Petroleum Potential of Wilderness Lands in Nevada

By Charles A. Sandberg

PETROLEUM POTENTIAL OF WILDERNESS LANDS IN THE WESTERN UNITED STATES

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This chapter on the petroleum geology and resource potential of Wilderness Lands in Nevada is also provided as an accompanying pamphlet for Miscellaneous Investigations Series Map I-1542

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ABSTRACT

Wilderness Lands in the Eastern and Western Basin and Range petroleum provinces are evaluated by application of plate-tectonic concepts to innovative regional-biostratigraphic and source-rock studies and by use of a unique geothermometry technique based on temperature-induced color changes in phosphatic microfossils called conodonts. Structural and stratigraphic complexities are thus deciphered and the thermal maturation of possible petroleum source rocks is interpreted. Wilderness Lands having oil and gas potential were grouped into 10 clusters in the Eastern Basin and Range province and into two clusters in the Western Basin and Range province. Of these, only two clusters have been evaluated to have a high potential, and two other clusters have been evaluated to have a medium potential. All four of these higher rated clusters are located in the Eastern Basin and Range province. The remaining eight clusters are considered to have low potential. Many Wilderness Lands, which were not clustered, are considered to have zero petroleum potential because they comprise terranes composed solely of intrusive igneous rocks, thick piles of extrusive igneous rocks, or metamorphic rocks. Although such terranes may be highly favorable to nonorganic mineral exploration, they contain no original or surviving hydrocarbons in petroleum source or reservoir rocks because of the high geothermal temperatures to which they were subjected.

INTRODUCTION

The resource evaluation of frontier petroleum provinces, such as the Eastern and Western Basin and Range provinces, presents problems quite distinct from those of already developing petroleum provinces. In developing provinces, such as the Williston basin, producing oil and gas fields provide analogs for predicting where and how similar accumulations might have formed under matching sedimentary and structural controls elsewhere in the basin. In the Basin and Range provinces, however, where subsurface well control is extremely sparse (Garside and Schilling, 1977; Garside and others, 1977), the controls necessary for petroleum accumulations—source rocks, reservoir rocks, traps, and hydrocarbon maturation—can be analyzed only by field (surface) lithostratigraphic and biostratigraphic investigations. At present, there are in Nevada only three, or possibly four, producing oil fields (Bortz and Murray, 1979; Duey, 1979; Veal, 1983), plus several deep abandoned wells that had good hydrocarbon shows and one area of significant oil and gas seeps (Foster and others, 1979). These widespread indicators of petroleum potential are located on figure 1. In addition, many small oil and gas seeps occur in and around areas of hot and cold springs (although some of these may yield only shallow biogenic gas); thin veins of solid hydrocarbons (dead oil) cutting sedimentary rocks are widespread, and some fossils such as cephalopods contain liquid petroleum (live oil).

Complicating the whole procedure of resource evaluation is the fact that the name Great Basin, which is popularly applied to the area of Nevada and western Utah, does not connote a single sedimentary or structural basin, but rather a large region of present-day interior drainage, wherein streams die out in the desert rather than feeding into larger and larger rivers that eventually reach the sea. In fact, the Great Basin represents the former northwest margin of the North American continent during the Paleozoic Era (Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods) and Mesozoic Era (Triassic, Jurassic, and Cretaceous Periods) of geologic time. Thus, the deposited sedimentary rocks, which are sources of hydrocarbons that generate oil and gas, represent many different ancient environments that have modern analogs—carbonate platforms similar to the present Bahamas Bank and Florida Bay but many times broader; continental shelves bathymetrically similar to the Atlantic Coastal Shelf; continental slopes and rises; and deep ocean basins like the Gulf of Mexico. Adding greatly to the complexity is the fact that this former margin of North America has been subjected to several plate-tectonic (oceanic plate against continent) collisions. These collisions not only have caused the continental margin to migrate progressively westward through accretion of orogenic highlands produced by the collisions but also have caused thin sheets of previously deposited sedimentary rocks to be obducted or pealed off as nearly horizontal thrust sheets and to be pushed landward across the surface of the continent. The net result is that most mountain ranges in Nevada contain rocks that have moved at least 200 kilometers (120 miles) generally eastward from their original sites of deposition. Consequently, the rocks in thrust sheets encountered by drilling below the thrust sheets closest to the surface may represent totally different depositional settings from those at the surface. Additionally complicating the structural scenario is the fact that following relaxation of compressional plate-tectonic forces, extension took place and produced nearly vertical faults that broke up the horizontal thrust sheets and allowed parts of them to be downdropped to form the desert basins between the mountain ranges. These high-angle extension or normal faults now parallel the steep fronts of ranges. Because of the many northward- and northeastward-trending, long rows of alternating ranges and basins, Nevada is more properly referred to as part of the Basin and Range province. A further complexity is that extension also permitted the upwelling of magmas through fractures and the outpouring of sheets of volcanic rocks, which have covered and obscured broad areas of sedimentary rocks.

Because of these structural complexities and extensive volcanic cover, most major oil companies almost totally dismissed Nevada as a petroleum province after conducting cursory field stratigraphic and source-rock studies during the 1950's and 1960's. A few hydrocarbon indications, such as the Bruffey oil and gas seeps, which were first reported in 1927, and the Eagle Springs oil field, which was discovered in 1954, were passed over as mere anomalies or curiosities related to Cenozoic Era (Tertiary Period) lake-basin source rocks. As discussed by Sandberg (1975) and Sandberg and Poole (1975), the myth developed that the sources of hydrocarbons in Paleozoic rocks of the Eastern Basin and Range province had been pervasively overmatured by geothermal processes and that any oil or gas that might have been generated from them had leaked to the surface along faults and fractures and long ago had been dissipated. Recent biostratigraphic and geothermometric studies of phosphatic marine microfossils known as conodonts, however, have helped to dispel these myths and to unravel the depositional and structural complexities. Studies by Sandberg (1975), Sandberg and Poole (1975), Sandberg and Gutschick (1977), and Poole, Fouch, and Claypool (1979), moreover, have suggested that oil and gas are still being generated today from Paleozoic source beds such as those in the Mississippian Chainman Shale and equivalent formations. This generation is occurring presumably after many of the faults and fractures that could have leaked oil and gas to the surface have been sealed. The Bruffey seeps (Foster and others, 1979), however, are an example of currently generated oil and gas.

AREA, PURPOSE, AND SCOPE OF REPORT

This report qualitatively evaluates the petroleum potential of 76 wilderness tracts, comprising about 4.9 million acres in the State of Nevada. An additional 3.1 million acres of Wilderness Lands have zero petroleum potential. Potential is rated as zero, low, medium, or high based on parameters that are unique to frontier provinces in Nevada and adjoining States. Such ratings are not quantitatively or qualitatively comparable to similar adjectival ratings for highly developed petroleum provinces. Ratings are based partly on thermal maturation of source rocks, as evidenced by geothermometry from conodonts in Paleozoic and Triassic source rocks and from spores and palynomorphs (microscopic plant remains) in Cretaceous and Tertiary source rocks. Potential source rocks were identified as such on the basis of organic carbon content greater than 0.5 percent. A few actual hydrocarbon analyses (Sandberg and Poole, 1975; Poole, Fouch, and Claypool, 1979) were used to substantiate the thermal maturation derived from conodont color alteration index (CAI) values (Epstein, Epstein,

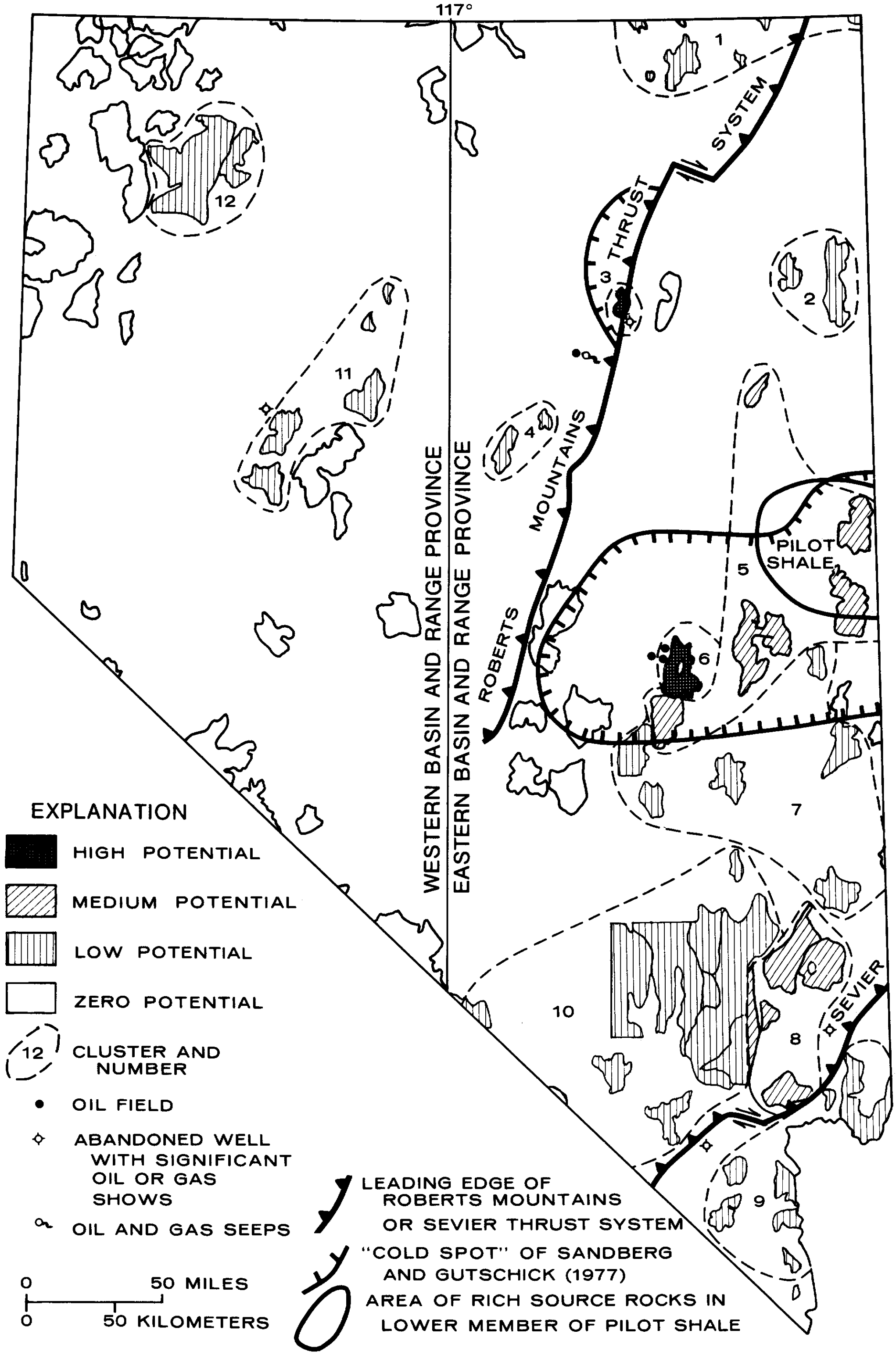

FIGURE 1.—Index map of Nevada showing petroleum provinces, Wilderness Lands and clusters, "cold spots" of Sandberg and Gutschick (1977), oil fields, and other evidence of petroleum generation.

and Harris, 1977). Ratings are also based on proximity to areas of known production or oil and gas shows and to areas of potential source and reservoir rocks. Trapping mechanisms were not considered because of a paucity of data. However, because of the great volume of source rocks, oil and gas accumulations could be expected even if all but a few percent of available hydrocarbons had leaked to the surface. Time did not permit an on-the-ground field check of most of the areas being evaluated.

SOURCES OF DATA AND ACKNOWLEDGMENTS

This report builds on 15 years of experience studying Paleozoic (mainly Devonian and Mississippian) rocks in Nevada. The knowledge gained through this experience was then applied to other areas—mainly in the Western Basin and Range province and Nevada Test Site—that are covered by the geologic literature but have not been visited personally. This report would not have been possible without benefit of the even greater experience of my Geological Survey colleague, Forrest G. Poole, who introduced me to the complexities of the Great Basin during parts of the 1968–1973 field seasons and coauthored many publications.

GEOLOGIC FRAMEWORK

A geologic map of Nevada by Stewart and Carlson (1977) is at the same 1:1,000,000 scale as the Miscellaneous Investigations Series Map I–1542 (in press), showing the color-coded qualitative petroleum evaluation of Nevada Wilderness Lands, and thus can be used to relate them to the geographic locations of basins and ranges and to the surface distribution of geologic formations. An excellent accompanying text by Stewart (1980) fully describes the geology of Nevada. A correlation chart by Langenheim and Larson (1973), although somewhat outdated in light of recent biostratigraphic advances, gives an overall picture of the distribution of geologic formations in the various mountain ranges of Nevada. Correlation charts by Poole, Sandberg, and Boucot (1977) and by Poole and Sandberg (1977) present the updated distribution of sedimentary formations of Silurian, Devonian, and Mississippian ages. Similar regional studies have been performed by other geologists for rocks of Cambrian, Ordovician, and Permian ages. Reconstruction of discrete depositional complexes or packages of rocks deposited at the same time in the geologic past, as exemplified by the reconstruction of Upper Devonian cratonic-platform and continental-shelf rocks (Sandberg and Poole, 1977), have been accomplished despite the previously described complexities. Moreover, even the ancient oceanographic and bathymetric setting of Nevada during a brief span of Mississippian time has been interpreted as part of a continentwide reconstruction by Gutschick and Sandberg (1983).

CONODONT BIOSTRATIGRAPHIC AND GEOTHERMAL STUDIES

Conodonts are the fossilized toothlike, phosphatic hard parts of enigmatic, soft-bodied organisms that lived in most marine environments during Paleozoic and Triassic times, but are now extinct. Because of their mineralogic composition (carbonate apatite), lack of internal permeable canal structures such as fish teeth possess, and imperviousness to most types of chemical alteration, they are generally preserved even in rocks that have been subjected to high-temperature metamorphism or hydrothermal solutions that destroyed other (mainly calcitic) fossil remains. The only notable change that occurs in conodonts when they are subjected to increasing geothermal temperatures, most commonly caused by increasing depth of rock burial, is a series of progressive and irreversible color changes. On the basis of color differences observed in the field and produced through high-temperature experiments in the laboratory, Epstein, Epstein, and Harris (1977) proposed a scale of conodont color-alteration index (CAI) values, numbered 1 to 8, that readily tell the maximum temperatures to which rocks have been subjected. In other words, their work established conodonts as virtual geothermometers with a scale of 1 to 8. The observed conodont CAI values can then be related to the thermal maturation of hydrocarbons contained in the rocks. The utility of conodonts as geothermometers, as virtual time planes for determining precise dates (within 0.5 million years) and rates of sedimentation, and for making biofacies interpretation of rocks deposited in greatly different paleotectonic settings in the Great Basin, was discussed by Sandberg and Poole (1977). Similar usages in nearby areas were discussed by Sweet, Harris, Sandberg, and Wardlaw (1981). The utility of conodonts to petroleum exploration in identifying source rocks and determining their thermal maturation was discussed by Sandberg and Gutschick (1977) and Sandberg (1980). Conodonts have proven to be almost infallible in determining precise ages of Paleozoic and Triassic rocks. The worldwide standard Late Devonian and Early Mississippian conodont zonations have been recognized throughout the Great Basin (Sandberg, 1979). Conodonts are also abundant and widespread in rocks of the other systems in the Great Basin and provide useful zonations, as described in a number of papers in a symposium volume edited by Sandberg and Clark (1979). The utility of Carboniferous (Mississippian and Pennsylvanian) conodonts for zonation, biofacies, and intercontinental correlation has been discussed by Sandberg, Lane, and Matthews (1979).

Because of the multiplicity of their usages, conodonts have proven to be the most valuable tool for evaluating the petroleum potential of Paleozoic and Triassic rocks in the Eastern and Western Basin and Range frontier petroleum provinces. On the basis of conodont CAI values, two "cold spots," wherein Paleozoic source rocks were abnormally cool and still within the oil-generation window, were delineated in Nevada by Sandberg and Gutschick (1977). These cold spots (CAI values of 2.5 or less) were based on conodonts contained in source rocks within the Mississippian Chainman Shale and equivalents and within the Late Devonian lower member of the Pilot Shale, whose richest source-rock area had earlier been identified and delineated by Sandberg and Poole (1975). The cold spots and the area of rich Pilot source rocks are located in relation to Wilderness Lands in figure 1. Large-scale thermal maturity maps that give the CAI values for Ordovician through Triassic rocks on a systemic rather than formational basis were compiled from many sources by Harris, Wardlaw, Rust, and Merrill (1980). These maps are invaluable in rating the wilderness tracts of Nevada.

PETROLEUM GEOLOGY

The petroleum resource appraisal of Wilderness Lands in Nevada, as elsewhere, is dependent on the four major parameters that govern accumulation—the presence of source rocks, maturation history, reservoir rocks, and traps. Because of the complex shuffling of many different rock types by several types of faulting, reservoir rocks and traps are considered to be broadly distributed throughout the State. Consequently, the prime parameter for consideration in frontier petroleum provinces, such as the Eastern and Western Great Basin and Range provinces, devolves to the presence or absence of source rocks and their maturation.

Additionally, of special importance in Nevada are present and ancient geothermal temperatures, which control the maturation of hydrocarbons in source rocks and the state of preservation of oil and gas that has already migrated into reservoir rocks. Because of the extremely complex geology, actual geothermal temperature measurements cannot be extrapolated for any great distance from their points of measurement in wells or hot springs. Consequently, geothermal-gradient and subsurface-temperature maps of North America (American Association of Petroleum Geologists and U.S. Geological Survey, 1976a, 1976b) do not map any part of Nevada except in the vicinity of the Eagle Springs oil field, and they show only data points and temperature values. Hence, conodont CAI values, which provide numerous additional data points, are of prime importance in determining the total effect of present and past geothermal temperatures on source and reservoir rocks. In areas where such rocks are slightly overmatured (CAI 3.5 to 4) at the surface, less heated rocks still may be encountered at depth in lower thrust plates. However, in broad regions that have been pervasively overheated (CAI values of 5 or greater), hydrocarbons are interpreted to have been destroyed from the surface down to great depth. Care must be taken not to extrapolate CAI values downward, however, without considering the local geologic structure. For example, in some areas, western facies rocks that have never been deeply buried (CAI 2.5 or less) occupy thin horizontal thrust sheets that veneer totally overmatured terranes (CAI 5 or greater).

In addition to the distribution of source rocks and their maturation, two other subjects must be addressed in making petroleum resource appraisals. One is the availability of a few analogs that are provided by evidence of hydrocarbon distribution from existing oil fields and known oil and gas seeps. The other is the consideration of previous qualitative appraisals that have been made by other qualified petroleum geologists.

OIL FIELDS AND OIL AND GAS SEEPS

At present there are in Nevada at least three producing oil fields—Eagle Springs field (Bortz and Murray, 1979) and Trap Spring field (Duey, 1979), which lie close together in Railroad Valley, and a newly discovered, unnamed, single-well field (Veal, 1983) in Pine Valley, which lies some distance north of the other two fields and west of the Roberts Mountains thrust (fig. 1). A possible fourth field, Currant oil field was discovered in 1978 (Foster and Dolly, 1980), but whether this field is still producing is not known. It lies north of Eagle Springs field in Railroad Valley and is the third field near the cluster shown on figure 1. The source of oil in the older Eagle Springs field commonly has been attributed to Cretaceous or Tertiary (Paleogene) lacustrine source rocks, but some workers, beginning with Picard (1960), have suggested that both Tertiary and Paleozoic affinities of the oil are possible, inasmuch as Paleozoic rocks enclose the Tertiary basin from which the oil is produced. A great difference exists between the characteristics of the oil produced at the Eagle Springs field and at the nearby, newer Trap Spring field, as discussed by Duey (1979). Thus, if one of these fields is largely from a Tertiary source, the other must be largely from a Paleozoic source, the Mississippian Chainman Shale. As pointed out in several presentations since 1975 (Sandberg, 1975; Sandberg and Gutschick, 1977), one key to characterizing oil types is the time of generation. Thus, if the major organic constituent of both the Tertiary and Mississippian rocks is somewhat similar and the Mississippian source rocks have been kept abnormally cool through most of geologic time, as indicated by low conodont CAI values, the oils being generated today from either source would be difficult to separate on the basis of physical and chemical characteristics. In fact, geochemical evidence has now documented that source rocks in the Chainman Shale have undergone two major cycles of generation and that one of these is taking place at present (Poole, Fouch, and Claypool, 1979).

Little is known about the recently discovered producing oil well that lies west of the leading edge of the Roberts Mountains thrust system (fig. 1). The source of oil could be the Ordovician Vinini Formation or Cretaceous-Tertiary lacustrine beds, as suggested by Veal (1983) or just as likely the Mississippian Chainman Shale or its lateral equivalents, the Diamond Peak and Webb Formations. This field lies close to the Bruffey oil and gas seeps (Foster and others, 1979), which suggest that petroleum in the vicinity is either migrating or being generated today. It also lies close to the smaller of the two cold spots of Sandberg and Gutschick (1977) and to a deep well that had significant oil shows in highly fractured or faulted rocks (fig. 1).

SOURCE ROCKS

In the Eastern Basin and Range Province, the Mississippian Chainman Shale and locally the equivalent part of the Woodman Formation contain the thickest, richest, and most widespread source rocks in the area (fig. 1) between the Sevier and Roberts Mountains thrust systems and for a short distance to the west (Sandberg, 1975; Poole and Sandberg, 1977; Poole and others, 1979). Locally, however, in east-central Nevada, the lower member of the Pilot Shale contains even richer source beds in the area outlined on figure 1 and equally rich source beds in an aureole to the northwest, west, and south. Source beds within the Chainman and Pilot are generally at the optimum maturation for oil generation within the larger cold spot of Sandberg and Gutschick (1977). This cold spot lies in the general area of, but extends farther east than, the Prichards Station, Pancake Range, and Warm Springs lineaments of Ekren and others (1976). In fact, the southern limit of the cold spot appears to be an eastward continuation of their independently hypothesized Warm Springs lineament. The Permian Meade Peak Tongue of the Phosphoria Formation (Maughan, 1979) may be a source rock in the extreme northern part of the province. The Ordovician Valmy and Vinini Formations and Devonian Woodruff Formations almost certainly are extremely rich source rocks in the area west of the Roberts Mountains thrust (fig. 1). The organic-carbon content of Mississippian source rocks in adjacent States and the difficulties encountered in estimating the organic-carbon and hydrocarbon values from outcrop samples were discussed by Sandberg, Grogan, and Clisham (1979).

Throughout the Eastern Basin and Range province, Cretaceous to Tertiary (Paleogene) lacustrine oil shales that were deposited in former lake basins between the mountain ranges may act as source rocks (McDonald, 1973; Fouch and others, 1979). Such rocks cover at least half the surface area of the province. In most areas, the hydrocarbons in these source rocks are regarded as immature. Locally, however, where they have been additionally heated by deeper burial, intrusive igneous rocks, or hydrothermal solutions, the contained hydrocarbons could be well within the oil-generation window.

In the Western Basin and Range province, Paleozoic rocks are no longer believed to contain source rocks because of broad areas of pervasive high geothermal temperatures, as exemplified by the Battle Mountain heat-flow high (Hyde, 1979). Cretaceous and Tertiary (Paleogene) lacustrine rocks in some parts of this province may be at or near optimum maturation at least at depths below 2,500 meters, as suggested by analyses reported by Hastings (1979). Possible Tertiary source rocks are present throughout most of the province (McDonald, 1973; Warner, 1980). Cretaceous source rocks may be present in the northern part of the province (Willden, 1979). However, a possible connection between the Sierra Nevada and Idaho batholiths has been postulated in that area by Taubeneck (1971). If such connecting igneous rocks exist at depth, any overlying source rocks would have been overmatured.

PREVIOUS QUALITATIVE APPRAISALS

In addition to my earlier evaluations of the petroleum potential of the Eastern Basin and Range province based on Paleozoic source rocks (Sandberg, 1975; Sandberg and Poole, 1975; Sandberg and Gutschick, 1977), three other evaluations have been presented at meetings of the American Association of Petroleum Geologists. Meissner (1978) discussed possible source rocks, existing oil fields, and dry (biogenic) gas accumulations. Foster and Dolly (1980) discussed methods of exploration, oil and gas indications, and possible stratigraphic and structural traps. Veal (1983) discussed possible Paleozoic and Cretaceous to Tertiary source rocks, mainly west of the Roberts Mountains thrust (fig. 1). The only evaluation of oil and gas possibilities based on wells drilled at the south end of the Eastern basin and Range province, adjacent to the Sevier thrust system (fig. 1), was made by Bissell (1973). Some of the exploration techniques employed by the petroleum industry in searching for a new prospect, as discussed by Dolly (1979), are highly relevant to the present evaluation of the petroleum potential of Nevada Wilderness Lands.

EVALUATION OF WILDERNESS AREAS BY CLUSTERS

The State of Nevada is arbitrarily divided into the Eastern and Western Basin and Range provinces by the 117° meridian (fig. 1). This province boundary projects the Oregon-Idaho State line southward from its junction with Nevada. It was selected because of the difference in source rocks between the two parts of the State and because the area of greatest heat flow lies generally west of the 117° meridian. This is exemplified by the maps of geothermal areas presented by Hyde (1979). Within each province, for ease of treatment, wilderness tracts are grouped into clusters on the basis of similar petroleum potential, inferred from matching geologic settings, source rocks, organic maturation, and distance from known oil production or oil and gas shows.

EASTERN BASIN AND RANGE PROVINCE

This province contains 10 clusters (fig. 1): clusters 1, 2, 4, 7, 9, and 10 are rated to have low petroleum potential; clusters 5 and 8 are rated to have medium potential; and clusters 3 and 6 are rated to have high potential. All Wilderness Lands outside these clusters are rated to have zero potential.

Cluster 1.—This cluster is identical in its geologic setting to Idaho wilderness cluster 4 discussed by C. A. Sandberg, chapter F, in this circular. Both clusters are underlain by Tertiary lake beds of the Lake Bruneau basin (Warner, 1980) but are covered at the surface mainly by slightly younger volcanic rocks. Little is known about the few small windows of presumably overmatured Paleozoic rocks that poke out from the extensive volcanic cover. Because the heating by volcanic rocks and minor areas of intrusive rocks may have raised the temperatures of some of the Tertiary source beds to optimum maturity, this cluster is rated to have a low potential. Quantitative resource estimates discussed by B. M. Miller, chapter A, in this circular were made using the Idaho-Snake River Downwarp province as an analog, instead of the Eastern Basin and Range province.

Cluster 2.—Wilderness Lands in this cluster lie in the mountain ranges that border the Steptoe Valley, where there has been some recent shallow exploratory drilling for reservoirs in Cretaceous to Tertiary lacustrine beds. The ranges themselves are composed mainly of Paleozoic rocks, which are largely overmatured thermally (CAI greater than 4). Some conodont samples (Harris and others, 1980) have CAI values that are within the oil- and gas-generating range, however. Because of the proximity to economically interesting lacustrine beds and the possibility of some Paleozoic source beds being at optimum maturity, this cluster is rated to have a low potential.

Cluster 3.—This cluster lies on or close to the buried trace of the leading edge of the Roberts Mountains thrust system (fig. 1). Cretaceous to Tertiary tuffaceous lacustrine beds and upper Paleozoic rocks that underlie the wilderness tracts are partly obscured by alluvial cover. Because this cluster is situated within one of the cold spots of Sandberg and Gutschick (1977), within a few miles of two deep wells that had excellent petroleum shows and less than 25 miles from a producing oil well and significant oil and gas seeps, it is a prime area for petroleum exploration and is rated to have a high potential.

Cluster 4—Wilderness Lands in this cluster are situated in the Roberts and Simpson Park Mountains. They are underlain mainly by Paleozoic sedimentary rocks and partly by Tertiary volcanic rocks. Rocks of the lower fault plate exposed at the surface generally are thermally overmatured (CAI 3.5 to 4), but those on the upper plate of the Roberts Mountains thrust, which contain rich source rocks, may have CAI values as low as 1 (Harris and others, 1980). Because lower temperature rocks, at optimum maturation for oil and gas generation, form a veneer on higher temperature rocks and because there is little indication of which temperature range might be encountered in rocks of lower fault slices at depth, this cluster is rated to have a significant but low potential.

Cluster 5.—Wilderness Lands in this cluster are situated in the Cherry Creek, Snake, Schell Creek, southern Egan, and Grant Ranges. They are underlain by Paleozoic sedimentary rocks that include the Chainman Shale in all five ranges and the lower member of the Pilot Shale in all but the Grant and southern Egan Ranges (fig. 1). All but one of these tracts lie within the larger cold spot of Sandberg and Gutschick (1977), and hence source rocks in the Chainman and Pilot are regarded to be at optimum maturation for oil and gas generation. Additionally, some of these tracts lie close to Railroad Valley, which is currently the main oil-producing area in Nevada. Because of the optimum maturity of source rocks and moderate proximity to oil fields, this cluster is rated to have a medium potential.

Cluster 6.—The single wilderness tract that constitutes this cluster lies in the Grant Range and is underlain by Paleozoic sedimentary rocks and Tertiary volcanic rocks. This cluster is regarded to have high petroleum potential because it directly borders the three oil wells in Railroad Valley and because Cretaceous to Tertiary source rocks in the valley and Paleozoic source rocks in the range are at optimum maturation for oil and gas generation.

Cluster 7.—Wilderness Lands in this cluster are underlain almost entirely by Tertiary volcanic rocks except for several small patches of Paleozoic sedimentary rocks. Nothing is known about the maturation of source beds in the Paleozoic rocks. However, because of the presence of volcanic rocks, some of the Cretaceous to Tertiary source beds in adjacent valleys may be thermally mature. Hence, this cluster is rated to have a low petroleum potential.

Cluster 8.—The five tracts that compose these clusters are situated in the Mormon, Muddy, and Meadow Valley Mountains, and Arrow Canyon and Las Vegas Ranges. On the basis of my own field work, I am familiar with both the local geology and conodont CAI values. Most of the tracts are underlain by Paleozoic sedimentary rocks that have CAI values of 2.5 to 3.5, but the southernmost tract also includes some Cretaceous to Tertiary lacustrine beds. A recent dry hole drilled just east of this cluster (fig. 1) had significant oil and gas shows, which I interpret to have been generated from Mississippian source rocks farther west, within cluster 8. Because the CAI values indicate organic maturation that is close to the upper limit for oil generation but in the optimum range for gas generation and because of significant nearby oil and gas shows, this cluster is rated to have a medium potential.

Cluster 9.—Tracts in this cluster are situated in several low mountain ranges bordering Lake Mead and south of the city of Las Vegas. They are partly underlain by areas of Precambrian metamorphic and intrusive rocks that have zero petroleum potential, partly by Tertiary volcanic rocks, and partly by Paleozoic, Mesozoic, and Tertiary sedimentary rocks. This cluster lies east of the Sevier thrust system, so Paleozoic source rocks, such as the Chainman Shale, are not present. The Mesozoic rocks are not believed to contain source beds, but some of the Tertiary rocks may. Because of nearby oil and gas shows, one of which was described by Bissell (1973), and recent exploratory drilling in the area just to the north, this cluster is regarded to have low petroleum potential, despite the thinness of the sedimentary sequence and the scarcity of source rocks.

Cluster 10.—This cluster comprises mainly the Nevada Test Site (fig. 1, large square group of tracts) and several smaller tracts in mountain ranges to the west. Most of these tracts are underlain by Paleozoic sedimentary rocks covered by small patches of Tertiary volcanic rocks and Cretaceous to Tertiary lacustrine rocks. A large part of this cluster has been thermally overmatured (CAI 4 to 5), but many conodont CAI values reported by Harris and others (1980) have a range of 2.5 to 3.5. Because such values are at the upper end of the oil-generation window and well within the gas-generation window, the cluster is regarded to have a low petroleum potential.

WESTERN BASIN AND RANGE PROVINCE

Because of widespread pervasive geothermal heating, only two clusters of Wilderness Lands have potential in this province. Both clusters, 11 and 12, have a low petroleum potential.

Cluster 11.—Tracts in this cluster are situated in the Stillwater and Tobin Ranges and Augusta Mountains. The tracts are underlain mainly by upper Paleozoic and Mesozoic sedimentary rocks, the source-rock potential of which is not known. However, Carson Sink, which is underlain by rocks of the Tertiary northern Fallon basin (Hastings, 1979), lies just west of the southern two tracts in this cluster. The Fallon basin has been explored by a large number of shallow (less than 1,000 meters) wells (Garside and Schilling, 1977), some of which recovered dry (biogenic) gas. At least one deep test, just west of cluster 11 (fig. 1), cores of which were analyzed for source-rock potential by Hastings (1979), gave indications that thermal maturation was occurring at about 2,500 meters depth. Similar Cretaceous to Tertiary basins lie among the tracts in this cluster. Consequently, this cluster is regarded to have a low petroleum potential.

Cluster 12.—Tracts in this cluster are situated in the Black Rock Desert and in ranges on either side of it. Little is known about the rocks in the Black Rock Desert because of an extensive alluvial cover. However, Willden (1979) has speculated that it is underlain by potential source and reservoir rocks and that it appears highly favorable for exploration. On the other hand, Taubeneck (1971) has speculated that the area may be underlain by intrusive igneous rocks forming a connection between the Sierra Nevada and Idaho batholiths. Because of these conflicting interpretations the cluster is regarded at this time to have a low petroleum potential.

SUMMARY

Of the 7,980,608 acres covered in this assessment of the petroleum potential of Wilderness Lands in Nevada, the potential acreage can be summarized as follows: high potential, 132.4 thousand acres; medium potential, 1,099.1 thousand acres; low potential, 3,631.2 thousand acres; and zero potential, 3,117.9 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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