Several shoreline trends are recognizable in the upper Muddy. They are progressively younger eastward and reflect the overall west to east transgression. These trends were controlled by the remnant Skull Creek topography and changing conditions of sediment supply.

Production from the Muddy Formation is principally stratigraphic, however, in places structure is important in localization of accumulations.

Lower Muddy production is restricted to updip channel boundaries and is localized by structural noses and updip channel reentrants. Upper Muddy production is controlled chiefly by porosity development and lateral facies changes.

Exploration for Muddy sandstone reservoirs is accomplished best by the use of an isopach of the total Muddy Formation. This map shows the configuration of the Skull Creek channels and therefore the distribution of the lower Muddy sandstone bodies. It is also helpful in predicting the orientation of the upper Muddy shoreline trends where they were related to remnant Skull Creek highs and by showing an increased Muddy thickness due to sand buildups in nonchannel areas. As the sand geometry is complex, abrupt stratigraphic changes are common. Electric log maps combined with zonal sandstone isopachs provide a means of visualizing these abrupt changes in sand geometry and also aid in the interpretation of depositional environments.

Exploration must be focused on the location of primary stratigraphic traps which have not been altered strongly by later structural movements. The ubiquitous presence of clay-filled porosity has eliminated large areas as nonproductive. It is believed that the clay fill largely is diagenetic and occurred subsequent to primary oil accumulation. The lower percentage of clay fill in the oil-filled primary traps suggests that the presence of the oil inhibited clay diagenesis.

In the last 3 years nearly 3,000 wells have been drilled in the study and search for Muddy oil. Each year new fields of significant size have been discovered. Abrupt stratigraphic changes require detailed stratigraphic work and, most important of all, courage to use the drill as an exploration tool.

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STATISTICAL METHODS OF PETROLEUM EXPLORATION IN PART OF DENVER BASIN, COLORADO

Pattern drilling, based on the hypothesis that any field with dimensions larger than the area between pattern wells certainly would be discovered, is tested in a sample area on the east flank of the Denver basin ("fairway" trend area) and compared with effectiveness of actual drilling. This test might be described as a combination of random and geologic-lead drilling. The pattern selected "discovers" $1.16 \times 10^8$ bbl of oil actually produced as of January 1, 1969. This quantity includes produced oil only and does not include estimates of reserves or total ultimate production. The pattern-drilling system yields 123,400 bbl/well of oil actually produced in the sample area (including dry holes). Actual drilling in the area has led to production of $1.53 \times 10^8$ bbl of oil or 66,500 bbl/well.

It is concluded that, in the sample area at least, pattern drilling could have been more economical than drilling according to geologic leads, promotional deals, and leasing arrangements, as has occurred in the area.

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REEVALUATION OF USE OF GLAUCONITE FOR RADIOMETRIC STRATIGRAPHIC DATING

(No abstract submitted)

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STRATIGRAPHY OF BLACK SHALE FACIES OF GREEN RIVER FORMATION (EOCENE), UINTA BASIN, UTAH

In the Uinta basin, Utah, the black-shale facies of the Green River Formation (Eocene) is divided into 5 rock units: 4 lacustrine units designated by the letters A-D, and a fluvial unit, the Wasatch tongue of the black-shale facies. The Wasatch tongue occupies the same stratigraphic position as unit C. Unit A contains the oldest lacustrine rocks of the black-shale facies, and is transgressive on the underlying fluvial Wasatch Formation (Paleocene-Eocene). All of the lacustrine units contain black fine-grained clastic rocks. Units B and D contain more carbonate rocks than do other units. Units B and D are also the most extensive of the lacustrine units. Units A, B, and C range in thickness from 100 to 300 ft, whereas the Wasatch tongue is 100–400 ft thick. Unit D has the greatest thickness range, from about 100 to 500 ft.

Rocks contained in the 4 lacustrine units vary in composition depending upon where they were deposited in relation to the center of the basin. The central lake environment of deposition produced mostly dark-gray to black, fine-grained clastic rocks and finely crystalline, brown to dark-brown carbonate rocks. The total clastic content of the lacustrine rocks and their model grain size increase toward the peripheries of the depositional basin and sandstone and siltstone become more abundant. Near the edges of the basin carbonate rocks are more saccharoidal in texture and contain larger amounts of silt- and sand-sized grains, oolite, pisolite, and shell fragments.

The depositional axis trends east-west and the depositional center of the lacustrine units is south of Duchesne, Utah, except for unit D where the center is farther south. Well control is sparse in the western part of the Uinta basin.

Lake Uinta was initiated by the coalescing of several small freshwater lakes on a broad alluvial plain. Downwarping led to the formation of the first moderately deep Green River Lake and the deposition of the black fine clastics and other rocks in unit A. The lake was thermally or chemically stratified, which is suggested by the preserved organic material and the presence of pyrite and salt crystals. As the lake transgressed over the fluvial sediments and became larger, the sediments of unit B were deposited. Unit B contains abundant carbonate rocks that were deposited over the entire lake, but particularly in the shallower part where the temperature was highest. A change in climate and/or increasing downwarping caused the lake to diminish its total area and unit C was deposited. During the deposition of unit C, the fluvial sediments of the Wasatch tongue of the black-shale facies were deposited along the southern part of the basin. The lake then transgressed back across the fluvial sediments and deposited unit D. The dominant rock types of unit D are very similar to those of unit B, indicating a similar environment of deposition.

Much of the oil and gas production in the Green

River Formation in the Uinta basin is from the black-shale facies or equivalent units.

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DEPOSITIONAL ENVIRONMENTS OF "J" SANDSTONE (LOWER CRETACEOUS), DENVER BASIN, COLORADO

(No abstract submitted)

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PALEOGEOMORPHOLOGY AND MINNELUSA ACCUMULATIONS, EAST FLANK, POWDER RIVER BASIN, WYOMING

Regional southwestward dip, the original paleotopography at the Minnelusa unconformity, and porosity and permeability changes within the subcropping Minnelusa sandstones together form various types of traps. Channel traps also exist, but are rare.

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GEOCHEMISTRY OF SOME LOWER EOCENE SANDSTONES IN ROCKY MOUNTAIN REGION

(No abstract submitted)

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FUTURE PETROLEUM POTENTIAL OF PRE-CRETACEOUS ROCKS OF EASTERN COLORADO

Through Permian time eastern Colorado was geologically in the northwestern part of the Anadarko basin. The Denver basin and the Las Animas arch are the major geologic features in this area, and both of these attained their present structural configuration during the Laramide uplift (Late Cretaceous through early Eocene). All during Pennsylvanian and Permian times the Las Animas arch, as reflected on the top of the pre-Pennsylvanian unconformable surface, was a south-trending nose in the northwestern part of the Anadarko basin.

Early Mississippian (Osagean) trapping mechanisms are primarily structural and are along the most obvious Early Pennsylvanian regional growth feature. Late Mississippian (Meramec) reservoirs also are structural traps but indicate definite stratigraphic influence. All series of the Pennsylvanian produce, and all of the production is from stratigraphic traps except 2 minor accumulations. Permian production is limited to the west flank of the Denver basin and primarily is trapped structurally.

Before 1965, the pre-Cretaceous well density in most of eastern Colorado was extremely sparse. Since 1965, 20 Mississippian and Pennsylvanian oil and gas fields have been found and over 200 wildcat wells have been drilled. The data from these wells have enabled many previous seismic, structural, and stratigraphic problems to be solved. As the result of the new interpretations of seismic and subsurface control, numerous prospects are being defined and no doubt will result in many pre-Cretaceous discoveries in the near future.

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STRATIGRAPHY AND PETROLEUM POTENTIAL OF DAKOTA GROUP (CRETACEOUS), WESTERN DENVER BASIN, COLORADO

The Dakota Group is the most important stratigraphic unit for petroleum production in central and eastern Colorado. In outcrop sections along the Front Range the Dakota is dominantly sandstone. However, minor shale and siltstone strata, and inorganic and organic sedimentary structures provide the basis for subdivision of the group into a lower Lytle Formation and an upper South Platte Formation. The South Platte Formation shows a uniform westward thinning from an average of about 250 ft along the eastern margin of the Front Range to 140 ft along the western margin in South Park.

Recognition of 3 genetic units within the Dakota Group permits correlation from the more shaly sections in the eastern area to the conglomeratic sandstone sections in South Park. Genetic unit A is a fluvial channel-floodplain unit corresponding to the Lytle Formation. Genetic unit B is the lower South Platte and represents a widespread submergence of the depositional basin with encroachment of marine and brackish water into central Colorado. The marine shales of the Skull Creek, Thermopolis, Kiowa, and Glencairn Formations were deposited in eastern Colorado during this submergence. Trace fossils are used as criteria to recognize the marine and brackish-water environments of genetic unit B in areas of the southern Front Range where the Dakota is dominantly sandstone of a fluvial-estuary-deltaic origin. Genetic unit C, including the upper South Platte, the Muddy sandstone, and the J sandstone of the subsurface, records a widespread regression of the shoreline by delta progradation and associated fluvial-channel deposition. An area of maximum channel development, accompanied by erosion of underlying marine shale, extends eastward across South Park into the Denver basin between Denver and Colorado Springs. Thirty feet of oil-saturated sandstone occurs in the upper part of genetic unit C at Turkey Creek, 10 mi southwest of Denver. The saturated sandstone is associated with an isopach thin suggesting deposition in a fluvial-estuary channel that may have as much as 100 ft of associated scour. All 3 genetic units in the southern Front Range area show strong influence of a north-, northeast-, east-flowing stream system that probably persisted throughout Dakota deposition.

The depositional framework for the Dakota Group, as inferred from the outcrop studies, suggests excellent petroleum potential from stratigraphic traps in the western Denver basin. The area with maximum potential lies between the old producing trends northeast of Denver and the outcrop section on the west at depths from 7,000 to 11,000 ft.

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STRATIGRAPHY AND HYDROCARBON POTENTIAL OF MINNELUSA GROUP, WESTERN NORTH DAKOTA

The Minnelusa Group is defined to include rock units in North Dakota lying above the truncated formations of the Big Snowy and Madison Groups (Mississippian), and below the Opeche Formation (Per-