with marine shale. In the eastern part of the basin four formations are readily distinguishable; they are, in ascending order, the Eagle Sandstone, Claggett Shale, Judith River Formation, and Bearpaw Shale. In the western part of the basin the equivalent stratigraphic section includes the Mesaverde (Gebo Formation of Hewitt), and the Meeteetse Formation. Non-marine deposits of the Lance Formation, including locally the Fox Hills Sandstone, overlie the Meeteetse-Bearpaw section.

Major transgressions are evidenced by the Claggett and Bearpaw shales and regressions by the nearshore and non-marine sediments of the Eagle, Judith River, and Lance formations. Minor transgressions and regressions produced a complex interfingering of sand and shale that complicates formational boundaries.

Isopachous maps, utilizing all available well information as well as fourteen partial surface sections, were compiled to show the distribution of each of the formations. The stratigraphic interval containing the Eagle Sandstone thickens from 200 feet near the Wyoming-Montana line to 800 feet along the south margin of the basin, but the sandstone content decreases southward as the over-all interval increases. Eagle sands are particularly well developed in the area between Worland and Coon Creek. The Claggett Shale is recognizable throughout the east half of the basin and reaches a maximum thickness of 275 feet along the eastern margin. The Judith River and Mesaverde formations thin northward and eastward throughout the basin while the overlying Bearpaw Shale displays a reciprocal relationship ranging in thickness from zero in the southwestern part to 1,000 feet in the north end. In the south part of the basin the Judith River is divisable into three mappable units: upper sandstones, middle continental deposits, and lower sandstones.

Marine and transitional beach environments, that have produced sandstone reservoirs and petroleum accumulations in several other basins in the Rocky Mountains are well represented in the Eagle, Judith River, and Bearpaw of the Big Horn basin. Numerous littoral and neritic sandstones provide a variety of trapping conditions in conjunction with both old and present-day structural features. Embryonic development of Laramide structures during late Cretaceous resulted in (1) thinning of sediments over some of the major structural features and (2) the accumulation of thicker and more porous sandstones along the flanks and over the crests. Examples of depositional thinning of the Claggett Shale may be observed in the vicinity of Five Mile, Worland, Slick Creek, and Sand Creek fields. Local thinning of the Judith River interval occurs at Worland and Slick Creek fields. Similar Laramide structural growth patterns have been mapped in association with oil and gas production in the Patrick Draw-Table Rock area of the Great Divide basin in southern Wyoming.

In approximately 60 per cent of the basin the top of the Judith River and Mesaverde is at a depth of 8,000 feet or less. There is no petroleum production from Upper Cretaceous rocks of the Big Horn basin at the present time. Significant shows have been found at (1) Neiber anticline where a well blew out and burned from gas in the Eagle, (2) Golden Eagle field where three cable-tool wells produced gas from the lower Mesaverde during the early stages of the field's development (1918–1923), (3) Golden Dome and Dry Creek fields in Montana where gas was produced from a zone in the lower Mesaverde, and (4) at the Berwin area northwest of Badger basin where oil was recovered on drill-stem tests of the lower Mesaverde. Smaller shows of oil and gas have been encountered in several other wells.

17. EDWARD L. REID, Murphy Corporation, Casper

OIL AND GAS OCCURRENCES IN DISTURBED BELT OF SOUTHERN ALBERTA AND NORTHERN MONTANA

Several of the most important "disturbed belt" hydrocarbon occurrences are briefly summarized in order of discovery and development.

The hydrocarbon trap at Turner Valley is primarily structural; however, there are some indications of pre-structural stratigraphic control of accumulation. The Highwood structure, 2 miles west of Turner Valley, has tested only water from the Mississippian. Producing porous zones at Turner Valley can not be easily correlated with porous units at Highwood, indicating that there may never have been a direct connection between the two reservoirs. In addition, some wells drilled east of Turner Valley have encountered tight Turner Valley producing zones. Gas reserves originally in place at Turner Valley were 1.74 trillion cubic feet.

Hydrocarbons at Jumpingpound are structurally trapped in the updip edges of a thrust-faulted Rundle slice. Jumpingpound will eventually produce about 700 billion cubic feet of gas.

Surface geology in the Pincher Creek area does not suggest the presence of an anticlinal fold or large thrust sheet at depth. In contrast to steep west-dipping surface beds, the Mississippian rocks of the reservoir block at Pincher Creek dip southwest at only 4°–8°. Pincher Creek accumulation is structurally controlled. Current estimates give Pincher Creek 2.29 trillion cubic feet of gas reserves. During the past 5 years, four more important discoveries have been made in the Waterton and Castle River areas near Pincher Creek. Structurally these blocks lie above and west of the Pincher Creek block.

Total in place Mississippian gas reserves in Southern Alberta "disturbed belt" fields currently stand at 8 to 8.5 trillion cubic feet.

Early and recent oil and gas occurrences in the Montana part of the "disturbed belt" are briefly reviewed. Wildcat density, time of structural movement, degree of crustal shortening, and Mississippian stratigraphy are suggested as possible reasons for lack of economic success in the Montana part of the disturbed belt. Mississippian stratigraphy and its influence on hydrocarbon accumulations near the disturbed belt are illustrated with the suggestion that the combination of proper stratigraphic and structural conditions have not yet been found in the Montana disturbed belt.

18. SIDNEY B. ANDERSON, North Dakota Geological Survey, Grand Forks

SELECTED DEVONIAN POSSIBILITIES IN NORTH DAKOTA

The Devonian System of North Dakota consists of rocks of Middle and Upper Devonian age. The Middle Devonian is represented in ascending order by the Winnipegosis, Prairie, and Dawson Bay Formations and the lower part of the Souris River Formation. The Upper Devonian is represented by the upper part of the Souris River Formation, the Duperow, and Three Forks Formations. These formations represent a total Devonian thickness of about 650 feet in south-central North Dakota, approximately 1,400 feet in the north-central North Dakota and about 800 feet in the southwestern part of the state. These units are dominantly carbonate rocks, the principal exceptions being the Three Forks shale and the evaporites of the Prairie Formation.

Though there is no Devonian production in these 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