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

overlying the trap are the factors necessary for the formation of a giant oil field. The five essential bodies—source bed, carrier bed, reservoir, trap, and cap rock—provided favorable geologic conditions that contributed to the formation of Daqing oil field.

2. Within the spatial assemblage, the favorable coordination among the geochemical conditions for the generation, expulsion, migration, and accumulation of oil and gas, and the stage of structure growth is obviously the key to the formation of a giant nonmarine oil field.

The vertical and lateral variations of properties of the crude oil in the main reservoir are discussed in detail. It has been determined that no differential accumulation ever occurred. Thus, it is possible for the huge space to receive great amounts of oil continuously and to form such a giant oilfield.

The formation processes of Daqing oil field provided an ideal model for the formation of a giant nonmarine oil field. The theoretical and practical investigation of this model and the analysis of the geologic and geochemical conditions for the formation of this kind of field, are of significance for understanding the formation regularities of giant nonmarine oil fields and are important for guiding exploration for oil and gas.

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Relationship of Vitrinite Reflectance to Heat-Flow History of North Sea

Vitrinite reflectance has been modeled for North Sea wells assuming that reflectance changes as a result of first-order chemical reactions. The Arrhenius equation is used to relate changes in the first-order rate constant to temperature, and is modified by including a term that allows the rate of a chemical reaction to exponentiate for every T_D increase in temperature above a "threshold" temperature of T_c. The approach treats time and temperature as knowns, deduced from thermal modeling and burial history, and tries to minimize the difference between calculated and measured reflectances by stepping through various values for the activation energy, E_a, scaling temperature, T_D, threshold temperature, T_c, and time varying heat flow, Q(t), using a nonlinear least-squares technique.

As a consequence of the modeling, we conclude that vitrinite reflectance can be modeled using an activation energy, threshold temperature, and scaling temperature of about 0.05 kcal/mole, 295°K, and 200°K, respectively. The model allows the prediction of depths and timing for oil generation in areas where the temperature history is known. Conversely, and significantly, an inverse approach can be taken whereby paleo-heat flow can be deduced from reflectance measurements. Applying this inverse approach in the North Sea has allowed us to determine its spatially varying heat flux over the last 100 m.y. or so, and also permits us to predict vitrinite reflectance with depth ahead of drilling operations.

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Geologic Framework, Evolutionary History, and Distribution of Hydrocarbon in Jizhong Depression

North China basin is a large Mesozoic to Cenozoic sedimentary basin in eastern China. A result of strong block-faulting activities, the inner part of the basin reveals the characteristics of multiple uplifts and depressions. Each depression is generally an independent exploration unit.

The practice of exploration in recent years has proved the following: taking each depression as an individual unit, the basic geologic framework and evolutionary history are quickly determined. This is very important in order to achieve the best effects in petroleum exploration.

Jizhong depression is located at the western part of the North China basin. This area is about 25,000 km² (9,650 mi²). Extensive seismic surveys and several hundred exploration wells have been completed during the past few years, resulting in the discovery of Renqiu and other oil fields. Taking the Jizhong depression as an example, the writer has considered the four following problems.

1. *Pre-Tertiary fault blocks and their distributional form.*—There are 11 primary fault blocks in the Jizhong depression. They are all the result of Himalayan movement, but they are obviously subjected to the effects of the structure lines of Yenshan stage.

2. *Some characteristics of block-faulting activities.*—At present, most geologists think that the eastern part of the Eurasian plate, where the Jizhong depression lies, is subject to the effect of subduction of the Pacific plate, which was first compressed and uplifted in Late Jurassic and Early Cretaceous times and then fractured and sagged in Late Cretaceous and early Tertiary. The writer, considers Tertiary block-faulting activities with characteristics of pulsation, through analysis of fault-block development of the Jizhong depression. This analysis follows the generation, development, and extinction of the faults in the depression. The result is that pre-Tertiary blocks are known to have experienced many processes of disruption and union. Because the active period of each fault is at a different time, the main periods of disruption and union in the different parts of the depression are also varied.

3. *Block-faulting in relation to the controlling of Tertiary sediments and structures.*—Block-faulting activities controlled the differences in source area and depositional center, giving rise to regional climatic differences and leaving clear and definitive time marks in the sedimentary bodies. In the Jizhong depression, each stage has its own special sedimentary formations. By analysis of the main faults and main structures, we may make a conclusion which is somewhat different from that previously accepted--that the block-faulting activities in this area may have formed either tensile structure or compressive and compressive-shear structures. Both of these structures contain petroleum.

4. *The types of oil and/or gas pools.*—Based on the analysis of the geoframework and evolution of the depression, there should be three main types of oil or gas pools: (a) Tertiary oil (gas) stored in Tertiary reservoirs; (b) Tertiary oil (gas) stored in older reservoirs (i.e., buried-hill oil or gas pools); and (c) sub-Sinian and early Paleozoic oil or gas stored in reservoirs of the same age.

In the future, the exploration of the buried-hill gas or oil pools will continue. This should expedite the exploration for the other two types of oil or gas pools. In addition, we should pay much attention to exploration for Tertiary stratigraphic-lithologic oil or gas pools.

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Hydrocarbon Potential of Newark Rift System, Eastern North America

Rift basins contain only 5% of the earth's sedimentary volume yet yield 10% of the world's hydrocarbon production. They consist of graben, half-graben, tilted fault blocks, and synclinal downwarps and are commonly preserved along continental margins. The Newark rift system represents the sediments preserved