GEOLOGY OF PETROLEUM IN THE PICEANCE CREEK BASIN, NORTHWESTERN COLORADO

by

Hal L. Dunn[1]

INTRODUCTION

The Piceance Creek basin encompasses nearly 4,000 sq mi, including parts of Delta, Garfield, Gunnison, Mesa, Moffat, Pitkin and Rio Blanco Counties. The basin is strongly asymmetric, with moderately gentle west and southwest flanks and steeply-dipping east and northeast flanks formed by the Grand Hogback monocline. The axis of the basin parallels the Grand Hogback in the central part of the basin and is bifurcated in the southern and northern parts by basinward-plunging anticlines. The basin contains a maximum of about 27,000 ft of sedimentary rocks, and this figure represents maximum structural relief on the Precambrian between the lowest point in the basin and the highest points on the White River and Uncompahgre uplifts.

GEOLOGIC HISTORY

PALEOZOIC ERA

Throughout the early Paleozoic, stable shelf conditions prevailed in the area. Broad epeirogenic movements produced periods of emergence and submergence, allowing arms of the sea to invade the area from the Cordilleran miogeosyncline to the west, and intermittent connections with the mid-continent area to the east. Because of the erosion during periods of broad emergence, original depositional edges are difficult to restore. Middle and Late Ordovician and Silurian, for which there is no local geologic record, surely must have been present, but were removed by erosion during a general emergence in Early Devonian time. The dominant northwesterly trends, evident in the present structural configuration of northwestern Colorado, probably were established in the late Precambrian. The lowest Paleozoic rocks of the area were deposited on a broad shelf area, yet their facies show a discernable northwest trend, indicating the presence of a slightly negative belt along which most of the marine incursions took place.

The lower Paleozoic rocks consist of carbonate, sandstone, and minor shale beds deposited in shallow and open seaways. Three general transgressions are recorded: the first sequence includes rocks ranging from Middle Cambrian to Early Ordovician age, the second involves only rocks of Late Devonian age, and the third is represented by Mississippian rocks. The intervening disconformities are of regional extent. Each sequence includes a lower sandy part and an upper carbonate part. The disconformity between the first and second sequences is moderately pronounced; it was produced by warping and bevelling of the underlying rocks. The disconformity between the second and third sequences is mostly inferred from the thin but widespread sandy unit at the base of the Mississippian carbonate rocks. During Early Pennsylvanian time, the former stable shelf broke into narrow basins and uplifts. Northwest Colorado was marked by a strongly subsiding northwest-trending trough termed the Maroon basin. This trough was bordered by adjacent uplifts which shed great fans of coarse clastic sediments into the trough. At times, these coarse sediments interfingered with marine mud, carbonate sediments, and evaporite deposits; at other times, they coalesced across the entire trough. The trough deposits interfingered northwest with mixed shelf deposits of a more open seaway. By late Permian, the highlands had been eroded to only moderate relief, and the finer-grained terrigenous and thin units of carbonate sediments were deposited across most of the old trough area.

MESOZOIC ERA

During Triassic and Early and Middle Jurassic time, the old shelf area again behaved as a single unit. Weathering of the highlands resulted in thick deposits of reddish, fine-grained sediments lapping onto the highlands. The Uncompahgre highland, on the southwest, was over-lapped in the Late Triassic; but not until Middle or Late Jurassic was the Front Range highland, on the northeast, finally overlapped.

In the Late Jurassic, regional emergence and deposition of continental deposits of the widespread Morrison Formation heralded the break up of the miogeosyncline

[1]Petro-Lewis Corporation, Denver, Colorado 80202.

to the west. Uplift in the geosynclinal area began an easterly migration of deformation which controlled Cretaceous sedimentation across the foreland and ultimately culminated in the foreland orogeny, generally assigned to the Laramide orogeny.

During Cretaceous time in northwestern Colorado, a sea transgressed from the north and northeast and gradually and cyclically regressed to the east. A thick, wedge-shaped lens of Cretaceous deposits records a dominantly marine lower half made up mostly of pro-deltaic marine mudstones of the Mancos Formation overlain by an upper half which is the dominantly non-marine Mesaverde Group. Sandstone, shale, and coal deposits of the Mesaverde record the general eastward advance of a large deltaic and coastal plain complex into a retreating sea.

The retreat of the sea in Late Cretaceous time marked the last marine sedimentation in the area. In latest Cretaceous and early Tertiary time, pulses of the Laramide orogeny began to break the region into the present structural uplifts and intermontane basins filled with Tertiary rocks.

CENOZOIC ERA

At the close of the Cretaceous, the Piceance Creek basin was tilted to the east as the basin axis subsided under the infill of sediments derived from the adjacent uplifts. The upper surface of Upper Cretaceous rocks was bevelled on the uptilted western flank of the basin. Paleocene and Eocene time is well represented in the basin by thick wedges of clastic rocks which thin westerly and interfinger in part with lacustrine shale and marlstone. By the end of Eocene time, the basin was nearly filled.

Oligocene time is not represented in the basin; all of northwestern Colorado probably was elevated. By Miocene time, residual highlands were almost buried by overlapping sediments. Extensive volcanic extrusives covered the remaining surfaces of the old highlands and spread across the filled basin. These basalts remain in places today capping the highest parts of the White River uplift and the Piceance Creek basin.

Epeirogenic uplift of the region during the Pliocene resulted in general basin exhumation and stream incision. The meandering courses of the major streams were entrenched at this time.

OIL AND GAS RESERVOIRS

In northwestern Colorado, oil and gas are produced from rocks ranging from the Pennsylvanian Minturn Formation (mostly Des Moinesian in age) to the Eocene Green River Formation. In the early cycle of exploration, most of the oil and the early gas was found by drilling structural closures mapped on the surface. When more emphasis was placed on the study of the stratigraphy of producing formations, production was found to be controlled to varying degrees by stratigraphic variations of the reservoirs, and encouragement was gained to drill stratigraphic prospects.

Of the pre-Pennsylvanian rocks, the best porosity development seems to be in the Mississippian carbonate rocks and to some extent in the carbonate and sandstone units of the Upper Devonian. Shows have been encountered in these rocks, but no production has yet been established. Most testing has found them water-bearing. Porosity is somewhat continuous, and the reservoirs were likely flushed prior to formation of the structural traps. These rocks do produce in southwestern Colorado, generally on structures with associated faulting and fracturing. If the rocks are to be found productive in northwestern Colorado, it probably will be in circumstances where early entrapment has had a favorable history and flushing did not occur, or where associated fracturing and faulting provided communication with other oil-bearing zones.

The Permo-Pennsylvanian section is noted for outstanding production from the Weber Sandstone at Rangely (Fig. 1). In that field, the producing sandstone units are multi-storied; they interfinger southeasterly with non-porous reddish facies of the Maroon Formation. The Weber production on the Axial Basin uplift is from a thin, southeast-directed lobe of the uppermost part of the Weber called the Schoolhouse Tongue. The Schoolhouse Tongue is entirely of Permian age, and oil-staining both on outcrop and in wells is very common. Production from this sandstone tongue generally is associated with fracturing, as matrix porosity usually is quite low. The Schoolhouse Tongue has been penetrated by 2 deep wells in the Piceance Creek basin and found to be tight at depths of 15,000 to 20,000 ft.

Only minor production has been obtained from Triassic rocks. The Upper Triassic Shinarump Formation is a fluvial deposit, mostly sandstone, and exhibits abundant stratigraphic variation. Shows are common, but established Shinarump gas and oil accumulations are small. Some oil also has been produced from fractures in the Lower Triassic Moenkopi Formation at Danforth Hills.

Prolific oil production has been established from the Jurassic Entrada Sandstone and Morrision Formation in Wilson Creek, Maudlin Gulch, Danforth Hills, and Iles fields on the Axial Basin uplift. The Entrada Sandstone and sandstones in the Salt Wash Member of the Morrison are excellent reservoirs. The accumulations appear to be entirely structural; however, the Morrison sandstone units exhibit considerable regional variation and may be prospects for stratigraphic traps. Gas is produced from the Morrison at several fields on the Douglas Creek arch,

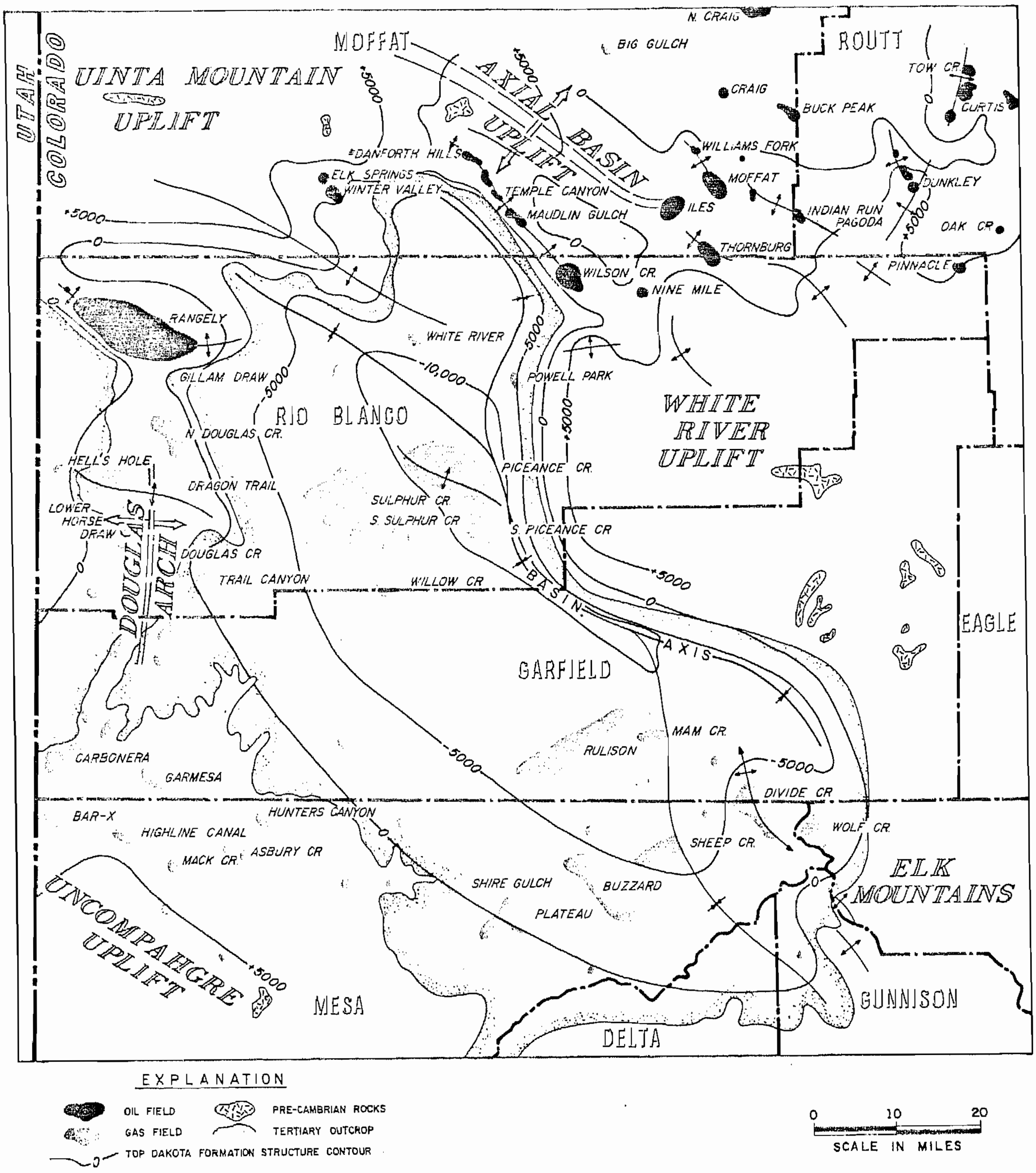

Figure 1. Oil and gas fields and major structural elements, Piceance Creek basin and contiguous areas, northwest Colorado.

and a few also produce gas from the Entrada. In this area, the production is from fluvial sandstone units at the top of the Morrison associated with the transition to the Lower Cretaceous.

Lower Cretaceous sandstone units of the Dakota Group produce oil from several fields on the Axial Basin uplift, northeast of the Piceance Creek basin. These accumulations are associated with structures, but stratigraphic variations are abundant and exercise varying degrees of control on the production. On the Douglas Creek arch, these sandstone units produce gas in many fields. The Dakota Group in this area is largely non-marine, with a fairly abrupt upward transition to the overlying marine shale of the Mancos. Because of the available gas outlets and moderate depths, these reservoirs have been extensively drilled on the Douglas Creek arch. Future exploration will be concerned mostly with attempts to extend production down-flank into deeper areas of the Piceance Creek basin. Rocks included in the Dakota Group of northwestern Colorado probably range from latest Jurassic in places to earliest Late Cretaceous age and include time equivalents of the well-known Muddy and Skull Creek intervals of areas to the northeast and east.

The Upper Cretaceous section of the Piceance Creek basin is a thick, complex stratigraphic sequence burdened with a rather complex nomenclature. For the purposes of this discussion, a description of gross aspect must suffice. The interval can be divided into a lower part consisting mostly of the marine shale of the Mancos Shale; and an upper part, containing the Mesaverde Group and younger rocks. The upper part is dominantly nonmarine, with a transitional and marine facies at the base. The entire sequence represents an eastward regression with numerous fluctuations of the shoreline. From west to east-southeast, the transition between the upper and lower parts rises stratigraphically across the area. The repeated fluctuations of the shoreline provide abundant possibilities for stratigraphic trapping of petroleum in the transitional facies. The overlying non-marine sections are so variable that physical correlation is difficult.

Oil is produced from fractured, limey shales of the Niobrara Member of the Mancos at Rangely and at several fields in the Axial Basin area. Gas is also produced from silty, fractured zones of the Mancos on the Douglas Creek arch. Exploration for fracture reservoirs requires a thorough knowledge of local fracture characteristics and a great deal of courage. A cautious approach to designing drilling programs for these potential reservoirs prescribes evaluating these zones while drilling through them to deeper prospects.

Heretofore, only gas production has been established from post-Mancos Upper Cretaceous rocks. In the Piceance Creek basin these rocks represent an almost totally regressive sequence, with some transgressive interruptions only at the base. The abundance of gas and paucity of oil in these rocks may result from the fact that they are dominantly nonmarine. Basal regressive sandstone units intertongue with marine shale, but sedimentation rates may have been too high to provide optimum source conditions for oil.

Mesaverde gas in the Piceance Creek basin occurs both in the nonmarine and in the lower transitional facies. Most of the reserves established to date are in the lower facies, which are largely marginal marine sandstone units of complex beach and bar origin. These interfinger southeast with the Mancos Shale, and gas production from the sandstone beds extends from the Douglas Creek arch across the southern and southeastern part of the basin, which seems to be the optimum band of reservoir development and/or gas entrapment. Gas is produced from sandstone throughout the nonmarine upper part of the Mesaverde in the west-central and southern parts of the basin. The nonmarine facies probably contains much more gas in place than does the lower facies. The nonmarine part has had less exploration and less production established, chiefly because it contains reservoirs of poorer quality, resulting in poorer completions and deliverabilities.

Gas and some associated oil are produced from Eocene sandstone beds in the central part of the Piceance Creek basin. The gas is stratigraphically trapped, even at Piceance Creek dome, where structural closure is present. The best sandstone development occurs in the central and eastern part of the basin, and gas production occurs in the middle and upper part of the Wasatch Formation and in the basal section of the Green River Formation. The better production seems to be controlled more by association with lacustrine shale and marlstone than by simple sandstone distribution. Fluvial sandstone beds are present in the Wasatch throughout the northern two-thirds of the basin, and where lacustrine deposits are present, mostly in the central portion; the better reservoirs may have originated as lake shore and fresh-water delta deposits. A knowledge of the paleogeography and differing trends of sand development will be useful for further exploration in these rocks.

HISTORY OF OIL AND GAS EXPLORATION AND PRODUCTION

Natural gas is and will continue to be the principal production of the Piceance Creek basin. Most of the gas production is stratigraphically entrapped, and vast amounts of gas in place await drilling and development. This development is chiefly dependent upon demand, outlet, and price and, in areas of tight reservoirs, also upon stimulation and production techniques. Stimulation by nuclear or massive hydraulic fracturing techniques someday may free large reserves of gas in the Piceance Creek basin. The results of the first two experimental nuclear projects still are too preliminary to draw firm conclusions about the effectiveness of nuclear stimulation.

The earliest geological work in the area was the king and Hayden Surveys in the 1870's and 1880's. Oil and gas seeps were known in the area from the earliest days, and some were mentioned in the reports of these times. Some of the earliest reported oil seeps were in Routt County in the vicinity of Tow Creek anticline and in northwest Moffat County near Dry Monutain. Gas seeps were also reported very early in the White River Valley west of Meeker.

The earliest recorded drilling was in the area of the White River gas seep in 1890. Two wells were drilled, and shallow gas was encountered. In 1902, shallow oil was discovered in fractures in the Upper Cretaceous Mancos Shale in Rangely field at depths ranging from 500 to 1700 ft. By 1920, this production amounted to 16,000 bbls/day.

There was little petroleum activity between 1902 and 1924. The 1920's opened an important period of petroleum development in Colorado, the period of surface mapping and drilling anticlinal structures. The conspicuous structures of the nearby Axial Basin uplift received early attention, and several oil and gas discoveries were made from the Cretaceous Dakota and Niobrara Formations and the Jurassic Morrision Formation on structures in the Axial Basin area. The first sizable Tertiary production was established in 1930 with the discovery of Piceance Creek gas field.

In 1933, 31 yrs after the shallow oil discovery, the California Company first discovered oil in Pennsylvanian rocks on Rangely anticline. The deep oil was in the Weber Formation, and it opened the largest field in Colorado. Another major field was discovered in 1937 when sandstone beds of the Morrison first produced oil on the Wilson Creek structure, which had been drilled to a shallow depth earlier, finding the Dakota sandstones to be water-bearing. The deeper Entrada Sandstone, also of Jurassic age, was found productive at Wilson Creek in 1941.

Early oil and gas pipelines were short, small lines to local refineries and towns. The first oil pipelines leading out of the area were developed when Service Pipeline Company extended the old Texas Company line from Craig northward into Wyoming, and the Utah Oil and Refining Company built a line extending northeast from Rangely in 1945. In 1948, the California Company laid a 10-in. line from Rangely westward to a refinery in Salt Lake City, Utah.

The first interstate pipeline to take gas out of the area came in 1955, when the Pacific Northwest pipeline was laid from the Four Corners region through northwestern Colorado and began taking gas from fields in this area. Several smaller gas pipelines supply gas to towns in the eastern and southern parts of the Piceance Creek basin and adjacent areas.

Most of the Piceance Creek basin gas was developed during the late 1950's and the early 1960's, when the Pacific Northwest Pipeline offered the first major outlet for the area. Gas development has been somewhat cyclical and generally restricted to areas of easiest access. Because drilling and operating costs are relatively high, full-scale evaluation and development await the stimulus of greater market and higher gas prices. The recent increased interest in gas has created an upsurge in drilling and leasing, but further price improvement still is needed.

Table 1 lists the oil and gas fields of the Piceance Creek basin in the order of their discoveries and gives their producing formations and cumulative production. The fields of the Douglas Creek arch are included as part of the Piceance Creek basin.

TABLE I

OIL AND GAS FIELDS IN THE PICEANCE CREEK BASIN

(From Petroleum Information, Denver, Colorado)

Discovery Year	Field Name	Location	County	Producing Formation	Total Field Cumulative Oil and Gas Production to January 1974
1890	White River Dome	1 & 2N-96 & 97W	Rio Blanco	Wasatch	1,002 MMCF
1902	Rangely	1 & 2N-102W	Rio Blanco	Mancos Weber Shinarump	495,135,863 Bbls 673,405 MMCF
1925	Garmesa	8S-102W	Garfield	Dakota Morrison Entrada	6,512 MMCF
1930	Piceance Creek	1 & 2S-95 & 96W	Rio Blanco	Green River Wasatch	93,197 Bbls 116,010 MMCF

TABLE 1 (Continued)

Discovery Year	Field Name	Location	County	Producing Formation	Total Field Cumulative Oil and Gas Production to January 1974
1943	Douglas Creek	2 & 3S-101 & 102W	Rio Blanco	Dakota Mancos	16,263 MMCF
1947	Elk Springs	5N-99W	Moffat	Weber	528,723 Bbls 13 MMCF
1949	Asbury (abd.)	9S-101W	Mesa	Dakota Morrison	2,406 MMCF
1951	Twin Buttes (abd.)	5S-102W	Garfield	Morrison Entrada	3,289 MMCF
1951	Highline Canal (abd.)	9S-103W	Mesa	Dakota Morrison	273 MMCF
1952	Hells Hole	2S-104W	Rio Blanco	Mesaverde Mancos	207 MMCF
1953	Bar X	8S-104 & 105W	Mesa	Dakota Morrison Entrada?)	3,495 MMCF
1953	Douglas Creek, East	2S-102W	Rio Blanco	Mancos	337 Bbls 9,741 MMCF
1955	Hunter's Canyon	8S-100W	Mesa	Mesaverde	1,362 MMCF
1955	Piceance Creek, South	3S-95 & 96W	Rio Blanco	Green River Wasatch	450 Bbls 1,994 MMCF
1955	Buzzard Creek	9S-93W	Mesa	Mesaverde	3,573 MMCF
1956	Douglas Creek, North	1S-101W	Rio Blanco	Weber Mancos	16,045 Bbls 14,180 MMCF
1956	Divide Creek	7 & 8S-91W	Garfield	Mesaverde	38,564 MMCF
1956	Rulison	6 & 7S-91W	Garfield	Mesaverde	2,877 MMCF
1956	Winter Valley	5N-98W	Moffat	Dakota	272,055 Bbls 12,642 MMCF
1956	Gilliam Draw (abd.)	1N-101W	Rio Blanco	Dakota	85 MMCF
1957	Carbonera	7S-104W	Garfield	Dakota Morrison	721 MMCF
1957	South Canyon	6 & 7S-103 & 104W	Garfield	Dakota	6 MMCF
1957	Mack Creek (abd.)	2N-3W	Mesa	Dakota Morrison	251 MMCF
1957	Powell Park (abd.)	1N-95W	Rio Blanco	Ft. Union Lance?	252 MMCF
1958	Prairie Canyon	7S-104W	Garfield	Dakota Morrison	1,707 MMCF
1958	Buzzard	9 & 10S-94 & 95W	Mesa	Mesaverde	1,240 MMCF
1958	Plateau	10S-96W	Mesa	Mesaverde	4,601 MMCF
1958	Sheep Creek	9S-92W	Mesa	Mesaverde	67 MMCF
1958	Grand Mesa (abd.)	11S-94W	Mesa	Mesaverde	741 MMCF
1959	Dragon Trail	2S-102 & 103W	Rio Blanco	Morrison Mancos	420 Bbls 51,030 MMCF
1959	Baldy Creek (abd.)	7S-90W	Garfield	Mesaverde	6 MMCF

TABLE 1 (Continued)

Discovery Year	Field Name	Location	County	Producing Formation	Total Field Cumulative Oil and Gas Production to January 1974
1959	Sulphur Creek area	2S-98W	Rio Blanco	Mesaverde Green River Wasatch	1,601 Bbls 392 MMCF
1960	Shire Gulch (abd.)	10S-96 & 97W	Mesa	Mesaverde	30 MMCF
1960	Lower Horse Draw	2S-103W	Rio Blanco	Mancos	18,134 MMCF
1961	Dragon Trail North	2S-102W	Rio Blanco	Mancos	11,559 Bbls 52 MMCF
1961	Cameo (abd.)	9S-98W	Mesa	Mesaverde	29 MMCF
1961	Wolf Creek	8S-90W	Pitkin	Mesaverde	11,252 MMCF
1961	Fruita (abd.)	9S-101W	Mesa	Mesaverde	606 MMCF
1963	Douglas Creek, South	4S-102W	Rio Blanco	Dakota	293 MMCF
1964	Roberts Canyon	10S-97W	Mesa	Dakota	376 MMCF
1964	Texas Mountain	3S-102W	Rio Blanco	Mancos	4,101 MMCF
1965	Mam Creek	7S-93W	Garfield	Mesaverde	553 MMCF
1965	Hells Gulch	9S-92W	Mesa	Mesaverde	125 MMCF
1966	Horsethief Creek	8S-96W	Mesa	Wasatch	141 MMCF
1967	Coal Gulch	8S-101W	Mesa	Mesaverde	76 MMCF
1967	Colorow	2N-97W	Rio Blanco	Weber Mancos?	Shut-in
1972	Banta Ridge	1S-103W	Rio Blanco	Dakota	757 Bbls 3 MMCF
1973	Foundation Creek	4S-102W	Rio Blanco	Dakota	4,329 Bbls 30 MMCF

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THE RANGELY BOOM

Rangely Anticline was known as an anticlinal structure from the days of the Hayden Survey. In 1902, shallow production from fractured Mancos Shale was discovered, and more than two million barrels of high-gravity crude oil was produced from a myriad of wells before the deep Weber reservoir was tapped forty years later. Thus Rangely, in addition to being a local trading center for stockmen, was a small oil camp from the early years of the century.

Discovery of the Weber reservoir at Rangely was made in 1933 by the California Company with its Raven No. 1 well. However, remoteness of the area, transportation problems and market conditions did not encourage development of the field. It was not until 1943 that World War II triggered the explosion of activity that was the Rangely Boom.

The 1933 discovery well was put on production in September 1943; and the second deep test, California Emerald No. 1, was spudded in April 1944. Rigs converged from all directions, and drilling was commenced hastily by half a dozen or so companies and individuals whose leases blanketed the sprawling structure. Through 1944 and 1945, the two wells increased to 182; and at one time during 1946, 54 rigs were running at once in the field. By the end of 1948, Rangely was delimited by 473 wells.

Every oil boom has a history of unbelievable happenings, colorful characters, fortunes made and lost, hardships and heartbreak. The "Oil Basin", as Rangely was known, was remote, 100 miles over crumbling blacktop, through mud and dust from the nearest railroad. It was war time with its tangle of allocations, rationing and shortages of everything but red tape. Often a bankroll couldn't buy a hamburger for there was none to be had. Flattened oil cans, packing cases and used and re-used tarpaper were fought over for building material. Re-capped tires failed, gas coupons ran out and the milk of human kindness and decency soured in the frenzy and frustration. At times the difficulties seemed insurmountable; but bits went down, gathering lines spread over the basin, and two major pipelines snaked across country to carry the surge of crude oil northeast and west to refining centers.

Rangely shared its boom with the whole region. Craig burst into activity as the 100-mile-distant railhead; and Vernal, nearest sizable town, strained at the seams with population that could not be accommodated at the field 40 miles away. A rash of exploration activity spread over northwest Colorado and eastern Utah as new Rangelys were eagerly sought after. The Weber, however, proved to be fickle and there is just one Rangely today.

When veterans of the boom meet, there is the usual swapping of yarns, the recalling of legend and lies and some incredible truths. There are stories of fun and frustration, exhilaration and exasperation. Most swear they wouldn't have missed it for the world; but, like beachhead veterans, they hope it never happens to them again.

—Howard R. Ritzma

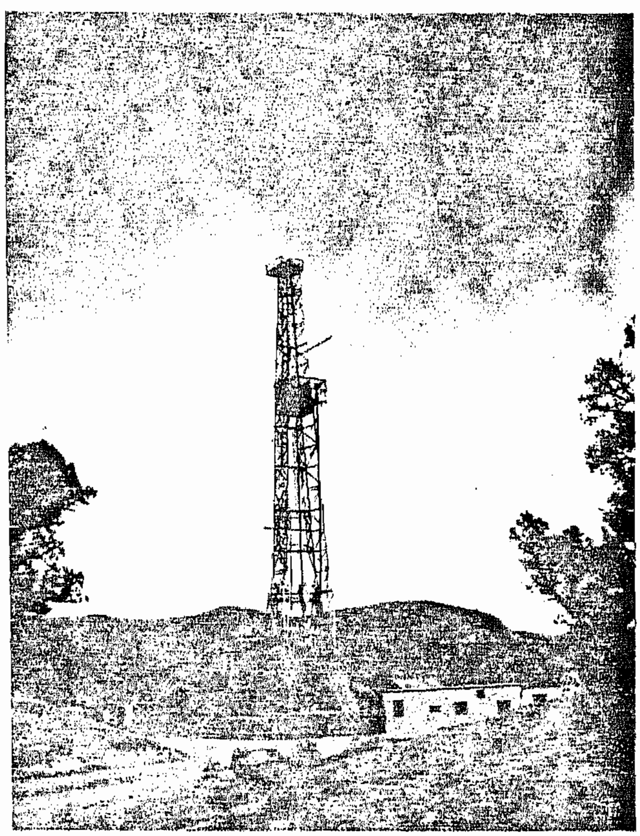
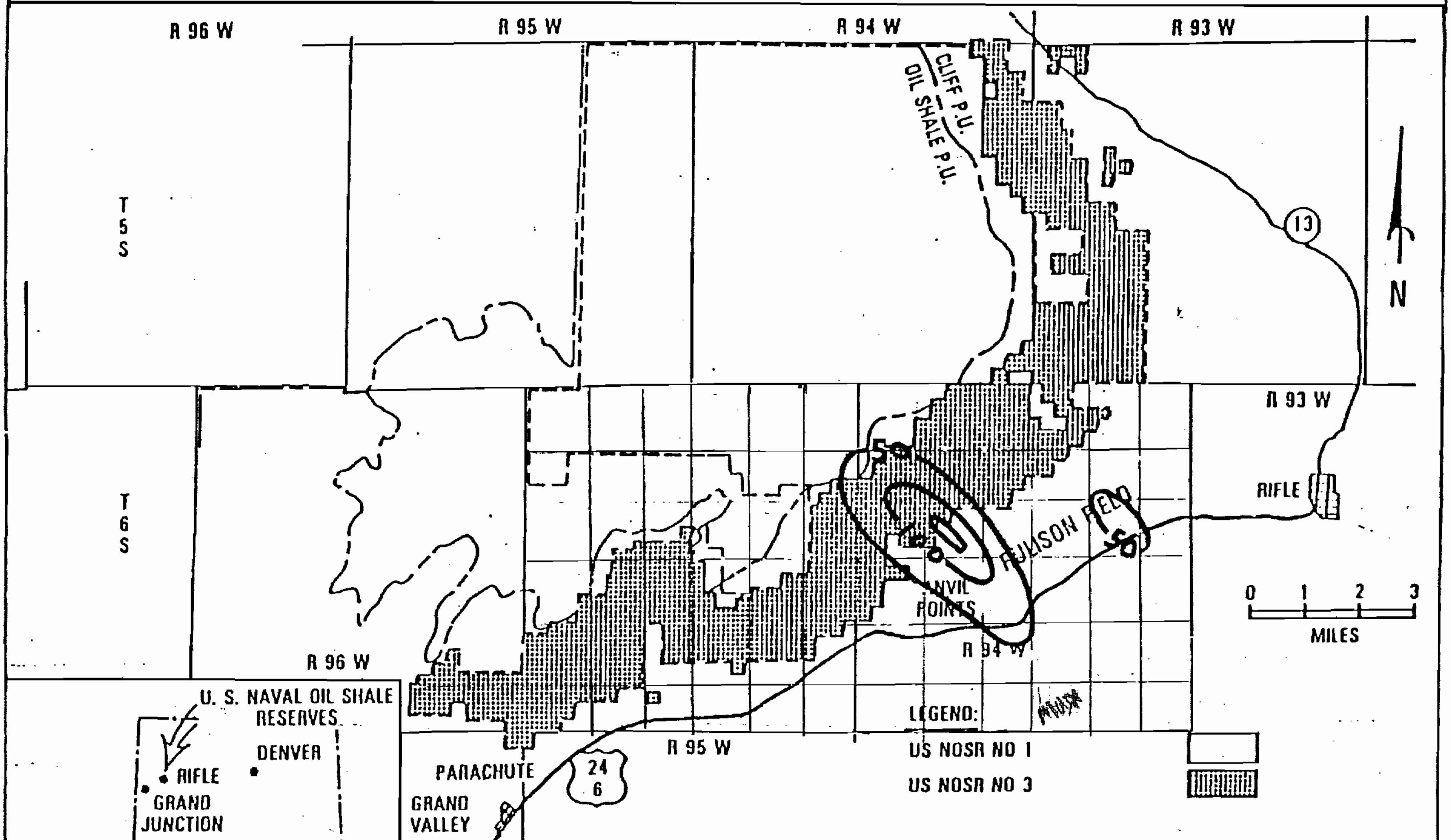


Photo by Jack Rathbone

Cities Service No. 1 Deep White River Dome (15,500′ Weber ss. test), Sec. 13, T. 2N., R. 97 W., Rio Blanco Co., Colo. (drilling July 1974)

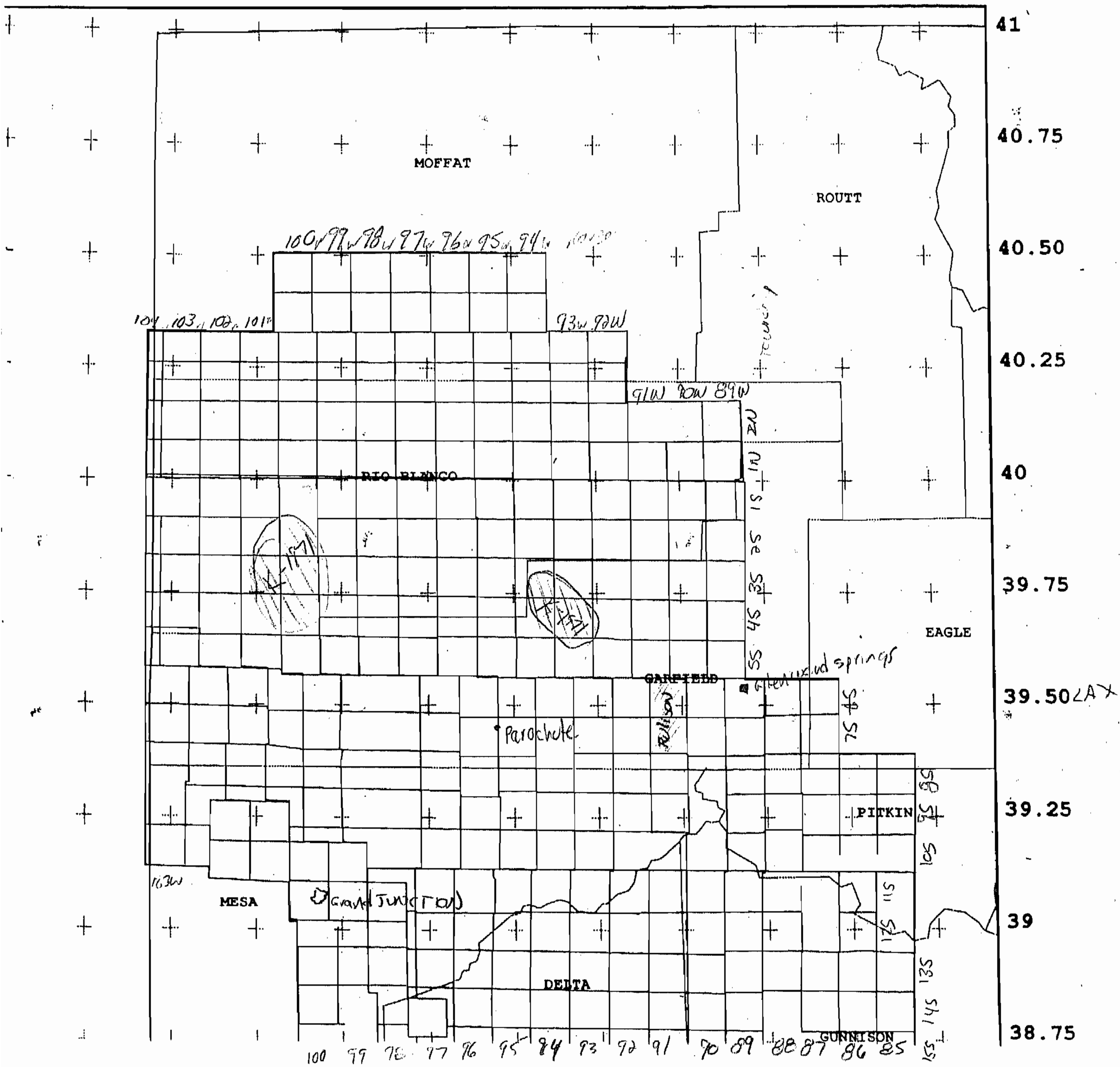
Knutson (1985)

50 + MMCF/Yr FIRST YEAR PRODUCTION MAP (M v)



GENERAL LOCATION MAP
THE NAVAL OIL SHALE RESERVES 1 & 3

FIGURE 14.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