course of the Ob River in the central part of the basin, production is largely oil from Lower Cretaceous arkosic sandstones on anticlines. Samotlor, the largest oil field in the USSR, is in this area. In the northern part of the basin, mainly gas is produced from Upper Cretaceous clastic rocks on anticlinal traps. Urengoy, the world's largest gas field, is located in this area.

CLAYTON, J. L., U.S. Geol. Survey, Denver, Colo., and P. J. SWETLAND, Gulf Science and Technology Co., Pittsburgh, Pa.

Petroleum Generation and Migration in Denver Basin

Crude oils and shales from the northern Denver basin were analyzed using organic geochemical techniques to determine relations between oil and source beds. Hydrocarbon analyses (gasoline-range, $C_{15}+$ saturates, and C_{15} to C_{20} isoprenoids) and stable sulfur isotope ratios show that, in general, Cretaceous oils are compositionally similar throughout the basin and are dissimilar to oil produced from the Permian Lyons Sandstone.

Shales were evaluated for source-rock potential based on organic richness, thermal maturity, and geochemical correlation with crude oils. These analyses showed that most of the Cretaceous oils have been derived from Carlile Shale, Greenhorn Limestone, Graneros Shale, and Mowry Shale. These units have a maximum collective thickness of about 600 ft (180 m) and can be grouped together on the basis of similar geochemistry. The source bed for the Lyons oil has not been identified.

Analyses of samples from the Carlile-Greenhorn-Graneros-Mowry interval from throughout the basin show that the effective source beds are limited to the basin-axis area. Although shale samples from eastern Colorado and southwestern Nebraska are organic-rich, they are generally thermally immature ($\bar{R}_o$ values 0.32 to 0.49%) and contain hydrocarbon distributions unlike the Cretaceous oils. Samples from the basin-axis area of Colorado have $\bar{R}_o$ values of 0.60 to 0.85% and petroleumlike distributions of hydrocarbons. Rocks in southeastern Wyoming generally have intermediate reflectance values (0.48 to 0.62%) but large quantities of extractable, heavy ($C_{15}+$) hydrocarbons ($\sim$700 to 1,600 ppm), and have good source potential. However, geochemical correlations revealed that the Wyoming samples are compositionally somewhat different from the oils and are not considered a major petroleum source in the Denver basin.

The occurrence of petroleum on the east flank of the basin and the limited geographic distribution of effective source beds indicate that extensive (perhaps 100 mi; 160 km) lateral migration has occurred. This suggests that an understanding of lateral-migration pathways is important for petroleum exploration in the Denver basin.

Cretaceous oils in the Terry and Hygiene reservoirs have probably undergone extensive vertical migration (2,500 ft or 762 m in the Central Front Range area).

CLIFFORD, HAROLD J., ROGER GRUND, and HASSAN MUSRATI, Arabian Gulf Exploration Co., Benghazi, Libya

Geology of a Stratigraphic Giant—Messla Oil Field, Libya

The Messla oil field is the most recent addition to the imposing list of 20 giant fields which have been discovered within the prolific Sirte basin of Libya. The field, discovered in 1971, is located in the southeastern part of the Sirte basin, approximately 40 km north of the supergiant Sarir oil field. Although in an early stage of development the field is estimated to contain approximately 3 billion bbl of original oil in place. The essential trapping mechanism is the updip truncation of the Lower Cretaceous Sarir Sandstone on a broad structural flexure.

The average oil column of approximately 100 ft (30 m) is productive from an average depth of 8,800 ft (2,640 m) over a 200-sq-km area.

The Messla field is a seismically defined stratigraphic accumulation located on the east-dipping flank of an ancestral basement high. The productive unit is the Lower Cretaceous fluvial Sarir Sandstone which wedges out westward on the Precambrian basement and is truncated by a marked unconformity at the base of the capping Upper Cretaceous marine shales, which are considered to be the source rocks.

The reservoirs consist of two Sarir sandstones separated by a continuous shale bed. Porosity values average 16% and the permeability 450 md. Production as of early 1978 is in excess of 100,000 bbl/day of 40° API gravity oil with a cumulative production of 45 million bbl.

CLIFTON, H. EDWARD, KEITH A. KVENVOLDEN, and JOHN B. RAPP, U.S. Geol. Survey, Menlo Park, Calif.

Spilled Oil and Infaunal Activity—Modification of Burrowing Behavior and Redistribution of Oil

A series of experiments in Willapa Bay, Washington, indicates the degree to which the presence of spilled oil modifies the burrowing behavior of infauna and the extent to which they redistribute oil into the sediment. Small amounts of North Slope crude oil introduced at low tide directly into burrow openings (mostly made by the crustacean *Callianassa*) caused a limited and temporary reduction in the number of burrow openings. The presence of low concentrations of oil to depths of 30 cm shows that the fauna mixed this oil into the sediment. In contrast, a layer of oil-saturated sand <1 cm thick buried about 5 cm below the sediment surface sharply reduced the number of burrow openings. After a year a few new burrows penetrated only the margins of the experimental plot (even though chemical studies showed that the oil was biodegraded in 6 months). Cores showed a dramatic reduction in bioturbation under the buried oily sand layer.

The experiments suggest that small amounts of oil temporarily stranded by tides have no long-range effect on burrowing behavior. The fauna, however, are capable of introducing measurable amounts of oil into the subsurface, where it is retained long after the stranded oil has moved elsewhere. A buried layer of oily sand greatly reduced infaunal activity, presumably because