both sides) is surrounded with source rocks, lateral secondary migration of oil and gas over a short distance is the main migration pattern of hydrocarbon during the formation of this giant nonmarine oil field. As a result, a typical model for a giant oil field in a large eutrophic-like basin is presented as follows.

1. A good reservoir composed of a huge delta complex, part of which directly extends as a carrier bed into source rocks; a large structural trap with a very thick sand body; and a large cap rock