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 November, 1962, at a depth of 1,240 ft. Cumulative production is more than 1,000,000 barrels and initial potentials have ranged up to 665 BOPD. Depth of the standstone ranges from 1,134 to 1,781 ft. and averages less than 1,500 ft. Dry-hole cost averages less than $5,500; completed wells cost $15,000–$20,000, and payout periods can be as short as 4 months. The productive sandstone ranges from 3 to 13 ft. in thickness, has a porosity of 9–24%, and a permeability of 1–872 md. Original bottom-hole pressure was 465 psi.

The producing body is an elongate, northwest-trending marine sandstone accumulation of Niobraran age. It is 25 mi. long and averages 0.5 mi. in width. The sandstone was deposited in erosional troughs formed on the Niobrara-Carlile unconformity. The unconformity rises toward the southwest across the basin. Usually sandstones are found in troughs formed by longshore currents or at the base and seaward edges of cliffs at the unconformity. Detailed isopach mapping shows irregularities along the trough.

Subsequent Laramide folding and faulting and post-Laramide erosion have caused a variety of fluid accumulations within the stratigraphic trap. Zones of fresh water, oil and brackish to salt water, oil, and gas caps occur at different positions along the trend of the sandstone. In Colorado the sandstone dips southeast for 12 mi., from an outcrop elevation of 5,400 ft. to a deep syncline at the Colorado-New Mexico boundary where the oil-water contact is at 3,900 ft. Southeast of the syncline, the sandstone rises 400 ft. in 2½ mi. onto the faulted asymmetrical Blue Hills anticlinal nose and finally descends gradually southeastward into the San Juan basin. A normal fault that divides the sandstone into separate reservoirs is located almost 1 mi. northwest of and essentially parallel with the axis of the plunging Blue Hills anticline. This fault causes the gas-oil contact to be 85 ft. higher on the upthrown (northwestern) side.

34. DONALD I. FOSTER, Consulting geologist, Evergreen, Colorado.

TRAPPING MECHANISMS OF SELECTED FIELDS, CHEROKEE RIDGE, WYOMING AND COLORADO

The Cherokee Ridge is a complex anticlinal arch separating the Washakie basin, Wyoming, from the Sand Wash basin on the south in Colorado. Several fields, primarily gas, are located on the Cherokee Ridge. Exploration has been based primarily on structural "plays" and has proved successful. With present control, it can be demonstrated that at least part of the fields are stratigraphic with only the area and size modified by the structural configuration.

The trapping mechanisms of several fields on the eastern and western ends of Cherokee Ridge are varied and provide templates to guide further exploration.

On the eastern Cherokee Ridge, traps for gas are formed by: (a) structural closure (South Baggs and West Side Canal fields); (b) closure against the downthrown side of a fault (Four Mile Creek field); and (c) porous Lewis and Mesaverde sandstones crossing the Cherokee Ridge (South Baggs and Pole Gulch fields).

On the western end of the Cherokee Ridge, gas accumulations are formed by: (a) structural closure (most fields in some degree); (b) truncation of reservoir sandstones in Lewis and Fox Hills across structural noses (West Hiawatha and Canyon Creek fields); (c) Almond sandstones (uppermost Mesaverde) developed on and across structures (Sugar Loaf, Canyon Creek, and Pioneer fields); and (d) facies change (with possible hydrodynamic reinforcement) in the Trail and Canyon Creek zones of the Mesaverde (Trail and Canyon Creek fields).

35. DONALD O. ASQUITH, Chevron Oil Company, Casper, Wyoming

MESAVERDE AND "ALMY" PRODUCTION, BIRCH CREEK UNIT SUBLETTE COUNTY, WYOMING

Birch Creek field is located on the LaBarge arch in the western Green River basin, and is a part of the Big Piney-LaBarge producing complex. Oil and gas are produced in this area from sediments ranging in age from Jurassic through Paleocene. Of concern here are the trap geometry and source of hydrocarbons of the shallower productive intervals within the Mesaverde and "Almy" Formations.

The Upper Cretaceous Mesaverde and upper Hilliard Formations together form a typical regressive sequence of, from northwest to southeast, lagoonal coal-bearing siltstone and thin sandstone, a littoral sandstone complex, and marine siltstone and shale. Uplift along the LaBarge arch during the Late Cretaceous or very early Paleocene resulted in the erosion of a portion of this sequence and an unknown thickness of Late Cretaceous rocks. A combination of the truncated edge of the upturned littoral sandstone complex in conjunction with lateral permeability changes and the gentle structure of the LaBarge arch forms the traps within the Mesaverde.

The Paleocene sequence, assigned to the "Almy" Formation by operators in the area, is composed of clastic sediments derived from two separate and distinct source areas. An upper sequence, consisting of conglomerate, varicolored shale, and siltstone, was derived from a sedimentary terrane probably in the rising thrust belt on the west. This sequence is characterized by pebbles and cobbles of limestone and quartzite and would be better assigned to the Chappo Member of the Wasatch Formation. The major (or lower) part of the Paleocene rocks at Birch Creek was derived from a granitic source on the east, probably in the vicinity of the Wind River Mountains, and is characterized by abundant mica and feldspar. The Paleocene forms a regressive lacustrine sequence of the following facies: (1) lacustrine shale; (2) marginal lacustrine sandstone; (3) paludal shale, siltstone, and thin sandstone; and (4) variegated mudstone and thick sandstone, probably deposited in a fluvial environment. A more logical formation assignment of this latter sequence would be to the Fort Union Formation.

Significant oil production and the major part of the gas production from the Paleocene at Birch Creek and surrounding fields are from reservoirs within the marginal lacustrine sandstone facies. Traps result from the updip and lateral pinchout of individual sandstones into lacustrine shale along the eastern flank and crest of the LaBarge arch. Structural modification of this basic trapping mechanism is present at some nearby fields such as LaBarge.

The close association of significant oil product and the greater portion of the gas production with the Paleocene lacustrine shale body strongly suggests that this shale is the source of the hydrocarbons produced from these reservoirs. The close association of production from the Mesaverde with the unconformity and the overlying shale body, the lack of a distinct difference between oils from Cretaceous and Paleocene reservoirs, and the lack of significant production from areas where shale is absent or poorly developed suggest that the source of hydrocarbons produced from these