the future by exploring in those areas more favorable to the accumulation of oil in primary traps that have not been modified greatly by Laramide folding. Oil initially in place may retard secondary silicification of the Tensleep sandstones.

23. STANLEY M. EDWARDS, Continental Oil Company, Casper Wyoming

PERMO-PENNSYLVANIAN OIL TRAPS OF WESTERN POWDER RIVER BASIN OF WYOMING

Most oil traps on the western flank of the Powder River basin at first glance appear to be the result of Laramide anticlinal flexures. This, however, is not true of the fields producing from the Minnelusa Formation. Several Laramide anticlines have little or no production from the Minnelusa rocks. What, then, are the true methods and conditions of oil entrapment in the Minnelusa Formation?

The Minnelusa Formation in this paper includes those rocks below the Permian Goose Egg Formation and above the Mississippian Madison Formation. The Minnelusa Formation has been subdivided in this area into three members by previous authors. The three members are termed Upper, Middle, and Lower. The Upper Member is considered to be Wolfcampian in age and is probably the most important oil producer in the area. The Upper Member has been further subdivided into three rock units named, for simplicity, A, B, and C. A and B appear to be the most productive and also exhibit the greatest stratigraphic variations. Understanding the stratigraphic variations and their relationships to the Laramide structures can lead to a better development program of existing oil fields and further the exploratory efforts in little-drilled areas of the western Powder River basin.

24. JOHN P. WELDON, Tenneco Oil Company, Casper, Wyoming

DILLINGER RANCH FIELD, CAMPBELL COUNTY, WYOMING

Located in east-central Campbell County on the eastern flank of the Powder River basin, Wyoming, the Dillinger Ranch field produces oil from the "B" Sand section of the Permian part of the Minnelusa Formation. The field is defined by 17 wells and 5 dry holes. Total field reserves are estimated to be 5–10 million barrels of oil. The trap is formed by the intersection of a structural nose with an updip truncation of reservoir sandstone in a shale-filled channel.

Post-Minnelusa streams cut deeply into the formation and removed substantial portions of the alternating sandstone, carbonate, and anhydrite sequence. The Opeche Shale was then deposited over the entire basin flank, filling in the drainage valleys. Much later, the Laramide orogeny tilted the eastern flank of the basin toward the southwest. Migrating hydrocarbons were unable to move updip at those places where the reservoir sandstones encountered the impermeable shale seal in the channels. It is anticipated that many more fields will be discovered in the Minnelusa in similar stratigraphic traps along the eastern flank of the Powder River basin.

25. IRVIN KRANZLER, Consulting geologist, Billings, Montana

ORIGIN OF LOWER TYLER OIL IN CENTRAL MONTANA

A study of the Heath (Mississippian) and lower Tyler (Pennsylvanian) sediments of central Montana suggests a close relationship between the oil accumulations and the relative positions of the Heath Limestone and the lower Tyler sandstones. Reconstruction of the pre-Amsden structure and the Tyler-Heath paleogeology shows that the oil accumulations at Sumatra, Stensvad, Ivanhoe, Keg Coulee, Bascom, Melstone, and Big Wall fields occur where the paleo-structural position of the lower Tyler sandstones is updip from, and in direct contact with, the Heath Limestone. The foregoing relationships seem to be further supported by a study of Alice and Porcupine domes. These domes have barren sandstone reservoirs in excellent structural-stratigraphic traps. The paleo-structural attitude in the area of the domes was flat and the Heath Limestone apparently not well developed.

Application of these reservoir-source relationships should be useful in exploring for new oil reserves in the lower Tyler. The concept also may be applicable in other geologic provinces.

26. DONALD E. CAMPAU, Consulting geologist, Billings, Montana, AND BILLY B. LANE, State geologist, Billings, Montana

PROBLEMS OF CORRELATING PERMO-TRIASSIC REDBEDS IN WILLISTON BASIN

Correlation of Permo-Triassic redbeds in the Williston basin is relatively easy when a normal section is present; however, when some of the section is missing because of truncation or salt solution, correlation becomes very difficult, especially where redbeds of Triassic age rest on similar beds of Permian age or older. Poor samples and inadequate mechanical logs within the redbed section make correlation even more difficult. Correlation with the outcrop in the Black Hills is complicated further by the presence of massive salt beds in the subsurface that are not present on the surface.

Salt solution is common and, where faulting and fracturing are known to exist, appears to be related to paleostructures. Failure to recognize this phenomenon could result in misinterpretation of structure, especially when the seismic method is used.

27. A. SATERDAL, Independent petroleum geologist, Denver, Colorado

LOWER CRETACEOUS OIL FIELDS OF NORTHERN SWEETGRASS ARCH, MONTANA

An Early Cretaceous age is considered to be most probable for the group of productive sandstones which are found in the northern Sweetgrass arch and which extend from a basal unit (Cut Bank), that lies directly on the deeply eroded Jurassic Rierdon Shale, upward 200 ft. in the section to include the main productive sandstones at Fred and George Creek and Flat Coulee fields (possible "Moulton" stratigraphic equivalents). Areas of substantial sandstone development, having good reservoir characteristics and oil "shows," occur at stratigraphic positions intermediate between the Cut Bank and "Moulton" and can be found at other localities on the northern Sweetgrass arch.

All of these sandstones have a general relationship with the underlying erosional surface on the top of the Jurassic Rierdon, and thus are indirectly related to each other.

Study of the oil and gas fields from the Lower Cretaceous of the northern Sweetgrass arch is confined for practical reasons to the more recently discovered fields for which electric logs are available. The three most important of these fields are Fred and George Creek, Flat Coulee, and Red Creek. Each produces from basal or near-basal Cretaceous sandstones but differs in detail regarding sandstone deposition and reservoir quality.

The Cut Bank Sandstone of the Red Creek area consists typically of black chert and quartz; it is conglomeratic at the base, grading upward into fine-grained, commonly clay-cemented sandstone. It is largely a blanket sandstone throughout the field. However a definite thinning of the major basal unit takes place on the eastern side of the field. The area of thinning coincides with development of a stratigraphically separate, relatively "tight" upper unit. The accumulation is largely structural, and the reservoir is filled nearly to the spill point. Approximately 45 ft. of critical closure is mapped on the reservoir beds, but shallower beds indicate only a north-plunging nose.

The main reservoir sandstone at Fred and George Creek shows evidence of having been deposited in a deeply eroded channel, probably at or near drainage base-level. Evidence of channel scour is prominent here as it is in some areas of "Moulton" deposition on the northwestern side of the arch.

The reservoir sandstone at Flat Coulee is, in depositional detail, considerably different from the sandstones at Red Creek and Fred and George Creek, although it may be nearly equivalent stratigraphically to the latter. At Flat Coulee, the reservoir sandstone appears to be a part of a major sandy shale unit (Ribbon) from which the shale has been removed, probably by shallow near-shore current activity.

28. DUDLEY W. BOLYARD, Clark Oil and Refining Company, Denver, Colorado, AND ALEXANDER A. McGREGOR, Samuel Gary, Denver, Colorado

Stratigraphy and Petroleum Potential of Lower Cretaceous Inyan Kara Group in Northeastern Wyoming, Southeastern Montana, and Western South Dakota

The Inyan Kara is a diversified group of sandstone, shale, conglomerate, variegated siltstone, claystone, and some lignite at the base of the Cretaceous in the Black Hills and surrounding subsurface area. Its unconformable contact with underlying formations reflects epeirogenic uplift and gentle folding in very Late Jurassic to very Early Cretaceous time. Thickness ranges from 22 ft. or less in central South Dakota to about 700 ft. in Black Hills outcrops.

Two dominantly sandy formations, the Lakota and the overlying Fall River, comprise the Inyan Kara Group. They are separated by a regional disconformity. The Lakota is a continental deposit with conglomeratic material, claystone, and variegated beds. The Fall River, which has greater regularity and bed continuity, consists of offshore shale, neritic to littoral sandstone, and deltaic and other marginal marine deposits of the first major Cretaceous marine transgression. The Fall River intertongues northwestward with the overlying marine lower Thermopolis Shale.

Persistent shale breaks divide the Fall River into three members (ascending): Liscom Creek, Morton, and Coyote Creek. Gross arrangment of members is shingle-like, for where one is thick the others tend to be thin or absent.

Most of the Inyan Kara sediments were transported seaward by streams originating on the Sioux uplift. During Lakota deposition, a major northwest-flowing river developed along the regional syncline which lay east of the Chadron arch and extended through the site of the Black Hills into Montana. Southward encroachment of the sea and shifting of deltas explain the thickness and facies relationships of the members of the Fall River Formation.

Many oil fields on the eastern flank of the Powder River basin in Wyoming have producing sandstones up to 80 ft. thick. Most of the oil is produced from channel sandstones in the Coyote Creek Member of the Fall River. Some important fields produce from Lakota channel sandstones. The oil is trapped behind convex updip permeability barriers at the margins of sandstones deposited in meandering channels which are approximately parallel to structural contours. Favorable stratigraphic and structural conditions for petroleum accumulation also exist in parts of southeastern Montana and western South Dakota.

29. JAMES A. BARLOW, Barlow and Haun, Inc., Casper, Wyoming, AND JOHN D. HAUN, Colorado School of Mines, Golden, Colorado, and Barlow and Haun, Inc.

Stratigraphic Accumulation of Oil in Salt Creek Field, Natrona County, Wyoming

Salt Creek field has produced about 420,000,000 barrels of oil. Most of this production is from the second Frontier sandstone, which is one of many sandstone bodies that are interbedded with marine shale in the lower part (between the top of the Mowry and the base of the Niobrara Shales, hereafter referred to as interval A) of the Upper Cretaceous, Rocky Mountain area, United States and Canada. Interval A is thick (over 1,000 ft.) in central, northeastern, and west-central Wyoming and southeastern Montana. Another area where interval A is thick is in northwestern Montana and western Alberta. In some areas, interval A is entirely marine shale; in other areas the interval contains abundant sandstone bodies. The sand was transported by a series of river systems that formed deltaic complexes at several places at the margins of the early Upper Cretaceous sea. These deltaic deposits are represented by the "D" sandstone of the Denver basin, the Ferrin Sandstone of Utah, the Cardium and Badhart Sandstones of Canada, and the Frontier Sandstone of Wyoming.

The second Frontier sandstone that produces at Salt Creek field is an offshore bar associated with the eastern terminus of one stage of the Frontier delta. The sandstone body is several miles wide, over 60 mi. long, and up to 100 ft. thick. Salt Creek anticline (formed at the end of the Cretaceous) is located in an area of excellent sandstone conditions and caused structural accumulation of primarily stratigraphic oil.

There are other sandstone bodies related to the Frontier delta containing stratigraphic oil that are not draped over an obvious anticline. The Wind River and Bighorn basins and parts of the Green River and Powder River basins probably contain more Salt Creek-type fields.

30. ROBERT J. WEIMER, Colorado School of Mines, Golden, Colorado

Patrick Draw Field, Sweetwater County, Wyoming—An Old Stratigraphic Trap

The search for new petroleum reserves can be greatly implemented by a more thorough understanding of why petroleum is trapped where it is. The Patrick Draw field, discovered in 1959, started a wave of exploration effort in the Rocky Mountains area to find additional giant stratigraphic traps in the Upper Cretaceous rocks where porous and permeable sandstones pinch out on structural noses. The failure to find another Patrick