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

Draw, despite a widespread exploration effort, signifies that factors not generally considered must have had a dominant influence in the accumulation. These factors are revealed only by examining the geologic history of the area, beginning with the deposition of the reservoir and source rocks and studying the structural attitude of these rocks through time.

Although several sandstones are petroleum-productive at Patrick Draw, the principal producing zone consists of two sandstone bars at the top of the Almond Formation (Upper Cretaceous). The spatial dimensions, lithologic characteristics, and stratigraphic framework of these bars suggest that they are barrier bar sandstones deposited along the margin of the Lewis sea. These porous and permeable linear barrier bars have a general north-south trend and, updip to the west, grade into impermeable shale and sandstone that were deposited in a swamp and lagoonal environment. A second important productive zone occurs approximately 40 ft. below the top of the Almond Formation. The areal distribution, lithologic nature, and stratigraphic framework of sandstones in this zone suggest that they were deposited as parts of a tidal delta in a lagoon. Each of the three main productive sandstones has a different oil-water contact.

The geologic history of the Patrick Draw area shows that, by the beginning of the time of deposition of the Lance Formation (Upper Cretaceous), conditions were favorable for petroleum accumulation. The reservoir sandstones had 1,200 ft. of overburden and several million years had elapsed since the reservoir sandstones were deposited. An early trap was formed where these sandstones were warped over an east-plunging structural nose, and early migration of petroleum produced a large accumulation a few miles south of the present field. When the present Wamsutter arch came into existence in post-early Eocene time, the first trap was opened and the accumulation spilled northward to be trapped at the present location of Patrick Draw field.

The search for more "Patrick Draws" must include more than an analysis of present structure and potential reservoir rock. The time of formation of the trap, the structural modification of the trap through time, and the associated origin and migration problems are hidden factors that play the dominate role in formation of a large petroleum accumulation. Exploration geologists must know more about the regional framework of sedimentation and the cause and effect of incipient structural development in depositional areas, and understand how these factors relate to the geologic history of a region.

31. J. C. HARMS, Marathon Oil Company, Denver, Colorado

STRATIGRAPHIC TRAPS IN A VALLEY FILL, WESTERN NEBRASKA

Oil is trapped in a trend of valley-fill sandstones in the Cretaceous "J" formation in Cheyenne and Morrill Counties, Nebraska. The valley fill is composed chiefly of porous and permeable sandstone, strikes north-south, and is about 1,500 ft. wide and 50 ft. thick. Oil has accumulated in the valley fill trend where it crosses the axes of northwest-plunging anticlines. Updip (eastward) escape of oil is prevented by the discontinuous nature of sandstones with low oil-entry pressures in the enclosing marine sediments of the "J" formation. The traps therefore are a combination of stratigraphic and structural.

The "J" formation in this area is a sandy and silty unit 38–77 ft. thick deposited in predominantly marine environments. The "J" is overlain and underlain by dark gray marine shale. The formation can be divided into two members, each relatively thin and with distinctive mineralogy, sedimentary structures, fossil content, and electric-log character. These members can be traced over hundreds of square miles in western Nebraska. After the deposition of the younger member, emergence caused a narrow valley to be cut and filled by a stream. Within the area of stream erosion, most of the previously deposited sediments of the "J" were removed. The sandstones of the valley fill also have distinctive sedimentary structures, textures, and electric-log character. The trend of the valley fill is nearly straight, suggesting that erosion and deposition were the work of a meandering stream whose width was less than the width of the valley.

Seven fields have been discovered along the valley fill trend within the study area. One well out of every 1.8 wells drilled into the valley fill has been completed successfully. These wells are rated as good producers and have long productive lives by Denver basin standards. Some production has been developed in marine sandstones of the "J" formation near the area of the valley fill, but only one well out of approximately every 15 drilled is successfully completed, productivity is low, and total reserves are smaller. Therefore, stratigraphic study leading to an improved understanding of the genesis and form of the sandstone reservoirs is of considerable economic value.

32. EARL G. GRIFFITH, Griffith Exploration Corporation, Denver, Colorado

GEOLOGY OF SABER BAR, LOGAN AND WELD COUNTIES, COLORADO

The Upper Cretaceous "D" sandstone is oil-productive at the Saber field from a barrier bar, a linear north-trending sandstone body at least 10 mi. long and approximately 1 mi. wide. The presence of the bar was suspected after two wells found a thick sandstone section in an area of generally thin "D" sandstone. Development drilling has found sandstone bodies with thicknesses up to 44 ft. and permeabilities of several hundred millidarcies. Permeabilities are expected to improve in future wells drilled farther seaward on the bar. The shape and internal structure of the bar suggest that it was formed by moderate wave action in shallow water with sand supplied by longshore currents. Regional reconstruction of the depositional environment can be an aid to predicting the occurrence of other "D" sandstone bars.

33. CURTIS J. LITTLE, Consulting geologist, Albuquerque, New Mexico, AND THOMAS C. CARLSON, Consulting petroleum engineer, Dallas, Texas.

MANY ROCKS—GALLUP FIELD, SAN JUAN BASIN, NORTHERN NEW MEXICO

This discussion is presented in the belief that through its understanding similar fields may be discovered. Favorable economics exist because of shallow depths of the producing sandstone. Reliable field records, a high density of core analyses, and good mechanical logs are of considerable aid in establishing the geologic history of this stratigraphic trap with its hydrodynamic, faulting, and folding complications.

The field is located on the northwestern side of the San Juan basin. Although the Upper Cretaceous producing sandstone is present in Colorado, commercial production is found only in New Mexico. The discovery well, Little No. 2-27 Navajo, was completed in No-