Petroleum Potential of Wilderness Lands in Washington

By Thomas D. Fouch

PETROLEUM POTENTIAL OF WILDERNESS LANDS IN THE WESTERN UNITED STATES

GEOLOGICAL SURVEY CIRCULAR 902-L

This chapter on the petroleum geology and resource potential of Wilderness Lands in Washington is also provided as an accompanying pamphlet for Miscellaneous Investigations Series Map I-1546

CONTENTS

ILLUSTRATION

Petroleum Potential of Wilderness Lands in Washington

By Thomas D. Fouch

ABSTRACT

The Wilderness Lands in the State of Washington cover nearly 4 million acres and are located principally in the area of the Cascade Range and in the Olympic Mountains in the northwest part of the State. Relatively small wilderness tracts occur in northeast and southeast Washington. The potential for other than trace or show amounts of oil and (or) gas in rocks underlying Wilderness Lands of the State are relatively low.

Wilderness Lands in the Cascade Range are generally underlain by volcanic and plutonic igneous rocks and by metamorphic units of various grades. Relatively small areas in the Cascade Range province contain nonmarine sedimentary rocks, Tertiary in age, with little or no indigenous organic matter that could be thermochemically transformed into petroleumlike hydrocarbons. Reservoir rocks may be sparsely developed and source beds for the most part are thermochemically immature.

Wilderness Lands in the Olympic Mountain range occur within the western Washington basin which is underlain by a sequence of Tertiary marine sedimentary rocks. Most of the organic matter in these basin rocks is thermochemically immature, but some rocks in the deeper parts of the basin are matured locally. Oil shows have been detected in drill holes and oil was recovered from wells in the vicinity of Grays Harbor. Oil seeps are also known in the western part of the Olympic Peninsula. Although the basin contains the primary elements of a petroleum province, the basin is at best sparsely explored and is a frontier area for petroleum exploration.

The Wilderness Lands in the northeastern Washington province are primarily underlain by volcanic, sedimentary, and plutonic igneous rocks. The province has very low or zero petroleum potential. The remaining wilderness tracts occur in the central and southeastern part of the State in the Columbia River Basalt basin. The basin is characterized by basaltic igneous rocks of Neogene age that contain interbeds of nonmarine sedimentary rock rich in carbonaceous matter. Drill holes penetrating the sequence of basalt have detected gas and coal beds of lignitic rank. Gas was produced from the Rattlesnake gas field in the southern part of the basin.

A qualitative assessment of the petroleum potential of the Wilderness Lands in Washington is reported by acreage as follows: a low potential of 952.4 thousand acres and a low to zero potential of 2,940.5 thousand acres, for a total of 3,892.9 thousand acres.

INTRODUCTION

Wilderness Lands in the State of Washington are located principally in the area of the Cascade Range and extend south from the Canadian border to the Oregon State border (fig. 1). A large area of Wilderness Land is located in the Olympic Mountains in the northwest part of the State. Relatively small wilderness tracts exist in northeast and southeast Washington.

The potential for other than trace or show amounts of oil and (or) gas in rocks underlying wilderness areas of the State are relatively low. Wilderness Lands in the Cascade Range are generally underlain by plutonic, igneous, and small amounts of sedimentary rock that contains little or no indigenous organic matter that could be thermochemically transformed into petroleumlike hydrocarbons. Relatively small areas of Wilderness Land in the Cascades may contain some nonmarine sedimentary rocks that are carbonaceous, but the maturation state of this organic matter is thought to be too low to have yielded hydrocarbons. Near plutonic bodies, sedimentary rocks have been locally metamorphosed to a thermal state too high to have preserved petroleumlike compounds.

Wilderness Lands in the Olympic Mountain region of northwest Washington are largely underlain by a sequence of Tertiary marine sedimentary rocks. These rocks contain terrestrial and marine sapropelic organic matter, but the maturation state of the matter is believed to be very low.

Wilderness tracts of northeast Washington are underlain by crystalline rock and seem to have little potential to yield oil or gas. The wilderness tract in the southeast part of the State contains Tertiary lava flows that may contain interbedded carbonaceous and coaly nonmarine sedimentary rocks. These rocks could locally yield small amounts of methane where the organic matter has been transformed into gas either by bacterial action or by contact thermal metamorphism where extrusive igneous lava came into contact with rocks rich in organic matter.

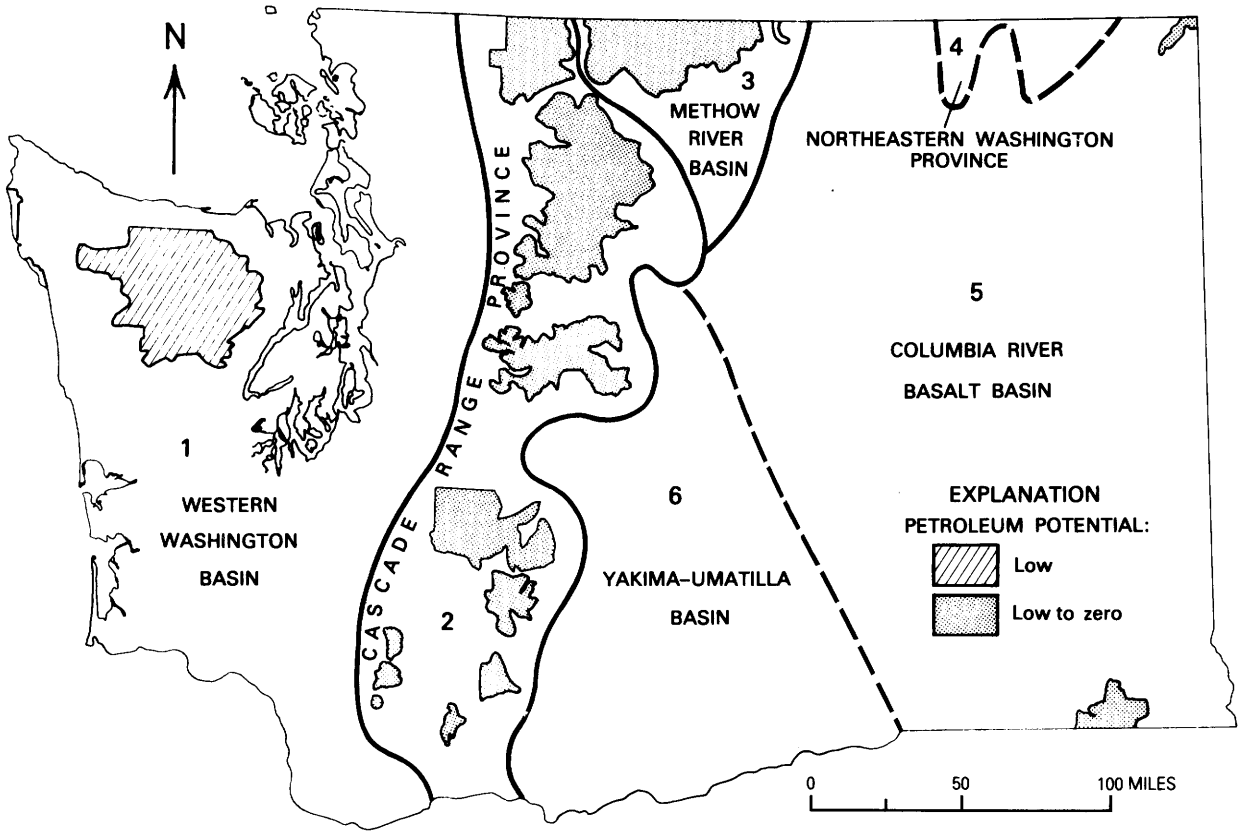

FIGURE 1.—Map of Washington State showing location of Wilderness Lands. Provinces and basins shown are (1) Western Washington basin, (2) Cascade Range Province, (3) Methow River basin, (4) Northeastern Washington province, (5) Columbia River Basalt basin, and (6) Yakima-Umatilla basin.

PURPOSE AND METHODS

The purpose of this paper is threefold: (1) to present a brief geologic characterization of rocks underlying wilderness areas in the State of Washington emphasizing those properties that can be related to evaluating the petroleum potential of the rocks for yielding hydrocarbons; (2) to indicate some of the publicly available data that can be utilized in assessing the petroleum potential of Wilderness Lands; and (3) to present a reconnaissance qualitative assessment of the potential of rocks in Wilderness Lands to yield other than show or trace amounts of petroleum. The assessments are based on publicly available data so that the assessments may be independently evaluated.

For purposes of this assessment of the petroleum potential of Wilderness Lands in Washington, rocks of the State are separated geographically into six provinces or basins in which the geologic elements are similar (fig. 1). Boundaries among the provinces and basins are approximately, and in some cases arbitrarily, drawn because the areal and subsurface extent of many of the important geologic units is uncertain. Of primary concern is the recognition of the presence and character of potential reservoir, source, and trapping units for petroleum, the principal ingredients of a petroleum province. Because oil and gas have been recovered only locally in the State, the petroleum potential of frontier nonproductive regions is estimated largely by identifying the presence or absence of organic matter in the rocks (i.e., coal, carbonaceous shale, or reports of fetid odor) and estimating the level of maturation of the organic compounds. Values of coal rank (Beikman and others, 1961; Walsh and Phillips, 1982) and vitrinite and Rock-Eval data (T. D. Fouch and D. A. Anders, 1981, unpublished data) provided the principal indices of thermochemical maturation. These indices were related to the major stages of

thermochemical maturation of organic matter into oil or gas by using the data summarized by Bostick (1979).

A qualitative estimate of the petroleum potential of the Wilderness Lands of Washington is provided by using the terms low or low to zero. Potential is used herein to indicate the expectation of detecting liquid and (or) gaseous hydrocarbons in other than trace amounts. Expressions of potential, such as low, medium, or high are relative to other areas in the State of Washington and may not equate to an expression of potential in a different hydrocarbon province. A map of Washington has been prepared at a scale of 1:1,000,000 which shows the petroleum potential of Washington's Wilderness Lands (Miscellaneous Investigations Series Map I–1546, in press).

PROVINCES AND BASINS

WESTERN WASHINGTON BASIN

The Western Washington basin is underlain principally by Paleogene and Neogene clastic sedimentary rocks formed primarily from sediments deposited in littoral to deep marine depositional settings. Basaltic volcanic units formed on the submarine floor of the Eocene ocean are nearly ubiquitous as are local accumulations of volcaniclastic sedimentary rocks formed in association with the volcanic rocks. Along the eastern margin of the basin, marine strata grade laterally into nonmarine rocks that locally contain coal. The nonmarine sedimentary rocks were formed from sediments deposited by streams flowing generally to the west. These streams were locally impounded to form wetlands along a north-south coastal plain (Buckovic, 1979). Herbaceous and woody plant material accumulated in the wetlands and was later transformed into carbonaceous rock and coal. Much of the terrestrial organic matter was flushed by the subaerial streams from the wetlands and washed into the sea and was further distributed to sites well removed from the coastline by marine processes.

Rock-Eval analyses (T. D. Fouch, and D. A. Anders, 1981, unpublished data) indicate that much of the organic matter recovered from both marine and nonmarine rocks in the basin was derived from terrestrial plants. However, sapropelic organic matter, which is a potential source of oil, has been detected in several areas of the basin in drill holes that penetrated marine shale units. Snavely and others (1977) indicate that some samples of Tertiary rocks from drill holes and surface exposures contain organic matter that can yield petroleumlike hydrocarbons upon maturation. Most of the organic matter in basin rocks is thermochemically immature, but some rocks from the deepest parts of the basin have been matured locally due to heating under a thick sequence of younger beds or by contact metamorphism with volcanic magmas.

Oil shows have been detected locally in drill holes, and oil was recovered from wells in the vicinity of Grays Harbor on the central part of the Washington coast (McFarland, 1981). Oil seeps from Oligocene and Miocene rocks are also known from the western part of the Olympic Peninsula (Braislin and others, 1971).

Arkosic sandstone reservoir beds of late Eocene and early Oligocene age are exposed in the southeast part of the basin. These same units yield gas at Mist field in northwest Oregon. These reservoir rocks can reasonably be expected to be penetrated in southwest Washington, but their areal extent is uncertain. Snavely and others (1977) give values of porosity and permeability for some beds encountered on surface exposures and in drill holes in Oregon and Washington. Wurden and Ford (1976) described Paleogene sandstones in the subsurface of the west-central part of the basin that are of such high reservoir quality that the units are utilized for underground storage of natural gas by a local utility company. These data indicate reservoir rocks are developed in the basin.

Although the basin contains the primary elements of a petroleum province, (source, reservoir, and trapping elements), the basin is at best sparsely explored and is a frontier area for petroleum exploration.

CASCADE RANGE PROVINCE

This province is principally underlain by volcanic and plutonic igneous rocks and by metamorphic units of various grade. Relatively small areas of the province contain sedimentary rocks that were formed largely in nonmarine aquatic depositional setting in the Neogene and Holocene. Some areas contain sparse Paleogene nonmarine sedimentary rocks that are rich in carbonaceous organic matter. Near the northeastern part of the province, Paleogene sedimentary rocks contain coaly beds, but the beds are not believed to be buried deeply in the subsurface of the province.

Reservoir rocks for hydrocarbons may be sparsely developed. Most potential reservoir rocks are composed of arkosic and lithic sandstones that have been variably altered to contain a variety of mineral cements that have largely reduced original porosity in the rocks to a very low value, a value perhaps too low to be a hydrocarbon reservoir rock.

Values of maturation of organic matter in sedimentary rocks of the province are highly variable. Paleogene and some Neogene units that border plutonic and other igneous units have been heated to stages of maturation beyond the range of stable liquid hydrocarbons, and in some cases gaseous hydrocarbons. Some Neogene and virtually all younger units are thermochemically immature for the generation of either gaseous or liquid hydrocarbons. Some methane may have been generated locally in very young rocks by bacterial action.

METHOW RIVER BASIN

Rocks of the Methow River basin are principally of Mesozoic and Cenozoic age and are of both a sedimentary and igneous origin. Cretaceous black marine shale, dense sandstone, and igneous units are locally abundant. Paleogene rocks in the basin contain carbonaceous shales.

Older Mesozoic rocks and some Cretaceous units have undergone at least the incipient stages of mineral metamorphism. In addition, vitrinite and Rock-Eval analyses of basin rocks indicate that all Mesozoic strata have been thermochemically matured beyond the range of stable hydrocarbons (T. D. Fouch, D. A. Anders, and M. J. Pawlewicz, unpublished data).

Analyses of the maturation of organic matter and the sparse development of reservoir units indicate that the potential for detecting hydrocarbons in the basin is low to zero. Potential source beds for oil and (or) gas may be developed in Paleogene strata, but the units are not known to be buried deeply in the basin's subsurface.

NORTHEASTERN WASHINGTON PROVINCE

This province is primarily underlain by volcanic, sedimentary, and plutonic igneous rocks. Some pre-Tertiary strata are metamorphosed. The distribution of sedimentary rocks is only partially documented, but they may be present in the subsurface beyond areas of exposure. Coal is locally developed but does not seem to be present near Wilderness Lands. The province has very low or zero petroleum potential.

COLUMBIA RIVER BASALT BASIN

This basin is characterized by the nearly ubiquitous development of basaltic igneous rocks of Neogene age that contain interbeds of nonmarine sedimentary rock rich in carbonaceous matter. Paleogene nonmarine sedimentary rocks that originated in a system of locally drained basins contain thick sequences of coal. Ancient lake beds exposed west of the basin may have been formed in lakes hospitable for the generation and preservation of lipid-rich organic matter, but this relation is speculative. Early Paleogene sedimentary rock sequences contain some interbeds of volcanic flow rocks where exposed. Most of the surface of the basin is underlain by volcanic strata.

Drill holes that penetrate the sequences of basalt have detected gas and coal beds of lignitic rank. Gas was produced from the Rattlesnake gas field in the southern part of the basin. Reservoir beds at the Rattlesnake field are fluvial and lacustrine sandstone units that are intercalated with coal in a sedimentary complex formed within the thick sequences of Neogene basalt. At least one drill hole has penetrated deeply buried Paleogene sedimentary and volcanic rocks beneath the Neogene units. These nonmarine beds are probably of Eocene and Oligocene age.

YAKIMA-UMATILLA BASIN

The basin is underlain by Paleogene and Neogene sedimentary and volcanic rocks that locally reach a thickness of greater than 6,000 meters. Mesozoic sedimentary rocks are exposed north and south of the basin, but their development in the subsurface of this basin remains speculative.

Paleogene sedimentary rocks are rich in organic matter that apparently formed in ancient basins with internal drainage. Lithic and arkosic sandstone and conglomerate beds formed from clastic debris shed off the topographically high features and formed fans that developed peripheral to the central part of the depositional and topographic basin (Frizzell, 1979). Analyses of the sedimentary rocks indicate wetlands with small lakes developed at the basin center. Swamps with herbaceous and woody plants dotted the wetland terrane. Open lake water received herbaceous and

woody plant material washed into the water from peripheral settings.

Neogene units are principally nonmarine fluvial, swamp, and volcanic units. Basalt is the dominant rock type, but it is principally developed along the basin's eastern margin.

Drill holes have penetrated Paleogene sedimentary and volcanic units that yield numerous shows of natural gas. The Eocene and Oligocene rocks have yielded noncommercial quantities of gas and some water where penetrated on possible structural traps.

Beikman and others (1961) give coal rank and other analyses of the coaly strata in the region that indicate exposed coals are of a rank that could yield gas upon thermochemical maturation. Indices of maturation from coal, Rock-Eval, and vitrinites analyses (T. D. Fouch, D. A. Anders, and M. J. Pawlewicz, unpublished data) indicate basin sedimentary rocks are thermochemically metamorphosed beyond the range of stable hydrocarbons only locally near igneous plutonic and flow rocks. These same data indicate that all of the analyzed units rich in organic matter contain terrestrial woody tissue. The presence of lipid-rich source rocks capable of yielding petroleumlike hydrocarbons is not documented.

Reservoir rock development in the basin may be the limiting factor for accumulation of other than very small amounts of hydrocarbons. Fractured volcanic rocks or porous interbeds seem to indicate reservoir units with fracture permeability are developed in Neogene strata. However, Paleogene reservoir rocks may be very limited and are not yet known to contain hydrocarbons in other than show amounts in the subsurface.

SUMMARY

Of the 3,892,921 acres included in this study for the assessment of the petroleum potential of the Wilderness Lands in Washington, the potential acreage can be summarized as follows: low potential, 952.4 thousand acres; and low to zero potential, 2,940.5 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.

REFERENCES CITED

Beikman, H. M., Gower, H. D., and Dana, T. A. M., 1961, Coal reserves of Washington: Washington Division of Mines and Geology Bulletin No. 47, 115 p.

Braislin, D. B., Hastings, D. D., and Snavely, P. D., Jr., 1971, Petroleum potential of western Oregon and Washington, and adjacent continental margin, *in* Cram, I. H., ed., Future Petroleum Provinces of the United States—Their Geology and Potential: American Association of Petroleum Geologists Memoir 15, v. 1, p. 229–238.

Bostick, N. H., 1979, Microscopic measurements of the level of catagenesis of solid organic matter in sedimentary rocks to aid exploration for petroleum and to determine former burial temperatures—a review, *in* Scholle, P. A., and Schluger, P. R., Aspects of Diagenesis: Society of Economic Paleontologists and Mineralogists Special Publication 25, p. 17–44.

Buckovic, W. A., 1979, The Eocene deltaic system of west-central Washington, *in* Armentrout, J. M., Cole, M. R., and Terbest, H. A., Jr., eds., Cenozoic paleogeography of the Western United States, Pacific Coast Paleogeography Symposium 3, Pacific Section: Society of Economic Paleontologists and Mineralogists, p. 147–163.

Frizzell, V. A., 1979, Petrology of Paleogene sandstone units in Washington, *in* Armentrout, J. M., Cole, M. R., and Terbest, H. A., Jr., eds., Cenozoic paleogeography of the Western United States, Pacific Coast Paleogeography Symposium 3, Pacific Section: Society of Economic Paleontologists and Mineralogists, p. 113–118.

McFarland, C. R., 1981, Oil and Gas Exploration in Washington 1900–1981: State of Washington, Division of Mines and Geology Information Circular 67R, 119 p.

Snavely, P. D., Jr., Pearl, J. E., and Lander, D. L., 1977, Interim report on petroleum potential and geologic hazards in the Outer Continental Shelf—Oregon and Washington Tertiary Province: U.S. Geological Survey Open-File Report 77–282, tables 2, 3, and 4.

Walsh, T. J., and Phillips, W. M., 1982, Coal rank and thermal maturation in King County, Washington: Washington Geologic Newsletter, Washington Division of Geology and Earth Resources, v. 10, no. 1, p. 9–18.

Wurden, F. H., and Ford, D. M., 1976, Appendix A, Jackson Prairie gas storage project, Chehalis, Washington, *in* Newton, V. C., Jr., and Van Atta, R. O., eds., Prospects for natural gas production and underground storage of pipe-line gas in the upper Nehalem River basin, Columbia-Clatsop Counties, Oregon: Oregon Department of Geology and Mineral Industries, Oil and Gas Investigations 5, p. 37–41.