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PETROLEUM POTENTIAL OF WILDERNESS LANDS, COLORADO

By Charles W. Spencer

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SPENCER—PETROLEUM POTENTIAL OF WILDERNESS LANDS, COLORADO 1:1,000,000 MAP I-1539

Petroleum Potential of Wilderness Lands in Colorado

By Charles W. Spencer

PETROLEUM POTENTIAL OF WILDERNESS LANDS IN THE WESTERN UNITED STATES

GEOLOGICAL SURVEY CIRCULAR 902-E

This chapter on the petroleum geology and resource potential of Wilderness Lands in Colorado is also provided as an accompanying pamphlet for Miscellaneous Investigations Series Map I-1539

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Petroleum Potential of Wilderness Lands in Colorado

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ABSTRACT

A comprehensive review of the geology of 4,501,128 acres of Wilderness Lands in Colorado has been made to assess the petroleum potential of these lands. The petroleum potential can be summarized by acreage as follows: high potential, 140.2 thousand acres; medium potential, 94.8 thousand acres; low potential 819.4 thousand acres; zero potential, 2,445.3 thousand acres; and unknown potential, 1,001.4 thousand acres. Lands classified as having unknown potential are in areas where geologic conditions are such that the potential cannot reasonably be predicted and therefore may or may not contain oil and gas accumulations. The Wilderness Lands rated as having high potential are adjacent to producing fields or on trend with production. Those wilderness tracts reported to have zero potential mostly comprise areas with exposed Precambrian rocks or very thin sedimentary cover with no potential for petroleum occurrence.

INTRODUCTION

A review has been made of the oil and gas potential of 4.5 million acres of various categories of Wilderness Lands in Colorado. The types of Wilderness Lands are shown on a map of Colorado prepared by the U.S. Bureau of Land Management (1981). These Colorado Wilderness Lands include: USFS and NPS Designated Wilderness, NPS Administratively Endorsed as Suitable (prior to 1981), BLM and USFS Further Planning or Study Areas, and BLM Lands Under Appeal.

The tectonic elements of Colorado and other Rocky Mountain States are identified and discussed by Grose (1972). The general surface geology of Colorado is shown by Tweto (1979). Structure contours on the top of the Precambrian in Colorado are shown by MacLachlan and Kleinkopf (1969). The general stratigraphy of Colorado and other Rocky Mountain States is discussed in Mallory (1972). The State of Colorado is bisected by the north-south trending Front Range uplift and adjacent Sangre de Cristo uplift. The cores of the Front Range uplift and many other mountain uplifts are predominantly Precambrian igneous and metamorphic rocks. Many of the Wilderness Lands are situated in these areas of exposed Precambrian rocks and therefore have zero potential for oil and gas. In a few localities Precambrian rocks are thrust over Phanerozoic (Cambrian and younger) rocks with low or unknown oil and gas potential.

Figure 1 is a map showing the location of Wilderness Lands in Colorado and selected basins and uplifts. These boundaries are based on geologic features and are slightly different from the province boundaries used by Dolton and others (1981) shown in figure 2, which are mostly placed along county lines in Colorado.

Through 1981, oil and gas fields in Colorado had produced 1,328 million barrels (MMB) of oil and 4,843 billion cubic feet (BCF) of gas (Colo. Oil and Gas Cons. Comm., 1981). Oil- and gas-producing reservoirs range in age from Mississippian to Tertiary. Most of the oil production comes from rocks of Permian-Pennsylvanian, Jurassic, Cretaceous, and Tertiary age. Most of the gas production is from Permian-Pennsylvanian, Cretaceous, and Tertiary sandstones. A map prepared by the U.S.

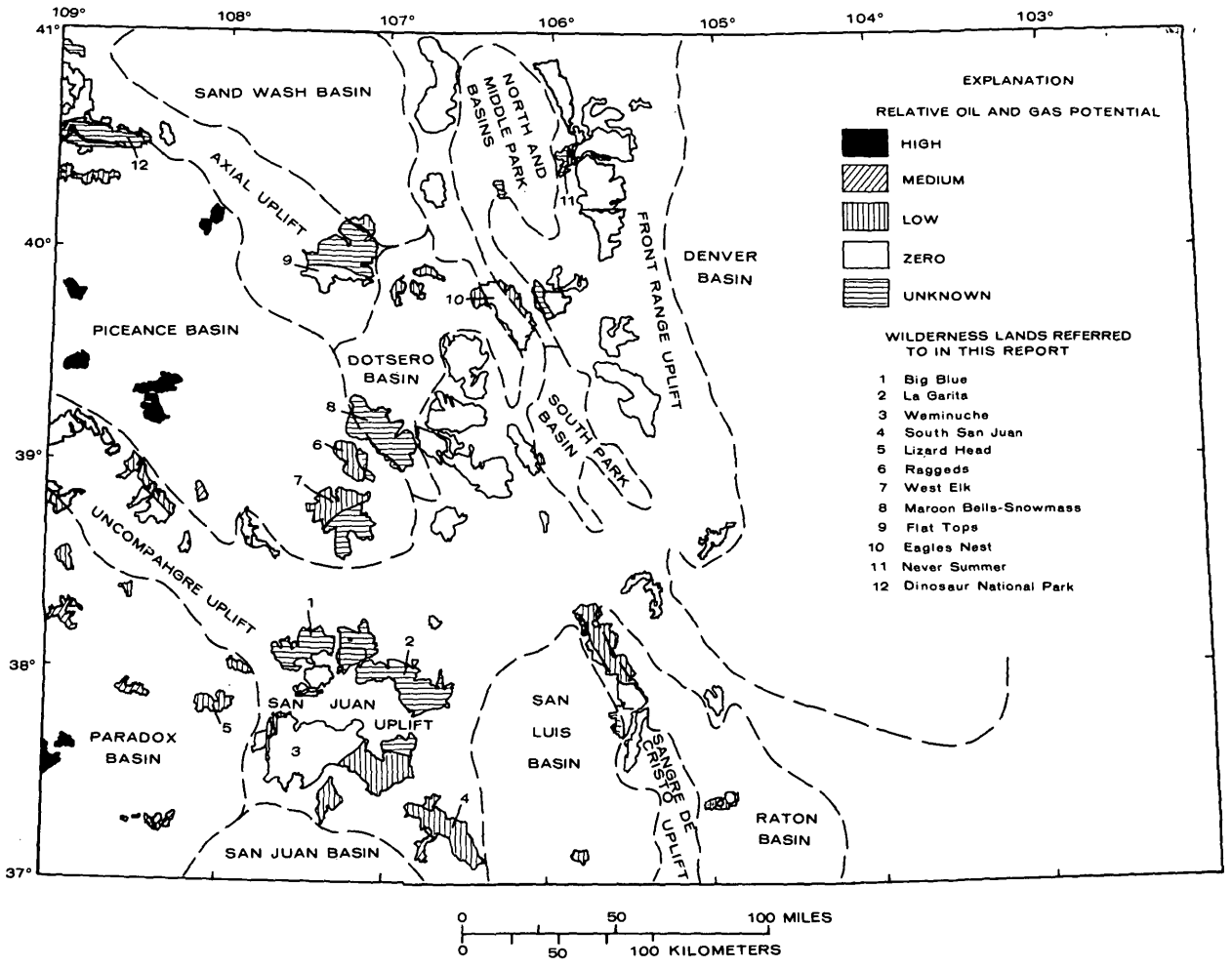

FIGURE 1.—Map of Colorado showing major basins and uplifts, Wilderness Lands, and oil and gas potential in Wilderness Lands.

Geological Survey and Colorado Geological Survey (1977) shows the more significant oil and gas fields and the age of the producing formations. Figure 3 shows the location of Colorado oil and gas fields. The geologic and engineering details of many of these fields are shown in Crouch (1982), and Fassett (1978).

ACKNOWLEDGMENTS

The many reports on the surface geology and mineral potential of Colorado Wilderness and Primitive Areas published by my U.S. Geological Survey colleagues were a valuable source of information to supplement information from wells drilled for oil and gas. I would particularly like to thank Ogden Tweto for his identification of areas where Precambrian rocks are thrust over potentially oil- and gas-productive rocks. His extensive knowledge of the geology of Colorado was also helpful in attempting to predict the presence or absence of oil and gas in areas covered by Tertiary volcanic rocks and volcaniclastic sediments.

METHODS OF EVALUATION

This evaluation is based on published and unpublished data. It takes into consideration the distribution and types of oil and gas accumulations in both producing and abandoned fields. The analysis is heavily weighted toward the known or interpreted distribution of reservoir rocks, hydrocarbon source beds, geologic history, and stratigraphic and structural style favorable for oil and gas accumulations in Colorado and adjacent States.

Hydrocarbon accumulations require four critical factors: (1) reservoir (porous) rocks, (2) hydrocarbon (organic-rich) source beds, (3) a relatively impermeable seal or barrier to prevent upward and lateral migration of hydrocarbons, and (4) favor-

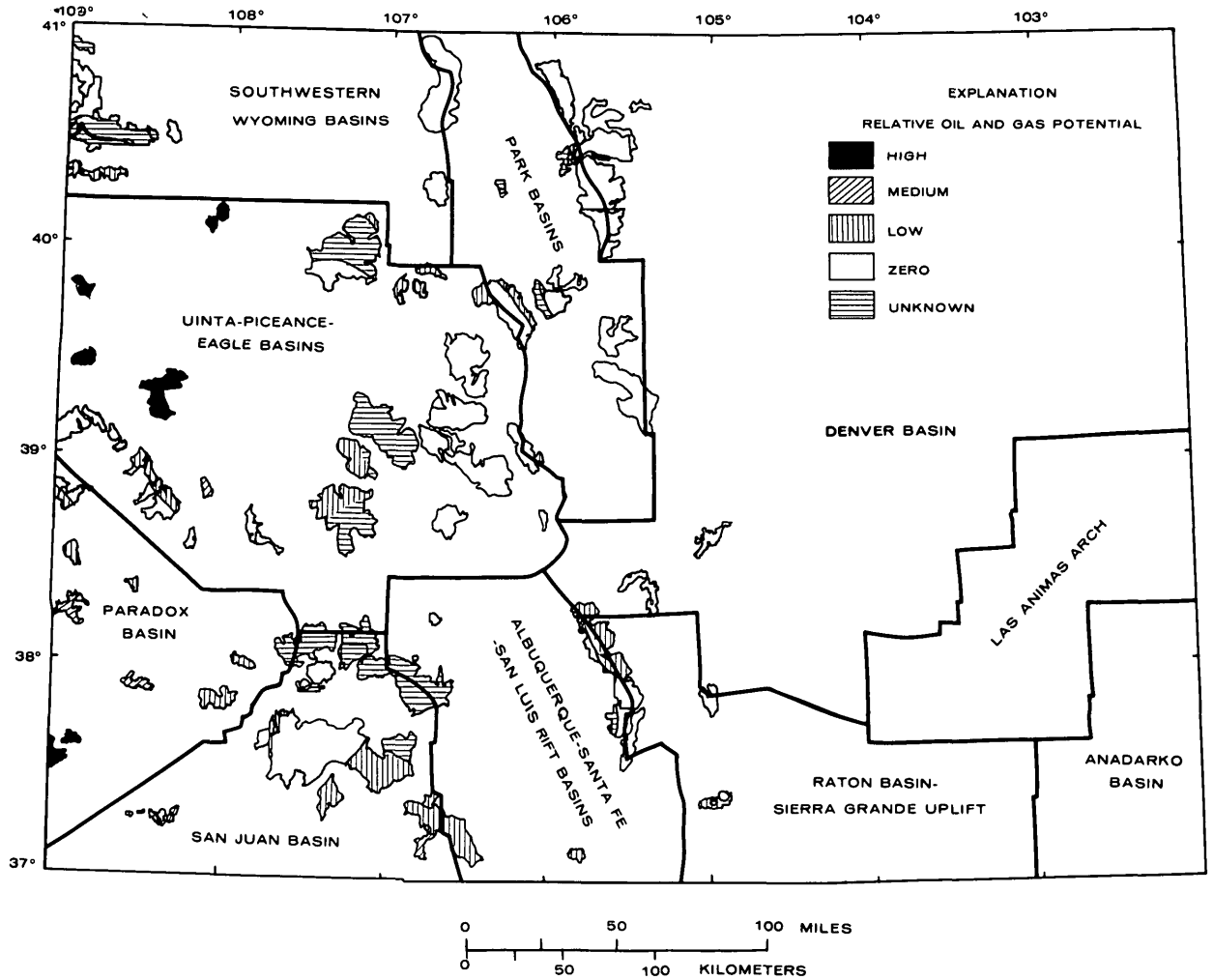

FIGURE 2.—Map of Colorado showing boundaries of USGS petroleum provinces used by Dolton and others (1981, p. 75) and location of Wilderness Lands with designated petroleum potential.

able thermal history. It is generally accepted that heat and time are required to thermochemically alter organic material (kerogen) and yield oil and (or) gas. Shallow, low-temperature gas of biologic origin is not believed to have any significant resource potential within any of the Wilderness Lands in Colorado.

Two main types of hydrocarbon traps are (1) structural traps, usually related to tectonic movement, including, but not limited to, folds (anticlines) and faults or combinations of folds and faults; and (2) stratigraphic traps, those traps formed by an updip change of porous sandstone or carbonate into impermeable shale or evaporites. In many fields the hydrocarbon trap is a combination of both structure and stratigraphy.

The relative ratings of hydrocarbon potential used in this evaluation are as follows:

High potential.—Geologic environment highly favorable for occurrence of oil and gas accumulations. Area is near or on trend with existing production from structural and (or) stratigraphic traps.

Medium potential.—Geologic environment favorable for the discovery of oil and gas fields. Contains known reservoir rocks and hydrocarbon source beds. Includes some areas of sparse subsurface control or areas where known or expected field size will be small.

Low potential.—Geologic environment interpreted to have low potential for oil and gas. Includes areas of poor or unknown hydrocarbon-source bed richness and reservoir quality. Generally includes areas of sparse or no well control and (or) expected thin section of sedimentary rocks.

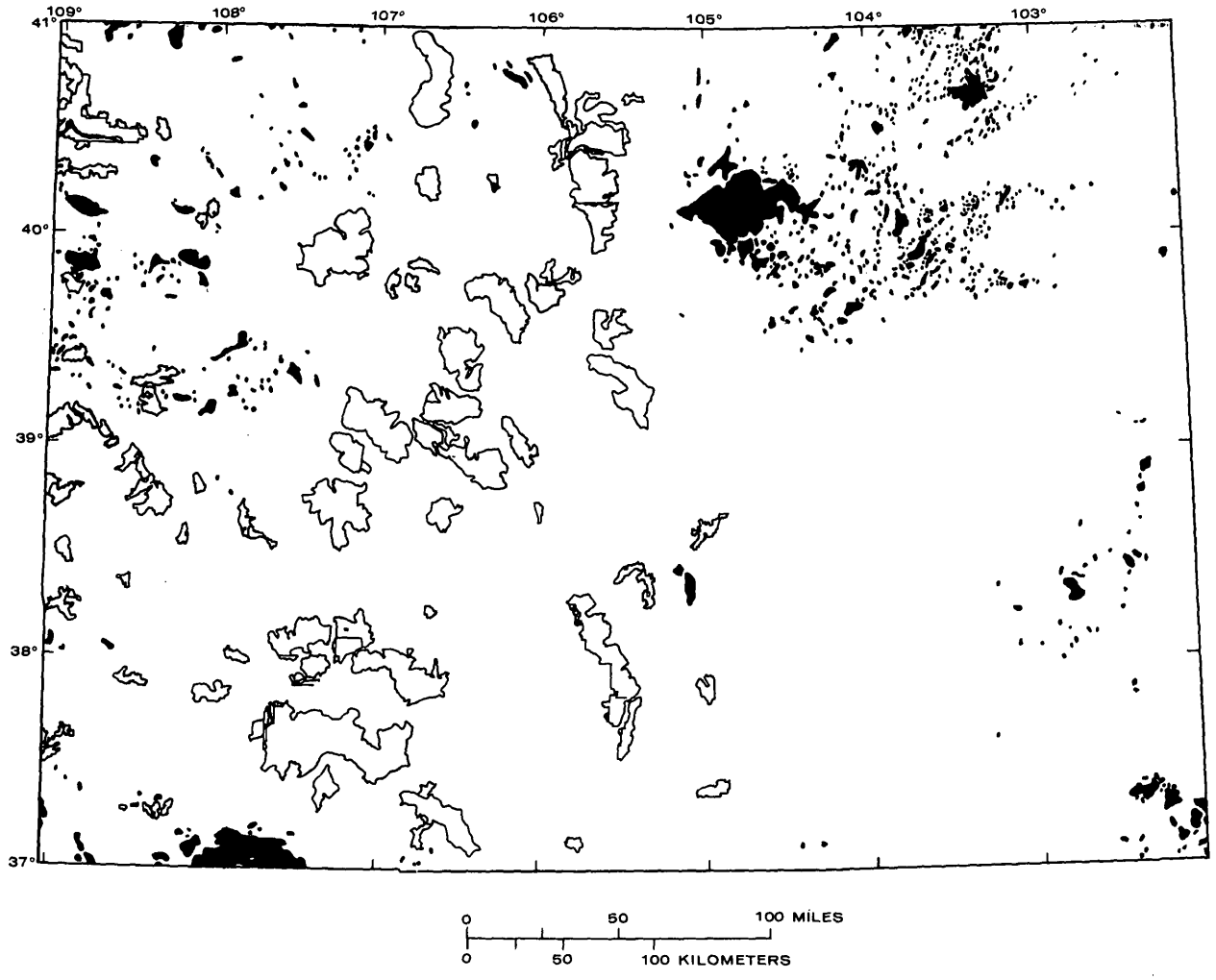

FIGURE 3.—Map of Colorado showing outlines of Wilderness Lands and oil and gas fields (shown in black) from U.S. Geological Survey and Colorado Geological Survey (1977). This map is an example of a machine-plotted map produced from the digitized wilderness data from a 1:1,000,000-scale map (U.S. Bureau of Land Management, 1981).

Zero potential.—Mostly comprises areas with exposed Precambrian rocks or very thin sedimentary cover with no potential for occurrence of sealed structural or stratigraphic traps.

Unknown potential.—Generally includes areas of no well control where Tertiary volcanic intrusions and volcaniclastic rocks are present on the surface. This cover, plus lack of subsurface well and geophysical control, makes prediction of hydrocarbon potential impossible. Includes some areas where Precambrian igneous and metamorphic rocks are thrust over Phanerozoic sedimentary rocks of unknown potential. Lack of control does not mean that no oil and gas potential exists but only that the potential can not reasonably be determined with present data.

PETROLEUM PROVINCE POTENTIALS

Province names are those used in Dolton and others (1981). The boundaries of these provinces are shown in figure 2. Selected geologic basins and uplifts of Colorado are shown in figure 1. The Wilderness Lands of Colorado are shown in the Miscellaneous Investigations Series Map I–1539 (in press) along with the qualitative petroleum potential assessments and other basic information.

RATON BASIN–SIERRA GRANDE UPLIFT PROVINCE

The Raton basin contains prospective Pennsylvanian sandstone, arkose and limestone, Triassic and Jurassic limestone and sandstone, and Cre-

taceous and Tertiary sandstone and fractured shale. The Raton basin has a few small fields but to date does not have any large oil and gas fields; however, significant carbon dioxide accumulations have been discovered in Cretaceous sandstones. Carbon dioxide is used to recover oil from depleted reservoirs and reservoirs containing low-gravity (heavy) oil. Though drilling is sparse in the basin, many of the dry holes have yielded oil and gas shows and noncommercial volumes of hydrocarbons from Cretaceous rocks. To the east of the basin, the sedimentary rocks are thin and hydrocarbon source beds are generally not present. Wilderness Lands within this province have low or zero potential. Wilderness Land with low potential in the northern part of the province is located on and adjacent to the Sangre de Cristo uplift. Potential is low here because the Pennsylvanian strata present have poor reservoir porosity, hydrocarbon source beds are generally thin, and Cretaceous strata are absent. Some of the lands on the Sangre de Cristo uplift have zero potential because of extensive exposures of Precambrian rocks.

To the south, the wilderness tract designated by BLM as 2–271 (U.S. Bureau of Land Management, 1981) is on and adjacent to the Spanish Peaks Tertiary igneous intrusions. Here, Cretaceous age rocks contain organic-rich shales, coals, and sandstone reservoir rocks but have low potential because of possible vertical leakage of hydrocarbons along the contact between the intrusives and the sedimentary rocks. Igneous intrusions per se are not particularly detrimental but in this locality the concentration of stocks and dikes is such that they downgrade the oil and gas potential. The main cores of the Spanish Peaks ingeous stocks have zero potential.

ALBUQUERQUE–SANTA FE–SAN LUIS RIFT BASINS PROVINCE

The San Luis basin part of this province (fig. 1) has no oil and gas production. Only a few oil and gas test wells have been drilled in the basin; however, many water wells producing from Tertiary and Quaternary sediments have had gas shows. This methane gas was generated by the metabolic processes of microorganisms (D. D. Rice, oral commun., 1982). The subsurface geology of this basin is very poorly known owing to lack of drilling. The few wells that have been drilled indicate that the basin is filled with a great thickness of upper Tertiary to Quaternary nonmarine deposits. Wilderness Lands have low and unknown potential within the San Luis basin.

SAN JUAN BASIN PROVINCE

The northern part of the San Juan basin province includes Wilderness Lands in the San Juan uplift area (fig. 1). The Tertiary volcanic complex of the San Juan uplift is situated west of the San Luis basin, north of the San Juan basin, and east of the Paradox basin. A small amount of oil production from Cretaceous sandstone and fractured shale has been found on the structural high between the San Luis and San Juan basins (Ryder, 1977a). Cumulative production from fields on this high area is about 6.3 MMB of oil through 1981. Wilderness Lands in the area in and adjacent to the San Juan uplift have been studied for their mineral potential (Fisher and others, 1968; Steven and others, 1969; Steven and others, 1977; Ryder, 1977b). Wilderness Lands on the north flank of the San Juan uplift in the Big Blue to La Garita Wilderness areas are rated as having unknown potential owing to thick Tertiary volcanic cover and lack of well or other subsurface control. However, Steven and Bieniewski (1977, p. 37) note that the oil and gas potential in the La Garita Wilderness is "slight at best." This large group of tracts with unknown potential is actually located at the boundaries of four provinces, as used by Dolton and others (1981) and shown in figure 2. These provinces are the San Juan basin, Albuquerque–Santa Fe–San Luis rift basins, Paradox basin, and Uinta-Piceance-Eagle basins. The western part of the Weminuche Wilderness has zero potential because of exposed Precambrian rocks. The eastern part of this wilderness tract has low and unknown potential because of a thick cover of Tertiary volcanic and volcaniclastic rocks. Prospective Cretaceous sedimentary rocks are interpreted to be present in the area with low potential. The South San Juan Wilderness and adjacent lands were discussed by Ryder (1977a; 1977b) and are rated as medium and low potential on the basis of the known or interpreted presence of prospective Cretaceous strata.

PARADOX BASIN PROVINCE

The Paradox basin (including the Four Corners Platform of Grose, 1972) of southeast Utah and southwest Colorado has many oil and gas fields (Fassett, 1978; Crouch, 1982). Producing reser-

voirs range in age from Devonian to Cretaceous. Most of the production is in the Utah portion of the basin. In Colorado most of the production comes from Pennsylvanian and Mississippian carbonate reservoirs, and Permian and Cretaceous sandstones. Donaldson and MacMillan (1980) list cumulative production and producing formations for the principal fields of the Colorado part of the Paradox basin. These principal fields produced 8,397,175 barrels of oil and 170.7 BCF of gas through 1978.

The potential of wilderness tracts in the Colorado part of the basin range from low on the north and east to high in the extreme southwest part of the State. In the north and east, Pennsylvanian source beds and carbonate reservoir rocks are thinner and of generally lower porosity. In the east, the Lizard Head Wilderness has low potential owing to the lack of nearby production and the presence of Tertiary igneous stocks; however, mineable coal beds in the Cretaceous Dakota Sandstone are present (Bromfield and Williams, 1972) and these coals could have yielded gas to adjacent sandstone reservoirs. Oil shows have been noted in two outcrop areas within 10 miles of the Mount Wilson Primitive Area (approximate area of Lizard Head Wilderness) by Bromfield and Williams (1972, p. A60). They note that this area could contain oil and gas accumulations but that the overall potential is poor. There is probably zero potential in the igneous stocks. Subsurface log and test data in the Colorado part of the Paradox basin indicate that the Pennsylvanian reservoir and source bed quality increases to the south and west. There are also oil and gas fields in this area. Hence wilderness tracts in this area have medium to high potential.

UINTA-PICEANCE-EAGLE BASINS PROVINCE

The Piceance basin of Colorado has many producing gas fields. The principal fields are listed in Donaldson and MacMillan (1980). They note that the principal fields in this basin produced 598 MMB of oil and 1,170.9 BCF of gas through 1978. Most of the gas was produced from Cretaceous and Tertiary sandstones and most of the oil came from the giant Rangely field that produces from the Permian-Pennsylvanian Weber Sandstone and fractured Upper Cretaceous Mancos Shale. Tracts in the main part of this basin have high potential because they are on trend with or adjacent to existing production.

Wilderness tracts in the south, on the northeast flank of the Uncompahgre uplift, were rated as having low potential owing to the thinner sequence of prospective Paleozoic and Cretaceous reservoir rocks in this area. Tracts higher on the Uncomphagre uplift have zero potential owing to exposed Precambrian rock or thin sedimentary strata.

In the southeast part of the basin the Raggeds and West Elk Wilderness Areas were rated as having low potential or unknown potential. Cretaceous source and reservoir rocks are present but have been intruded to varying degrees by Tertiary intrusive igneous rocks. Meeves and Bieniewski (1977) studied the mineral potential of the West Elk Wilderness and noted gas shows and minor oil shows in coreholes drilled for coal in an area between the Raggeds and West Elk Wilderness Areas.

Insufficient subsurface data are available to evaluate the oil and gas potential of the Maroon Bells–Snowmass Wilderness north of the Raggeds Wilderness Area. Therefore, the area is rated as having unknown potential. This is an uplifted, mountainous area with extensive exposures of complexly folded and faulted Paleozoic and Mesozoic sedimentary rocks intruded by Tertiary igneous rocks. If any potential exists, it is fairly low and probably would be gas associated with Cretaceous coal beds.

Some areas of low potential were identified in the Dotsero basin of Ogden Tweto (oral commun., 1983), formerly called the Eagle basin by others, and southeast part of the Sand Wash basin (fig. 1). Only a few wells have been drilled in this structurally complex area. There is no production in the Dotsero basin. The few wells that have been drilled indicate that potential exists for small production from Pennsylvanian and Cretaceous reservoirs (where present). Mallory and others (1966) studied the Flat Tops Wilderness Area and noted that the oil potential was poor in the southern part of the wilderness. This part of the Flat Tops area has been rated as having either unknown or zero potential. The north edge of the Flat Tops Wilderness was rated as having low potential for production from Mesozoic and Paleozoic reservoirs.

Tweto and others (1970) studied the mineral potential of the Eagles Nest Primitive Area and noted that the Precambrian outcrop areas had zero potential for oil and gas but that a small area of exposed Cretaceous through Pennsylvanian age

rocks on the west side of the area had some remote chance of containing oil and gas but that none is known to exist (Tweto and others 1970, p. C96). This area is located on the east side of the Dotsero basin and is rated as having low potential for oil and gas in Pennsylvanian reservoirs.

PARK BASINS PROVINCE

The North and Middle Park basin is an intermontane basin almost completely surrounded by uplifts composed of Precambrian rocks. This basin has produced 12.4 MMB of oil and 658 BCF of gas through 1981 (Colo. Oil and Gas Cons. Comm., 1981). Most of the gas has a high content of carbon dioxide and is nonflammable. The producing rocks are of Cretaceous and Jurassic age. Most of the Wilderness Lands in the Precambrian outcrop areas surrounding the basin have zero oil and gas potential; however, a small area on the east flank of this basin is an area (Never Summer Wilderness) where Precambrian rocks have been thrust over Tertiary, Cretaceous, Jurassic, and Triassic rocks (Pearson and others, 1981). This area is rated as having unknown potential. Pearson and others (1981, p. 54) interpreted the Never Summer Wilderness to have poor petroleum potential because of strong thermal metamorphism (heating); however, methane gas is thermally very stable and small amounts of flammable gas might be present.

Tract 010–155 (U.S. Bureau of Land Management, 1981), in the south-central part of the basin, has unknown potential. Here Tertiary volcanic rocks are present on the surface (Tweto, 1979) and the presence or absence of prospective Cretaceous and Jurassic rocks under this cover can not be determined. Several wells drilled north and east of this tract have tested gas from Cretaceous reservoirs. The North and Middle Park basin is connected to the South Park basin by a narrow intermontane trough. Parts of wilderness tracts on the west side of the trough and the west side of South Park basin have low potential for oil and gas. Cretaceous and Jurassic rocks with low oil and gas potential are also present under the east side of the Eagles Nest Wilderness bordering the west side of the trough. A small part of the wilderness area on the west side of the South Park basin has low potential for oil and gas in Pennsylvanian rocks. Unknown potential is given to U.S. Forest Service Wilderness Study Lands on the east side of the structural trough connecting the Park basins. Cretaceous and Precambrian rocks are exposed in this area (Tweto, 1979). The Precambrian outcrop area with unknown potential has Precambrian rocks thrust over prospective Cretaceous and Jurassic sedimentary rocks (Ogden Tweto, oral commun., 1983). Gries (1983) shows the east edge of this trough to be bounded by an east-to-west directed thrust fault.

SOUTHWESTERN WYOMING BASINS PROVINCE

The Southwestern Wyoming Basins province extends into northwest Colorado (fig. 2). In Colorado most of this area is called the Sand Wash basin (Grose, 1972). Wilderness Lands located in the southwest corner of this province (fig. 2) are located on the Skull Creek anticline and are rated as having low potential for oil and gas. These lands are geologically on the edge of the Piceance basin. The tracts are about 12 miles north of the giant Rangely oil field which produces oil chiefly from the Permian-Pennsylvanian Weber Sandstone and some oil from fractured Cretaceous shales. The tracts are mostly situated on the large, east-west trending Skull Creek anticline. The Weber Sandstone, which is the producing reservoir at Rangely, is exposed at the eastern end of the anticline, thereby greatly reducing the hydrocarbon potential of these tracts. However, Ball Associates (1965) describe scattered tar or asphaltic impregnation in Permian-Pennsylvanian, Triassic, and Jurassic rocks in the area. They note that "most of the accumulations are on the north and northeast flanks of the Skull Creek anticline and along the Wolf Creek fault * * *." (Ball Associates, 1965, p. 91). Several wells have been drilled without success on the anticline; however, one of the wells had oil shows in samples of Paleozoic carbonate rocks. The lack of success of the wells drilled on structure and the partial exposure of the reservoirs that are productive at Rangely field warrant a rating of no higher than low potential.

National Park Service Wilderness Lands in Dinosaur National Park lie north of the Skull Creek tracts. Much of these lands have unknown potential. Most of the area with unknown potential is a structurally high area that has extensive exposures of Pennsylvanian and Permian sandstone, shale, and carbonates. Several faults cut through the area and the possibilities for trapping hydrocarbons seem poor. However, Ball Associates (1965, p. 92) did report one small asphalt-impreg-

nated deposit in the Weber Sandstone in the unknown potential area.

One small tract in the extreme northwest corner of Colorado is located at the east end of, and on the north flank of the Uinta uplift (Grose, 1972). This is an area where Precambrian sedimentary rocks of the Uinta Mountain Group are exposed. A well drilled just northeast of this tract penetrated 7,100 ft (2,164 m) of overthrust Precambrian sediments and then entered Upper Cretaceous Mancos Shale (Gries, 1983). The well was then abandoned in the Weber at 13,780 ft (4,200 m). A few oil and gas shows were reported (Gries, 1983). The possibility exists that Cretaceous and older rocks may be present under this tract with unknown potential.

SUMMARY

Of the 4,501,128 acres of Wilderness Lands in Colorado included in this assessment the petroleum potential can be summarized by acreage as follows: high potential, 140.2 thousand acres; medium potential, 94.8 thousand acres; low potential, 819.4 thousand acres; zero potential 2,445.3 thousand acres; and unknown potential 1,001.4 thousand acres. The petroleum potential by acreage of all Wilderness Land categories in the Western United States is shown in this circular by B. M. Miller in table 1, chapter P.

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