areas, the conditions necessary for accumulation are present and the Devonian formations that produce elsewhere in the Williston basin extend into these areas. In south-central North Dakota, conditions necessary for stratigraphic traps are present where the Devonian Duperow and Birdbear formations have been truncated by erosion and are unconformably overlain by an updip seal in the form of lower Mississippian shale.

In north-central North Dakota (southwestern Bottineau County) conditions necessary for structural traps are present. In the 1½ miles between the Cardinal Keeler (NW., NW., sec. 1, T. 159 N., R. 82 W.) and the California Blanche Thompson (SW., SE., sec. 31, T. 160 N., R. 81 W.) removal of salt by solution from the Prairie Formation has resulted in collapse of the overlying sediments, creating a reversal in dip. It is probable that this is not an isolated situation along the edge of the salt and potentially extensive development of traps is indicated.

In southwestern North Dakota, Devonian sedimentation was influenced by the structure of the Cedar Creek anticline, causing the Winnipegosis, Prairie, Dawson Bay, and Souris River Formations to wedge out southwestward by non-deposition. The Duperow Formation is extensive, though thinned by erosion over the North Dakota part of the Cedar Creek anticline, and the overlying Birdbear and Three Forks formations have been removed by erosion. A thin shale, thought to be Mississippian in age, overlies these truncated formations. These conditions suggest that Devonian production from extensive stratigraphic traps may be found along the northeastern flanks of the Cedar Creek anticline in North Dakota.

19. ROBERT R. BERG, Embar Oil Company, Denver, Colorado

GEOLOGY OF MINNELUSA OIL IN NORTHEAST POWDER RIVER BASIN, WYOMING

Since 1957, with the opening of the Donkey Creek Minnelusa pool, 35 successful exploratory tests have proved the potential of upper Minnelusa (Permo-Pennsylvanian) sandstones. Oil is produced from structural, permeability, and unconformity traps, or from combinations of these. Trapping conditions are illustrated by the Robinson Ranch and Raven Creek fields.

Oil fields usually are associated with low-relief structures, and Minnelusa accumulations are accompanied by stratigraphic changes in younger beds of Permian, Triassic, and Jurassic age. The most obvious change occurs in the superjacent Opeche Shale. Updip thickening of the Opeche coincides with wedging-out of Minnelusa pay sandstones. Therefore, current geologic exploration relies largely on subsurface isopach mapping of the Opeche. Future exploration should consider other techniques of geologic interpretation, such as thickness changes in all younger units and use of the seismograph for stratigraphic as well as structural control.

More than 10 million barrels already have been produced from the Minnelusa. It is evident that many new fields are yet to be discovered. Average size of fields is small, but excellent reservoir sandstones may yield as much as one million barrels per well. Exploratory drilling, aided by moderate costs, will continue at a high level of activity for many years. Improved geological interpretation will help maintain an adequate success ratio.

20. CHARLES E. TRANTER, Mobil Oil Company, Casper

RAVEN CREEK FIELD, CAMPBELL COUNTY, WYOMING

Raven Creek field is located on the eastern side of the Powder River basin of Wyoming. Discovered in March, 1960, the field presently consists of 38 producing wells and 11 dry holes. Production is from the "B" sand unit of the upper member of the Minnelusa formation of Permo-Pennsylvanian age. Depth of production is about 8,300 feet. The trap is formed by updip truncation of the "B" sand unit against Opeche shale at the post-Minnelusa unconformity. Erosion of the productive sandstone appears to have been controlled by a resistant dolomite which overlies the "B" sand unit and by structural configuration present at the close of Minnelusa deposition. The trap is on the western flank of a pre-Opeche anticline, the axis of which has been breached by post-Minnelusa erosion. Basinward tilting has destroyed the anticlinal closure which probably existed and strengthened the stratigraphic closure along the western flank.

21. W.G.A. TECHNICAL STUDIES COMMITTEE, BERNARD E. WEICHMAN, Chairman, Superior Oil Company, Casper

RÉSUMÉ OF MINNELUSA GEOLOGY AND HISTORY OF MINNELUSA PLAY

The terminology of the Permo-Pennsylvanian rocks varies with different parts of the Powder River basin. The rocks are called the Minnelusa on the east, Hartville on the southeast, Casper on the south, and Tensleep, Amsden, and Darwin on the west. The sequence can be divided into three members, the Lower, Middle, and Upper, except for the Casper, where only the Middle and Upper are present. The Minnelusa is truncated northward from the central Powder River basin to a zero edge in Montana.

Compressive forces from the northeast and southwest produced a major northwest-southeast and a minor north-south trend of folding during late Minnelusa time. The north-south folds seem to be located over basement fault zones. Subsequent subaerial erosion breached the folds and truncated the upper Minnelusa beds. Following this the Opeche shale was deposited filling in the breaches and covering the Minnelusa beds.

The first commercial Minnelusa production was encountered in 1930 at the Mule Creek field from the Leo sands. In 1936 production was encountered in the Converse sand of the upper Minnelusa. Until recent years Minnelusa oil exploration was restricted to anticlinal structures with the Converse and Leo sands as objectives. The current active upper Minnelusa sand play began in 1957 at Donkey Creek and accelerated to its present activity in 1960 with the discovery of Raven Creek. Nine Minnelusa fields were discovered in 1961, ten in 1962, and five in the first two months of 1963, all from the Upper sandstone beds.

Five known types of traps are possible: (1) primarily structural; (2) structural and stratigraphic combined; (3) stratigraphic by buried topography; (4) stratigraphic by facies change; and (5) stratigraphic by regional truncation.

The primarily structural-type trap is evidenced at the Robinson Ranch field where 75 feet of closure exists on the Minnekahta.

The structural and stratigraphic combined-type trap is evidenced at Donkey Creek where there is 60 feet of closure on the Minnekahta. The "B" sand is a structural reservoir and the "A" sand is truncated through the center of the field, causing a stratigraphic pinch-out.

The buried topography type trap is evidenced at the Raven Creek field where the oil is located in the downdip ridge flanking a Minnelusa age structure, long since