Petroleum Resource Assessments of the Wilderness Lands in the Western United States

By Betty M. Miller

PETROLEUM POTENTIAL OF WILDERNESS LANDS IN THE WESTERN UNITED STATES

GEOLOGICAL SURVEY CIRCULAR 902-A

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ABSTRACT

The USGS conducted an investigation of the oil and gas resource potential of the designated and proposed Wilderness Lands in the Western United States. These assessments are based upon a Wilderness System containing approximately 74 million acres of Wilderness Lands in the States of: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The Wilderness Lands are administered under four Federal agencies: Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), and Fish and Wildlife Service (FWS). The Wilderness Lands included in this study are identified under the following categories: Designated Wilderness, Administratively Endorsed as Suitable (prior to July 1981), Further Planning or Study Areas, BLM Lands Under Appeal, BLM Wilderness Inventory Not Completed, and U.S. Forest Service RARE II under litigation in California.

This paper defines the background, scope, and objectives of the study and discusses the procedures and methods used to combine a variety of geologic and geographic data, along with logged information on wells and petroleum statistics, by applying computer and digital cartographic techniques for the purpose of assessing the petroleum resources in the Wilderness Lands.

The methodology briefly described in this paper involves a review by geologists of existing information and evaluating the geologic characteristics for each wilderness tract to determine the favorability, or lack of favorability, for petroleum occurrence. Basic assumptions incorporated into the resource-appraisal methods are (1) resource potential is not uniformly distributed throughout a petroleum province; (2) total distribution of all recoverable petroleum resources is considered, both discovered and undiscovered; and (3) consideration of all the geologic characteristics essential for the occurrence of petroleum resources for each wilderness tract.

The assessments of the petroleum resources are analyzed in two phases: by a designated qualitative rating of the petroleum potential for each wilderness area, displayed on State maps; and by estimating the amounts of oil and gas within each province or basin that occur in the Wilderness Lands, expressed as probability distributions for the quantitative estimates.

INTRODUCTION

The U.S. Geological Survey (USGS), in 1975 and 1981, completed and published two separate assessments of the remaining conventional, undiscovered petroleum resources, both onshore and offshore, for the United States (Miller and others, 1975; Dolton and others, 1981). These assessments were conducted on a regional basis within the geologic framework of the country and the results were reported by basin or geologic province for all lands regardless of ownership. Petroleum resource assessments were not separately determined or reported by land ownership, whether on public or private lands. Thus a systematic study to assess the petroleum resources occurring for all the respective Federal land categories has not been conducted by the USGS. The two basic reasons for this have been due (1) to the Geological Survey's past philosophy of conducting petroleum assessments on a regional scale (with the exception of Outer Continental Shelf (OCS) tract assessments by the former Conservation Division, now the

Minerals Management Service (MMS)); and (2) to limitations on the availability of time, workforce, budget, and essential data for assessing resource potential for tract-sized areas.

In the last few years, national concerns over sources for continuing energy supplies within the United States have generated many controversial issues centering around the probable occurrence of energy and nonenergy minerals on Federal lands with limited access to exploration and development, particularly in Wilderness Lands. In light of the fact that the USGS had not assessed the Federal onshore lands separately from the total province assessments, a pilot program was started in the USGS in the spring of 1982 to conduct an investigation, based upon currently available information, of the potential oil and gas resources in the designated and proposed Wilderness Lands for the Western United States. This pilot study for the Wilderness Lands of the Western United States will provide a framework for conducting similar assessments for the remaining Federal lands.

Future petroleum assessment studies of this nature on the remaining Federal lands of the United States will be compatible to application by the USGS in its Federal Mineral Land Information System (FMLIS). FMLIS is being developed in support of the USGS's charter to collect, analyze, and disseminate information about the Nation's water, mineral, and energy resources. Specifically, FMLIS is designed as a tool for developing land management and policy objective regarding the Nation's strategic and critical minerals and energy resources. Central to this objective is the creation of a data base on Federal surface ownership, subsurface mineral rights, Federal restrictions to mineral development, and resource occurrence and potential input similar to this study for the Wilderness Lands.

BACKGROUND

The Federal Government owns approximately 738 million acres of land in the United States, nearly one-third of the Nation's entire land area. It also retains control over the subsurface mineral rights to an additional 66 million acres (Bureau of Land Management, 1980). Approximately 49 percent of all the onshore Federal lands lie within the borders of the 11 Western States. Thirty-one percent of these Federal lands, classified as designated and proposed Wilderness Lands, are included in this study (American Petroleum Institute, 1981a).

The Federal Government also controls the submerged lands under the OCS seaward of State ownership. These offshore Federal lands are estimated to cover nearly 1 billion (965.8 million) acres (U.S. General Accounting Office, 1981). Of this acreage, some 528 million acres lie shoreward of the 200-meter water depth.

Numerous studies by industry, government, and academic scientists have been done on various segments of these Federal lands; many of these studies forecast that large percentages of this Nation's future energy and mineral resources may lie beneath Government-controlled lands. No one can be sure of the accuracy of these estimates because most of these lands have not been open to any kind of exploration and data are limited. However, scattered information does exist within or adjacent to many of these Federal lands that is useful to the geologist for interpretative purposes to appraise the geologic characteristics favorable for the occurrence of energy and mineral resources on these lands.

PURPOSE AND SCOPE OF STUDY

It is the objective of this study to assemble through various means all the available pertinent information that can be brought together within the USGS and which can be focused upon the single issue of reviewing the geological and geophysical data to determine the geologic characteristics favorable or unfavorable for the occurrence of petroleum resources in Wilderness Lands.

In this initial effort the scope of the study is limited to conventional petroleum resources occurring in all the designated and proposed Wilderness Land categories in the Western United States, as of July 1981. This includes the Wilderness Lands administered under four Federal agencies: Bureau of Land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), and Fish and Wildlife Service (FWS). The Wilderness Lands included in this study are identified under the following categories: Designated Wilderness, Administratively Endorsed as Suitable (prior to July 1981), Further Planning or Study Areas, BLM Lands Under Appeal, BLM Wilderness Inventory Not Completed, and U.S. Forest Service RARE II under litigation in California (Bureau of Land Management, 1981a–j).

The area of the study includes approximately 74 million acres of Wilderness Lands in these 11 Western States: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming (fig. 1).

COMMODITIES ASSESSED

In the regional petroleum assessments of the USGS, published as Open-File Report 82-666–A (Varnes and others, 1982), separate estimates were provided for crude oil, associated-dissolved gas, and nonassociated gas; an estimate for total gas, which is an aggregate of the separate gas estimates, based on the assumption that one or both are present, was provided also.

In this assessment for the Wilderness Lands the two commodities assessed are the conventionally recoverable crude oil and total natural gas. The associated-dissolved gas has not been reported on separately in this paper, but is included as a part of the total natural gas.

Definitions for commodity and resource terms and a summary of the methods used to derive the regional resource estimates are documented in USGS Circular 860 (Dolton and others, 1981).

REGION AND PROVINCE LOCATIONS AND BOUNDARIES

The nationwide petroleum resource appraisals reported by the USGS in 1975 and 1981 were conducted on a systematic regional basis. Regional boundaries were established to facilitate the study and to orient the reader with reference to the geographic distribution of these resources (fig. 1). The 11 onshore regions were subsequently divided into two or more individual geologic basins or provinces that exhibit certain common geologic features characteristic of the terrane they occupy. The same region and province boundaries used for the national assessments and for reporting purposes in Circular 860 (Dolton and others, 1981) are used in this study (fig. 2).

Wilderness Lands occur within 38 of the 39 petroleum provinces or parts of petroleum provinces which fall within the 11-State area. The names of the provinces included in the study are listed in the appendix. The regions that cover the total 11-State area are Region 2, Pacific Coast; Region 3, Colorado Plateau and Basin and Range; the major part of Region 4, Rocky Mountains and Northern Great Plains; and a small part of Region 5, West Texas and Eastern New Mexico.

SOURCES OF DATA

The primary sources of geologic data for this study were the direct contributions of USGS geologists with expertise in their respectively assigned areas; published geologic information, field reports, and maps; published statistical data on petroleum exploration, reserves, and production; and unpublished materials in the USGS.

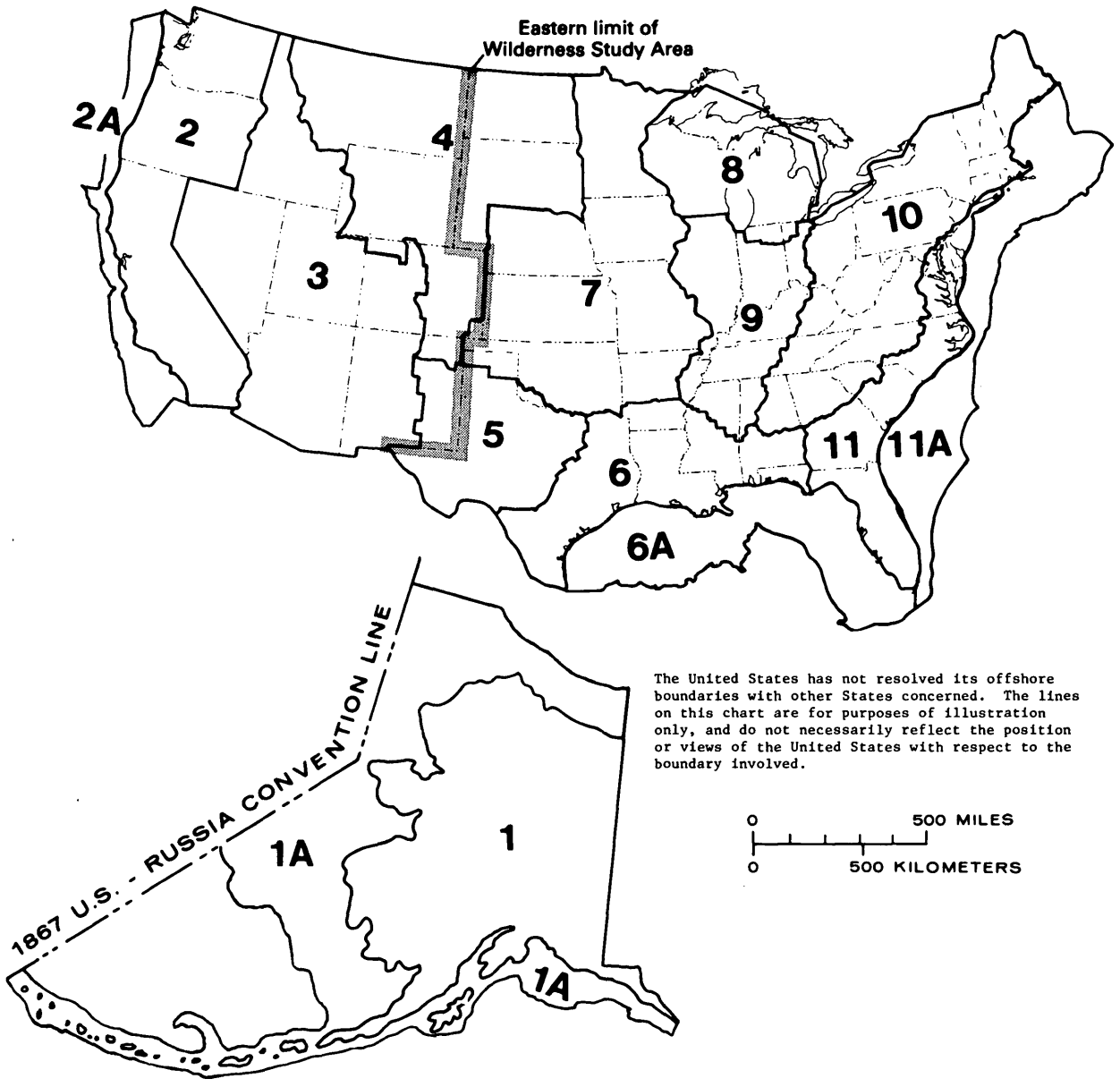
The primary sources for estimates of undiscovered petroleum resources on a regional basis were taken from the Survey's earlier publications on national petroleum assessments, USGS Circular 725 and Circular 860 (Miller and others, 1975; and Dolton and others, 1981).

Subsurface geological information and well production data for wells drilled within or adjacent to Wilderness tracts were obtained on contract from Petroleum Information Corporation's Well History Control System (WHCS).

Maps used to determine the location and boundaries for the Wilderness Lands in the Western States were obtained from the BLM's Wilderness Status Map Series, June 1981 (with updated revisions) for 10 of the 11 States (Bureau of Land Management, 1981a–j). The Wilderness Lands map used for the State of Washington was taken from the American Petroleum Institute (API) Federal Land Status Map Series (American Petroleum Institute, 1981b).

AN OVERVIEW OF DATA PROCESSING PROCEDURES

The initial problem that needed addressing was a procedure in which multiple types of information (multivariate data, in a sense) could be brought together, preferably as a mappable product, to analyze the petroleum potential in Wilderness Lands. These analyses required the combination of the following types of data: locations of the Wilderness Lands, their boundaries and calculated acreage; location and interpretative boundaries of the various geologic and tectonic or structural units; the location and identification of sedimentary rock units; the location and boundaries of the USGS's petroleum provinces; and the location and compilation of data on all wells drilled either within or adjacent to all the wilderness tracts. The solution to the above phase of the investigations was conducted in the USGS as a joint effort between the Geologic Division (GD) and the National Mapping Division (NMD) by utilizing NMD's



EXPLANATION

Region 1, Alaska;
Region 1A, Alaska Offshore;
Region 2, Pacific Coast;
Region 2A, Pacific Coast Offshore;
Region 3, Colorado Plateau and Basin and Range;
Region 4, Rocky Mountains and Northern Great Plains;
Region 5, West Texas and Eastern New Mexico;
Region 6, Gulf Coast;
Region 6A, Gulf of Mexico;
Region 7, Mid-continent;
Region 8, Michigan Basin;
Region 9, Eastern Interior;
Region 10, Appalachians;
Region 11, Atlantic Coast;
Region 11A, Atlantic Coast Offshore.

FIGURE 1.—Petroleum regions of the United States (from Dolton and others, 1981) and the boundary marking the eastern limits of the 11 Western States included in this study.

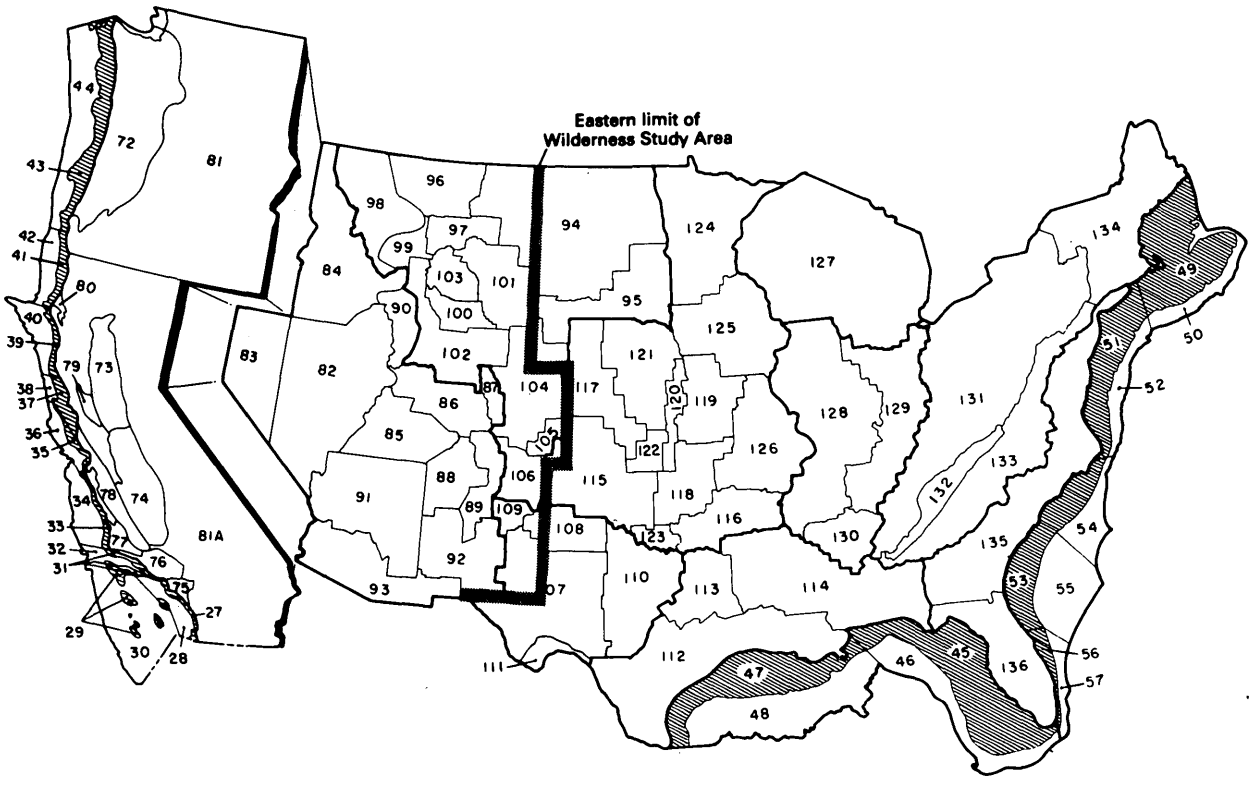


FIGURE 2.—Index map of lower 48 States showing USGS petroleum provinces. Shading denotes offshore shelf areas. Names of onshore provinces included in this study are listed numerically in the appendix (from Dolton and others, 1981). The heavy boundary marks the eastern limits of the 11 Western States included in this study.

capabilities in digital cartographic techniques and by assembling the required multivariate information in a computer-based digital cartographic data system that could serve a range of applications in machine-plotted graphics used in assessing the petroleum resources in Wilderness Lands. Eventually, all public lands could be subject to this type of multivariate analysis.

The location and boundaries of the Wilderness Lands were digitized by NMD in a metric coordinate system, which was then converted to latitude-longitude coordinate pairs from the BLM Wilderness Status Maps and the API Federal Land Status Map of Washington at a scale of 1:1,000,000. The acreage of each wilderness polygon (a closed plane figure (tract or area), especially one with more than four sides and angles) was calculated and identified by a four component code scheme identifying the State Federal Information Processing Standards (FIPS) code, the agency, the wilderness category, and a unique number for each polygon.

The participating geologists prepared State maps at a scale of 1:1,000,000 showing interpretative delineating boundaries for the geologic and tectonic or structural provinces and the identification of the sedimentary rock units relative to the igneous, metamorphic, and volcanic rock units. Each of these maps was digitized by NMD with identifying codes indicating geologic or geographic province names and identification of rock types.

The USGS's petroleum province boundaries, as published in Circular 860 (Dolton and others, 1981), were digitized by NMD at a scale of 1:1,000,000. The petroleum province boundaries identify the province framework within which the USGS has published its previous regional resource assessments.

The search for the locations and logged well information on any wells drilled either within or adjacent to the boundaries of the wilderness tracts was performed under a service contract by Petroleum Information Corporation. All well locations and well information was compiled, computerized,

and identified by the coded boundary coordinates for the wilderness polygons. The well search and retrievals were conducted within the minimum and maximum latitude and longitude coordinates of the wilderness polygons and additionally in the areas included in a zone extending 2 miles outward from the minimum-maximum latitude-longitude boundaries for each of the designated areas. A total of 5,414 wells were retrieved from the 11 Western States which met these search requirements. A summary of the number of wells by State retrieved in this search are Arizona, 93; California, 585; Colorado, 1,275; Idaho, 5; Montana, 695; Nevada, 84; New Mexico, 414; Oregon, 33; Utah, 1,229; Washington, 10; and Wyoming, 991.

Digital cartographic map products produced on a Gerber Plotter, Model 4477, at a scale of 1:1,000,000 generated in the initial procedures for assessing the favorability of petroleum occurrence relative to the Wilderness Lands were the location and boundaries of the wilderness polygons; the wilderness polygons identified by controlling agency and wilderness category; the petroleum province boundaries; and the basic geological and tectonic units and the identification of major rock units. The computer listings for the compiled data on wells within or adjacent to the Wilderness Lands were cross-referenced by use of the polygon code for rapid referral. Later in the project the actual well locations with their respective well status, for example, dry hole, oil producer, gas producer, geothermal well, etc., were mapped relative to the wilderness polygon boundaries by Petroleum Information Corporation under contract to the USGS.

Detailed procedures of the digital cartographic techniques used by NMD to prepare the digital data for computer processing and produce machine-plotted maps are covered in this circular in chapter B discussing digital cartography.

The mapped and computer-produced products discussed above provided the essential input for the geologist in the next phase of the study.

ANALYSIS OF THE GEOLOGIC CHARACTERISTICS OF THE WILDERNESS LANDS

The analysis of the geologic characteristics favorable or unfavorable for petroleum occurrence in conjunction with the geologic settings for all the Wilderness Lands scattered within the framework of the petroleum province boundaries was performed by a team of approximately 11 geologists. In their respective areas of expertise, the geologists analyzed the basic geologic data and provided the geological interpretations for the province or provinces within which the individual wilderness tracts were located.

Discussions of the geologic framework for each of the 11 Western States and a review of the geologic characteristics for the wilderness tracts within each of the States have been prepared by the geologists and are reported as separate chapters (C through N) in this circular.

Two basic geologic assumptions were maintained thoroughout this study: (1) that petroleum resource potential is not uniformly distributed throughout a petroleum province or basin; and (2) that the total distribution of all petroleum resources must be considered, both the discovered (production and reserves in known fields) and the remaining undiscovered resources. The geologists examined the geographic locale for each wilderness tract relative to its respective geological setting. Characteristics favorable for the accumulation of oil and gas were determined from geologic data by analysis and by geologic interpretation. The geologic characteristics were reviewed for each wilderness tract to determine the presence or absence of the following:

- An adequate thickness of sedimentary rock, preferably organically rich marine sediments for the generation of oil and associated gas, or nonmarine organically rich sediments for genesis of nonassociated gas and (or) oil;
- Porous and permeable reservoir rocks;
- Adequate geologic trapping mechanisms;
- A favorable thermal history;
- A suitable geologic environment and timing for the maturation, petroleum generation, and migration relative to the development of traps;
- Oil and gas seeps, or adjacent drilling with shows or production;
- Favorable sedimentary rock sections underlying volcanics such as lava flows or underlying faulted and overthrust areas; that is, areas in which the surface geology does not reflect the subsurface geology.

In many of the wilderness tracts there has been no exploratory drilling and therefore no well data relative to the nature of the subsurface geology. In situations such as these the geologists interpret the known geology in adjacent areas and extrapolate by using their best geologic judgments regarding the probable nature of the geology within the locale of the wilderness tract. This of course generates a degree of uncertainty regarding the probable geology in some of the tracts. Uncertainties are inherent, however, in estimating undiscovered quantities of oil and gas, and only direct information that comes with drilling can promise any greater certainty toward determining the final resource estimates. Quantitative resource estimates reported in this study are expressed as probability distributions in an attempt to show the risks of uncertainty.

RESOURCE APPRAISAL METHODS AND PROCEDURES

The assessments of the petroleum resources on the Wilderness Lands were completed in two separate stages. In the first stage the geologists evaluated the geological characteristics as described above for the favorability or lack of favorability for the occurrence of oil and natural gas within each wilderness tract and assigned a qualitative rating of each tract's potential for the occurrence of oil and gas resources. The second stage in evaluating the petroleum potential for the wilderness tracts was to attempt a quantitative assessment that could be developed upon the foundation of the qualitative assessment procedures and results and that could be designed for the geologist as a natural progression in the analysis of the geologic favorability of the area from a rating of the qualitative assessment to a quantitative assessment. This stage requires a more complex procedure than the first one and probably induces a greater degree of uncertainty in the resulting quantitative estimates due to a lack of detailed information within the tracts and also due to limitations inherent in the methodology employed.

A brief account of the qualitative and quantitative methods and procedures used in the two separate stages follows.

QUALITATIVE ASSESSMENTS OF PETROLEUM POTENTIAL

The assessment procedures followed by the geologists to conduct the geologic analysis to determine a qualitative assessment of the petroleum potential for each wilderness tract provide the foundation for the entire study. The geologic interpretations made by the geologists at this stage are carried through into the quantitative assessments.

The location of each wilderness tract was established relative to its regional and local geologic setting. An analysis of the known geologic characteristics favorable or unfavorable for the occurrence of conventional petroleum resources was made for each of the wilderness tracts. Using his or her best judgments regarding the probable nature of the geology within the locale of each wilderness tract, the geologist made the qualitative assessment relative to the probable potential of the tract as having favorable or unfavorable geologic conditions for the occurrence of petroleum resources.

A qualitative rating was assigned to each wilderness tract. The rating scale used in the initial qualitative assessments was as follows: high, medium to high, medium, low to medium, low, low to zero, zero, and unknown.

The qualitative ratings of petroleum potential used in this evaluation are generally defined 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 occurrence of oil and gas accumulations. Contains known reservoir rocks and hydrocarbon source beds. Includes some areas of sparse subsurface control or areas where expected field size will be small.

Low potential—Geologic environment interpreted to have low potential for the occurrence of oil and gas accumulations. Includes areas of poor or unknown hydrocarbon source bed and (or) reservoir quality. May include areas of sparse or no well control and expected thin sequence of sedimentary rocks.

Zero potential—Areas generally with exposed Precambrian rocks or with very thin sedimentary section with no potential for occurrence of sealed structural or stratigraphic traps with hydrocarbons.

Unknown potential—Generally includes areas

with no well control where Tertiary volcanic intrusions and volcaniclastic rocks are present on the surface. This cover, plus lack of subsurface control, makes prediction of hydrocarbon potential extremely difficult. Includes some areas where Precambrian igneous and metamorphic rocks are thrust over Phanerozoic (Cambrian and younger) sedimentary rocks of unknown potential. Lack of subsurface control does not mean that no oil and gas potential exists, but only that the hydrocarbon potential cannot reasonably be determined with present data.

These ratings were assigned to the wilderness tracts relative to their basin and regional petroleum potential. These ratings *do not* include the potential mineral resources within a tract. Ratings, for example, for areas of low to zero or zero petroleum potential may, in many instances, due to their geologic settings within igneous and metamorphic terranes, have high mineral potential. The rating of unknown is used in some wilderness areas where the geology is almost completely unknown or not enough information is available currently for the geologist to make any judgment on the favorability of the area for petroleum potential. These are frequently areas that have not been penetrated in the subsurface, which underlie massive volcanics, such as the Yellowstone Park area, or areas in which sedimentary rocks underlie overthrust and faulted sections.

The qualitative rating scale used for the potential petroleum resources in the wilderness tracts can be easily adapted to the computer-based digital cartographic data system with machine-plotted, color-coded maps produced for the qualitative petroleum potential in all the wilderness tracts for the 11 Western States. These maps are discussed in more detail later in this circular.

QUANTITATIVE ASSESSMENTS OF PETROLEUM POTENTIAL

To complete this study expeditiously and to keep the petroleum assessments consistent within the framework of the USGS's latest published resource estimates (Dolton and others, 1981), the geologists assumed that the resources of all the lands, including the Wilderness Lands, within each of the USGS's petroleum provinces were included as a part of the total USGS assessment of the remaining undiscovered petroleum resources for that province. The objective then was to determine what part of the total probability distribution for the petroleum assessment within each petroleum province occurs in the Wilderness Lands. First, the Wilderness Lands within a basin were identified and grouped by the geologists as "clusters" of wilderness tracts that occur within geologically similar areas. The homogeneity of the geology for these areas determines which of the Wilderness Lands are included for assessment within each of the clusters. In this manner the geologic characteristics evaluated for the favorability of petroleum occurrence within each of the clusters were the determining factors for the assessment of the petroleum potential for the wilderness tracts occurring within the respective clusters. The basic method considers the resource potential of the wilderness clusters relative to the USGS resource estimates for the respective basin or province within which the wilderness clusters occur.

The resource estimates for the basins or provinces for oil and total gas within the 11 Western States are taken from Circular 860 (Dolton and others, 1981) and Open-File Report 82–666–A (Varnes and others, 1982). In Circular 860 the resource estimates are presented as unconditional estimates that incorporate the risk that oil or gas may not be present in the areas assessed. Those estimates were derived from an assessment of (1) the likelihood of the particular recoverable resource being present, called the marginal probability, and (2) a conditional estimate of the amount present *given* that at least some of the recoverable resource occurs, reported as a probability distribution (95 percent, 5 percent, and most likely estimates).

Using the above resource information and marginal probabilities for the basins, the geologists made the following subjective estimates: (1) a marginal probability for each wilderness cluster given the marginal probability assigned for the basin, and (2) the assignment of a rating or richness factor for the wilderness cluster as to its relative potential when compared to an evenly distributed resource throughout the basin, that is, compared to the average (mean) quantity of resource per unit area in the basin. The mean estimates are the means of the probability distribution for the oil and gas resource estimates in a particular basin.

The first estimate, the marginal probability, is a

subjective probability of the condition that the resource actually will be present in recoverable quantities within each wilderness cluster. The second estimate, the rating or richness factor (r), consists of assigning a range of estimates for the richness factor—a minimum (95 percent) and a maximum (5 percent) value as to the relative potential per unit area in each wilderness cluster *if* compared to an assumed mean quantity of resource distributed evenly per unit area. The geologists used a general rating scale for the richness factor based upon the concept that if the qualitative assessment were given a medium (or average) rating, the quantitative assessment would have a range around the mean value of $r=1$, which implies the resource estimate would be as *if* the resource were evenly distributed throughout the basin, that is, the wilderness cluster would have an average potential compared to the basin on the average. The minimum and maximum value might range from $r=0.5$ to $r=1.5$ times the richness compared to a mean quantity distributed evenly per unit area in the basin.

A high rating for a wilderness cluster might be assigned a richness range of 2 to 4 times the average resouce potential for the basin per unit area. The rating for the richness range is a subjective estimate based upon the geologist's evaluation of the local geology for each of the wilderness clusters. Thus the local geology is assessed for each cluster and the assessments are based upon the premise of *nonuniform* hydrocarbon distributions within a basin.

The area of the wilderness cluster being assessed is the sum of the areas of each of the wilderness tracts that fall within that cluster. The area for the cluster of the Wilderness Lands relative to the area of the petroleum province is the sum of the areas of all the wilderness tracts within the cluster relative to the total sedimentary area of the basin or province. A hypothetical example of the previous exercise by a geologist might be recorded as in table 1.

The exercise is repeated by the geologist to assess separately the same wilderness clusters for their natural gas resources. The potential richness ratings for natural gas in these tracts may or may not be similar to those for the occurrence of oil. A wilderness cluster may be more oil prone, more gas prone, or equally favorable for the occurrence of oil and gas.

From this stage on, the input shown in the table is mathematically and statistically processed by means of the computer. Briefly, the fraction of the conditional quantity of the undiscovered basin resource occurring in the wilderness clusters is dependent upon the following: (1) the basin or province estimates for (a) the marginal probability for resources in the basin and (b) the conditional probability distribution for the remaining undiscovered resources in the basin; and (2) the wilderness area or cluster estimates for (a) the conditional marginal probability for the wilderness cluster, (b) the rating or richness factor of the wilderness cluster as to its relative potential when compared to an evenly distributed resource throughout the basin (expressed as a minimum and a maximum), and (c) the fraction of the total basin area that is the area of the wilderness cluster. Applying the marginal probability for the cluster area and its range of richness factors to the basin probability distribution for total oil and gas resources, one derives the proportionally smaller unconditional probability distribution of remaining undiscovered resources for the individual wilderness clusters. The probability distributions of the oil and gas resources for the individual wilderness clusters are aggregated by using a Monte Carlo simulation program to determine the total resource distributions. The aggregations for both the oil and gas resources are reported by individual States and for the total 11 Western States by B. M. Miller in chapter P in this circular. A detailed discussion of the mathematical and statistical procedures is presented in chapter O in this circular on the statistical methodology for probabilistic assessments.

TABLE 1.—*Wilderness cluster input*

[Oil assessment]

Petroleum province number	Cluster identifier	Cluster area (acres)	Conditional[1] marginal probability	Qualitative petroleum potential	Ratings or richness factor for oil (min.–max.)
100	1	40,000	1.00	high	2–3
100	2	25,000	.80	medium-high	0.9–2.5
100	3	10,000	.50	low	.2–.5
100	4	20,000	.25	low-zero	0–.3

[1]Conditional probability that the resource is present in the area or wilderness cluster given that the resource is present in the basin.

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