Since Utah reached its peak production in 1959, the state has experienced a continued drop in oil production of about 3 million bbls. per year. This rate of decline was observed for 1965, and will be about the same for 1966.

The Uinta basin in Utah was the only geologic province that remained active as a result of several successful wildcat completions. These discoveries were significant because they expanded the Red Wash field into a belt of production that presently extends for 50 mi.

Although exploration for conventional oil fields has declined in recent years, a great upturn in drilling activity became apparent in the evaluation of numerous oil shale and bituminous sandstone deposits of Utah. Shell Oil Company presently is conducting a steam-injection pilot flood in the Sunnyside area and two additional thermal recovery projects are pending.

Drilling activity in Nevada has been concentrated in the Eagle Springs oil field. Presently there are 10 producing wells which have proved the existence of 800 productive acres. Elsewhere, Gulf Oil Corporation is drilling the fifth well in its current series to evaluate the stratigraphy and petroleum potential of various basin valleys in east-central Nevada. It has been reported that Gulf Oil Corporation will drill several additional wells.

3. ALEXANDER C. BOARDMAN, Petroleum geologist, Denver, Colorado

EXPLORATION DEVELOPMENTS IN COLORADO-NEBRASKA, 1965–1966

During the past 12 months, total exploration and development drilling in the Denver basin maintained the relatively low but consistent plateau established during the previous year. Approximately 80–90% of the tests were drilled by independent operators. Major oil companies have been active in development drilling, secondary-recovery projects, and exploration in pre-Cretaceous formations, particularly the Permian and Pennsylvanian.

Significant discoveries in the Cretaceous "D" and "J" sandstone bodies were found in the older so-called "fairway" part of the basin. Here both subsurface control and land are available. In the available-land category are Logan and Morgan Counties, Colorado, and Cheyenne County, Nebraska.

Seismic activity took place only in the following areas: Weld County, east of Black Hollow field, the extreme southern part of the basin in Crowley and Pueblo Counties, and in the evaluation of "D" and "J" sandstone prospects.

The Colorado and Nebraska legislatures passed involuntary unitization laws. This, together with improved secondary-recovery methods, should increase ultimate recovery and profit on a per-well basis.

Largely because of the increased number of tests and information available, a few companies are using computers in their exploration programs.

The exploration pattern established during the past few years should continue.

4. ROBERT T. YOUNG, Consultant, Durango, Colorado

EXPLORATION AND DEVELOPMENT OF FOUR CORNERS AREA, 1965–1966

Important oil and gas production has been established in Cretaceous, Permian, Pennsylvanian, Mississippian, and Devonian rocks. To date, Cretaceous terrigenous clastic and Pennsylvanian carbonate reservoirs have been the most productive of oil and gas.

Although exploratory and development drilling in the Four Corners area decreased from 1964, there was activity in all basins and significant developments in two previously dormant parts of the area. These are the Chaco slope, where significant new oil discoveries were made in the Cretaceous Gallup Sandstone, and in the Colorado part of the Blanding basin, where important thicknesses of Pennsylvanian algal carbonate were found. Both areas, especially the Chaco slope, will be the sites of considerable activity during 1966.

5. HERMAN ASHMORE, Amerada Petroleum Corporation, Williston, North Dakota

EXPLORATION AND DEVELOPMENT, MONTANA AND DAKOTAS, 1965–1966

Total exploratory drilling in the three-state area has increased from the preceding year. This is primarily the result of successful operations in the Sweetgrass arch area of Montana. This paper relates exploration developments in the three-state area. Examples are given of exploratory drilling that utilized some of the concepts presented in papers given at previous annual meetings of the Rocky Mountain Section. Areas of greatest drilling activity are outlined and discussed. Secondary recovery projects approved by appropriate state agencies are listed and discussed.

6. KEITH W. CALDERWOOD AND W. C. FACKLER, Phillips Petroleum Company, Anchorage, Alaska

SIGNIFICANT OIL AND GAS DEVELOPMENTS IN ALASKA, 1965–1966

Recent oil exploration in Alaska is centered in five sedimentary basins: Cook Inlet basin; Arctic (North) Slope province; Bristol Bay basin; Gulf of Alaska province; and Copper River basin. Surface and seismic exploration parties have been active in each, greatest emphasis being in the Cook Inlet basin and the Arctic (North) Slope province.

The oil industry in Alaska during 1965 drilled 19 exploratory wells, resulting in the discovery of 3 oil fields, 3 gas fields, and extensions of 2 oil fields and 1 gas field. The 3 oil discoveries, all under Cook Inlet waters, are Granite Point, Trading Bay, and McArthur River. The gas discoveries are on the upland area of the Cook Inlet basin at Birch Hill, North Fork, and Moquawkie. The Granite Point discovery was extended north more than 3 mi. by subsequent drilling. A discovery was made 6 mi. south of production at Middle Ground Shoal. Gas production at the Cook Inlet field was extended about 2 mi. southwest. Two exploratory wells drilled in 1965–66 on the Arctic (North) Slope were reported non-productive. Two shallow dry exploratory wells were drilled on the north flank of the Copper River basin. Both were unsuccessful.

The first two permanent platforms in Cook Inlet were installed at Middle Ground Shoal oil field during 1965, and development drilling began. A twin 8-mi. crude-oil pipeline was completed connecting the two platforms with an onshore treating facility. This furnished the first outlet for crude oil other than that at the Swanson River field. Contracts were let for 6 additional offshore-drilling and production platforms to be erected during 1966.

The most significant event since the discovery of oil in the Lower Kenai Conglomerate (Hemlock) at Swanson River was the discovery of multiple-pay sandstone beds in the Middle Kenai Formation. These sandstone beds furnish an additional objective and have higher porosity and permeability than the Lower Kenai Conglomerate. Gas pay zones have been found in both the Middle Kenai and Upper Kenai sandstone zones.

7. ROBERT M. WILLINGHAM AND JAMES A. McCALEB, Pan American Petroleum Corporation, Denver, Colorado

Influence of Geological Heterogeneties on Secondary Recovery from Permian Phosphoria Reservoir, Cottonwood Creek Field, Wyoming

A thorough study was made of all available geologic and engineering data from the Cottonwood Creek Phosphoria dolomite reservoir. The data obtained correlate well with injection and production performance of secondary-recovery operations which at first were disappointing. Oriented fractures and other reservoir heterogeneities were identified; this information is being used to modify field operating practices in order to improve reservoir oil-recovery performance. The review also resulted in a better understanding of the reasons for the occurrence of such a prolific field.

The Cottonwood Creek field is on the east side of the Big Horn basin in northwestern Wyoming. It is on a west-southwest-dipping monoclinal surface along the southwest flank of Hidden Dome anticline. There is about 5,500 ft. of structural relief through the productive interval.

Isopachous-lithofacies studies indicate that the western half of Wyoming during the Permian was the site of a large arcuate marine embayment, with a westward connection to the Cordilleran miogeosyncline. Throughout the time of Phosphoria deposition the boundary between the carbonate facies and red shale-anhydrite facies fluctuated along a north-south zone in the eastern part of the Big Horn basin. Cottonwood Creek field is in the zone where the two facies intertongue. Reservoir zones interfinger with a red-shale anhydrite facies on the north, east, and southeast. The stratigraphic traps for hydrocarbons are the impervious strata of the redbed sequence where it grades into the carbonate facies. Within the productive area outlined by Cottonwood Creek field, upper Phosphoria shoaling and bioclastic thickening occurred together with a concomitant porosity increase within what generally is a dololutite facies.

The Ervay tongue ranges in thickness from 30 to 100 ft. and contains net pay intervals a few feet to 70 ft. thick. Porosity through this interval averages 10% and permeability averages 16 md. The increased porosity of the producing intervals is a result of the particulate nature of the carbonate material. This porosity is broken by the occurrence of discontinuous, irregular zones of dense dololutite. The producing interval contains oölites, lithoclasts, and residual fossil bioclasts. Vugs are numerous; some appear to be fossil molds. In general the rock appears to be related genetically to some form of organic accumulation, probably more biostromal than biohermal, associated with high-energy wave action; the high-energy environment periods alternated with periods of probable restricted hypersaline environment.

Cottonwood Creek field was discovered in 1953 and has produced more than 20 million bbls. of oil from 14,200 productive acres. Field development essentially was completed by 1958. During June, 1958, a crestal gas-injection program was begun to maintain reservoir pressure and increase ultimate oil recovery. Gas injection resulted in rapid movement of gas to producing wells and, in many wells, oil production rates declined. During the next 6 years, gas-injection operations were relocated in the reservoir three times to reduce the gas breakthrough to producing wells.

A crestal water-injection program was begun in 1959 and was expanded to mid-structure during 1962. In many places, injected water channeled rapidly to producing wells and resulted in decreased oil production. Some areas of the field responded to both gas- and water-injection programs. After injecting 22 million bbls. of water, it became evident that the reservoir was not responding to water injection in the desired manner.

To account for reservoir performance, all available geological, engineering, and production data were reviewed. These indicated that reservoir performance is dependent on both the primary (matrix) rock characteristics and a superimposed fracture system. The fracture system was the primary cause of poor injection performance.

The geologic conception of the reservoir was found to correlate well with field performance and resulted in a rational explanation of the poor secondary-recovery performance. A variety of methods was used to determine areal geological variations in the reservoir. The fracture system was delineated by core studies, bottom-hole pressure studies, injected-fluid movement, and a structural residual map. Good correlation was found to exist between the fracture system indicated by cores and the structural residual map. Matrix rock properties were determined by lithologic studies and log analyses.

Results from the study are being used to change field-operating practices extensively to improve reservoir performance.

8. IRVIN NIELSEN, Oil shale consultant, Glenwood Springs, Colorado

Economics of Oil Shale

Most shale-oil production cost estimates are between \$1.25 and \$2.10 per bbl. of pipeline crude produced from oil-shale deposits in northwest Colorado. Two companies have not released cost figures, but Union states that a 27½% depletion allowance is necessary before shale can be developed commercially. Other companies and organizations have conducted or are conducting shale-research projects, but none has published firm shale-oil cost estimates.

M. A. Lekas of the Atomic Energy Commission has speculated that costs of producing shale oil may be as low as \$0.29/bbl. He maintains that these costs can be achieved by using nuclear blasts to create permeable, underground, *in situ* retorting chambers. The A.E.C. hopes to detonate such a test soon in oil shale.

The recent discoveries of valuable sodium minerals commingled with oil shale in the center of the basin may change significantly the economics of production.

The problems confronting this unborn industry are well known. The decision to start the industry should be based on the optimum combination of land, reserves, technology, operators, market, legal status, political, and governmental support. The decision can not be made unless these factors can be combined reasonably and with the knowledge that the conditions governing them are relatively stable.