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A Systematic Method for Resource Rating with Two Applications to Potential Wilderness Areas

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ENERGY DIVISION

A SYSTEMATIC METHOD FOR RESOURCE RATING WITH TWO APPLICATIONS TO POTENTIAL WILDERNESS AREAS

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Thanks are also extended to our hard-working students Mike Hodgson and Kerry Hake, who tamed the computer for us and fed it a constant diet of data. Basic understanding of wilderness designation issues was stimulated by Larry Regens, a political scientist and consultant to ORNL.

A SYSTEMATIC METHOD FOR RESOURCE RATING WITH TWO APPLICATIONS TO POTENTIAL WILDERNESS AREAS

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ABSTRACT

A versatile method has been developed to rate the energy- and mineral-resource potentials of areas in which land management and resource development decisions must be reached with a minimum expenditure of money and time. The method (1) surveys published and personal information on resources in the region being assessed, (2) selects the most appropriate information, (3) synthesizes the information into map overlays and tract descriptions, (4) rates the potential of tracts for particular resources, (5) rates the overall importance of each tract for resource development, and (6) documents the ratings and their significance.

The method differs from traditional assessment procedures in three significant ways. First, when time constraints preclude gathering new data, the method utilizes existing data and the personal knowledge of experts. Second, the design of the subjective rating process is based on principles of small-group interaction. Data synthesis, consensus building, and internal rating checks are facilitated by this design. Third, the method produces three unique ratings to aid the decision maker. Two of these ratings are coupled in a dual rating that delineates the geologic favorability of the area for each resource and the certainty of the occurrence of each resource in the area, in which both favorability and certainty are scaled from 1 through 4. Once dual ratings are assigned for a tract, the third rating, overall importance, is assigned to the tract by using predetermined criteria, individual resource ratings, and other pertinent background information gathered prior to the rating exercise. Basic criteria considered by the assessment team include (1) the favorability and certainty ratings, (2) the overall availability of each rated resource within this country, (3) the size of a given tract, (4) economic factors, and (5) the number of resources in a tract.

The method has been applied to two separate but roughly similar geologic regions, the Idaho-Wyoming-Utah thrust belt and the central Appalachians. Undeveloped tracts of national forestland in these regions that are being considered for possible designation under the Roadless Area Review and Evaluation (RARE II) planning process were rated for their resource value. The results of the assessment support earlier indications that the 63 tracts comprising the western thrust belt possess a high potential for future resource development. Nearly one-half of these tracts were rated either 3 or 4. However, the wide spread of the importance ratings between 1 and 4 suggests that some tracts or portions of tracts can be added to the National Wilderness System without compromising resource development. The 72 eastern thrust belt tracts were given lower ratings, which indicates the reduced significance of the few remaining roadless areas in this region in satisfying the nation's near-term resource needs.

A comparison of the ratings by this method with ratings produced by other groups demonstrates general agreement but shows our method to be more sensitive to individual tract anomalies.

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1. THE ASSESSMENT METHOD

1.1 Overview

Greater demand and higher prices for energy and mineral resources have focused attention on exploration and development of lands previously considered to have low-resource potential. Because of past inattention, these lands are not well known, and resource developers do not generally have sufficient data to make well-informed resource decisions without new exploration. However, competing and often exclusionary land uses such as wilderness are forcing premature land-use decisions well in advance of the normal exploration/development cycle.

Decision makers attempting to interpret and apply the results of past resource assessments to multiple land-use questions have experienced two problems. First, traditional assessment studies normally take from one to three years, depending on the size of the area being studied. Mounting pressure for exclusionary land uses makes such time periods inadequate to identify and protect areas of high resource potential. Second, the manner in which results of assessments are reported is usually not meaningful to the land manager or politician untrained in geology or mineral resources. Data and interpretations are reported in a factual manner, resources are not rated formally, and no value judgment on the overall importance of the tract is attempted.

Such value-free reporting is in part to preserve the "scientific" objectivity of the study but also in part to avoid forcing the participating agencies into consensus on value issues. The decision of tract worth is left to the land manager or the politican. Unfortunately, these decision makers have little skill in interpreting the geologists' tables or their guarded statements about possible new deposits. Our method attempts to bridge this communucation gap with precisely defined ratings and documentation that allow a given rating to be traced and checked through independent means.

A need exists for a procedure that can bridge this communication gap and still identify areas with high-resource potential. Such a procedure must be rapid and must use existing data whenever time and money do not allow the collection of field data. The method described here satisfies these requirements through both an improved rating concept and a carefully designed procedure. Design criteria underlying the method are listed in Appendix I, and a detailed description of the procedure is contained in Appendix II.

The method depends on the efficiency of a tightly knit team of experts moving systematically through a series of decision steps. A core team of three individuals manages the process and maintains continuity throughout the several months required to conduct a regional assessment. Using principles of group dynamics (Blake and Mouton 1961), the team creates and maintains an environment conducive to mutual support and consensus building.

Primary tasks of the core team are to gather and synthesize data, to conduct rating sessions, and to document results. The data synthesis and rating activities culminate in two intensive work sessions involving invited experts, who bring greater personal knowledge and understanding into the process. We depend on the collective judgment and personal knowledge of the team plus invited experts (1) to adopt appropriate resource-occurrence models, (2) to interpret and supplement available data, (3) to extrapolate available data to tracts being evaluated, and (4) to rate the resource potential of the tracts. However, limited data as well as a limited understanding of resource accumulation in specific environments impairs assessment accuracy, no matter how good the procedure. Thus, used for undeveloped regions, the proposed method should be considered either as an initial judgment that is sufficient for beginning a planned exploration program or as an expedient for use in multiobjective land-use decisions when time or money preclude new exploration.

A review of the few approaches (Sect. 3.2) that have attempted to rate subarea resource potential revealed that such systems usually create a single rating by combining an estimate of the likelihood of resource accumulation with data on mineral occurrences. Usually, no attempt is made to show the reasoning followed in creating a rating. Such ratings are often inconsistent and/or unduly influenced by occurrence data (Sect. 3.2). Furthermore, although a single rating for each subarea is needed to identify that group of subareas having high-resource potential, the rating is not adequate to make well-informed decisions between subareas in that group.

The method overcomes these deficiencies by means of three unique ratings. Data is interpreted and synthesized by the core team and invited experts to create a dual rating (Sect. 1.2) of each subarea for each resource. These ratings are then considered with other information to create an overall importance rating (Sect. 1.3) for each subarea. The overall importance rating is equivalent to the single rating discussed above but is superior for reasons to be described. The sequence of steps followed in generating the importance rating forces the core team through a logical thought process and allows the decision maker or technical expert to trace the process followed.

The dual rating characterizes both the geologic favorability of an area for each resource and the certainty that the resource occurs in the area. Favorability is defined as the potential of a particular geologic environment to contain exploitable quantities of mineral resources. The favorability of any region for a particular resource is based on commonly accepted occurrence models. These models are usually only mental constructs that try to explain the geological processes that have combined to produce a mineral deposit. It is possible to apply a model developed for one region to another region with similar geology, although the new region may not be developed or even explored. The favorability rating relies on the ability of resource specialists to draw such *inferences* through resource-occurrence models. In this way, it is possible to rate the favorability of undeveloped regions for which the geology is known but for which little exploration has been accomplished. The rating is scaled between 1 and 4, and explicit definitions have been developed for each of the four levels.

Certainty refers to the presence or absence of a resource in a tract. The degree of certainty is fundamentally a statement of region-specific or site-specific occurrence and usually requires the *extrapolation* of these data to the tract from currently producing mining districts, old mining districts, oil and gas fields, or other direct evidence of resource occurrence. Thus, certainty depends on past or current production, specific sampling, and detailed mineral investigations. Favorability and certainty are not completely independent because a high certainty (good data on resource existence or nonexistence nearby) will modify local favorability. Thus, these ratings are assigned simultaneously. Certainty is scaled from 1 to 4, and each of the four levels has an explicit definition.

Because subjective inputs are used in the rating process, a special effort is made to document the basis for team decisions. This documentation is accomplished through a form on which the team records:

1. pertinent information collected prior to the rating exercise,
2. the ratings assigned, and
3. justification for the assignments.

The form contains three sections: area description, rating, and supporting data. The form is described further in Sect. 1.4.

Land-use planning usually requires public participation. The documents created by our method (assessment forms, overlays, and a descriptive report) provide land managers with the information necessary to support decisions and to discuss those decisions with interested groups.

The method designed is flexible and can be adapted to a variety of resource-assessment applications. Possible applications include:

1. Development of new exploration programs in response to expected future demand or new resource models.

2. Narrowing targets in ongoing exploration programs. If repeated at critical decision points, the method would help to determine priorities for investment of capital. As exploration proceeded, ratings would be revised by using new and improved data. The definition of each rating category and each overall importance criterion would become more exact

as additional information became available. Guidance of exploration planning through iterative review of data gathered by exploration and development projects has long been used by mining companies. However, details describing the procedures are seldom published. We would welcome comparisons of our method with proprietary methods used by mining companies.

3. Resource assessments for use in land-management decisions on either public or private lands. Choices are made here between resource values and other values such as ecologic, recreation, or aesthetic. Limited data often preclude precise comparison of values in making management decisions.

Two applications of the method are discussed in Sect. 2. The applications assess the resource potential of tracts being considered for possible wilderness designation under the RARE II planning process of the Forest Service (FS). Section 2.5 discusses the results of the two applications, and Sect. 3 evaluates the method, based on our experience.

1.2 Dual-Rating System

After reviewing the published resource-evaluation methods used by the FS (USDA 1978), the Department of Energy (DOE) (DOE 1978), and the U.S. Geological Survey (USGS) (Pearson 1978) in the RARE II program, we decided on a dual rating system. We designed a system that rates:

1. *favorability* of the geologic environment for the accumulation of the resource and
2. *certainty* that the resource actually occurs in the area, based on production, assays, geochemical sampling, and so forth.

A detailed discussion with examples follows the formal definitions of favorability and certainty given below.

1.2.1 Favorability

Favorability is the potential of a particular geologic environment to contain exploitable quantities of mineral and energy resources. Favorability does not consider the feasibility of extraction, the accessibility to the tract, or other factors that might preclude economic development of the resource. The favorability of any region for a particular resource is based on occurrence models. These models try to explain the geologic processes that have combined to produce a mineral deposit. A model developed for one region can be applied to another region with similar geology, even though the new region may not be developed or even explored. Our favorability rating depends on the ability of resource specialists to draw such inferences through resource-occurrence models.

The accuracy and resolution of available data do not seem to justify more than four favorability categories, which we have scaled between 1 and 4. Definitions of each rating level are as follows:

Rating	Definition
1	The lowest measure of favorability. The geology of the tract has none of the characteristics normally associated with the resource being evaluated. In fact, most of the geological characteristics identified may adversely affect the accumulation of significant amounts of the resource.
2	A lower intermediate level of favorability. Some of the broad geologic characteristics needed for the accumulation of a particular resource are present, but the more specific characteristics do not suggest significant accumulations of the resource or, at best,

Rating	Definition
	indicate only very scattered and relatively small accumulations.
3	A higher intermediate level of favorability. A rating of 3 indicates the presence of many broad regional characteristics as well as a few of the more detailed features associated with the occurrence of a specific resource.
4	The highest level of favorability. The geology of the tract shows many regional and local characteristics that are known to be related to the occurrence of the resource being evaluated. Conversely, no adverse geologic characteristics can be identified.

1.2.2 Certainty

Certainty refers to the presence or absence of a resource in a tract. The degree of certainty is fundamentally a statement of region-specific or site-specific occurrence and usually requires the extrapolation of these data to the tract from currently producing mining districts, old mining districts, oil and gas fields, or other direct evidence of resource occurrence. Thus, certainty depends on past or current production, specific sampling, and detailed mineral investigations.

Each tract is assigned a certainty from 1 to 4 for each resource. Certainty ratings are defined as follows:

Rating	Definition
1	The lowest degree of certainty. No direct data (assays, analyses, or identification by other means) are available to indicate the presence of the resource, regardless of the geologic favorability, and any direct evidence that does exist is so far away as to preclude extrapolation to the tract under consideration. Accordingly, the tract will be well outside any known resource district.
2	A lower intermediate degree of certainty. As in the "1" certainty rating, no direct data supporting resource occurrence are known for the tract. However, the tract must lie within or close to a known resource district or near direct evidence of resource occurrence. Extrapolation from producing areas to the tract must, of course, be based on sound and reasonable geologic inferences.
3	A higher intermediate degree of certainty. A certainty of 3 is assigned whenever all conditions in "2" are fulfilled and whenever there is at least <u>one</u> piece of direct evidence for resource occurrence within the tract (assays, and so on) or whenever extrapolation from producing areas to the tract seems stronger than for a "2" certainty in the opinion of the resource specialists.
4	The highest degree of certainty. A 4 rating is assigned to tracts in a region of abundant resource exploration and exploitation. For example, a tract with existing mines or oil and gas wells would definitely be given a 4. However, data showing the absence of resources can also strengthen certainty. When used with a favorability of

Rating	Definition
	1, a certainty of 4 indicates a high degree of assurance that the resource does not occur in the tract.

1.2.3 Discussion of the dual-rating system

The dual-rating system has a distinct advantage over single-rating systems because it offers more information to the decision maker in considering trade-offs among tracts. For instance, a tract with a high favorability and a high certainty of resource occurrence would probably be assigned a nonwilderness designation by a land manager because of its unquestioned importance for resources. On the other hand, the land manager might designate a tract with the same high favorability but with low certainty to further planning in order to investigate its resource potential. The decision maker may not be able to distinguish between the two tracts in a single rating system even though the immediate energy and mineral development potential is higher for the first tract.

As defined above, favorability is an expression of the variations of geology within the region being evaluated. However, resource-occurrence data can influence the assignment of local favorability, which indicates that favorability and certainty are not completely independent. In order to understand this interdependence, the steps followed by the team in assigning dual ratings must be outlined.

The process begins by establishing the overall or regional favorability of those portions of the study region with a favorability of 2 or more for a particular resource. Regional favorability is based on the applicability of resource-occurrence models. These models may be based on successful past or present production of the region being studied or from similar geologic environments thousands of miles away that have or are currently producing the resource. The initial favorability of any region for a resource may therefore be established by the record of successful production from similar areas anywhere in the world. Each tract is assigned the regional favorability unless local geology suggests a modification. For example, a distinct geologic-physiographic region such as the Great Basin has a relatively low potential for oil and gas development. Selected areas within the Great Basin, such as valleys with thick accumulations of Cretaceous rocks as well as subsurface anticlines and fault traps, would be considered slightly more favorable for oil and gas, based on local geologic features. The certainty of resource occurrence has meaning for local geology within a province only and is not specified for the province as a whole.

Certainty can also influence local favorability assignments, which can be understood best through the following example. The favorability of the outer continental shelves of the United States for large oil and gas accumulations is quite high. This high favorability is based on the following model of oil and gas accumulation: a marine depositional environment, abundant organic activity, gradual subsidence, conversion of the organic constituents into hydrocarbons, migration and accumulation of the hydrocarbons, and subsequent geologic history of the region. Whether or not large quantities of oil and gas actually exist is still questionable because drilling is just beginning in this region. As a result, certainty in most areas of the province is low. However, oil and gas "shows" along the central part of the eastern outer continental shelf have increased the certainty of resource occurrence in this portion of the province. Because of probable variations in geology along the continental shelf, the increased certainty in this area cannot be extended to the length of the outer continental shelf from eastern Canada to Florida. How far the increased certainty can be extended from a well is largely a matter of judgment of the resource specialists, based on their interpretations of local geology. For example, to extrapolate the certainty of resource occurrence from a producing well to an area 100 miles away would not be a reasonable geologic inference, whereas it might be for an area 20 miles away. However, as drilling continues, occurrence data will increase for many local areas of the continental shelf, and the favorability of these areas may increase or decrease as local certainty increases. Furthermore, this accumulation of data may either increase or decrease the overall regional favorability.

In summary, developing a regional pattern of favorability/certainty is a complex, iterative process in which a background or regional favorability is adjusted for individual tracts from local variations in geology or certainty. The process results in a coherent spatial picture of the region's resource potential, limited only by the quality of occurrence data available. In turn, data limitations are not hidden from the decision maker but are recorded in the certainty rating.

It is useful to compare our rating classification with the USGS classification of mineral resources (McKelvey 1973) shown in Fig. 1. Resources within the "identified" and "undiscovered" categories would be assigned a *favorability* of 4, based on our dual-rating system, whereas the *certainty* of resource occurrence would be a 4 for all identified resources, 3 or 2 for hypothetical resources, and 2 or 1 for speculative resources. Favorabilities of less than 4 do not appear in Fig. 1 but could be included as a third axis along which the favorability decreases.

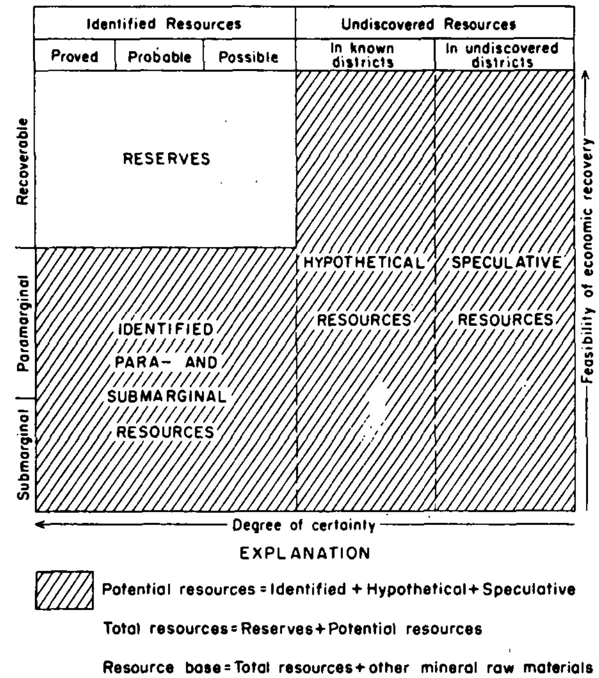

Fig. 1. Classification of mineral resources by the U.S. Geological Survey. Source: V. E. McKelvey, 1973. *The Mineral Position of the United States, 1975-2000,* University of Wisconsin Press, Madison, pp. 67-82.

1.3 Overall Tract Rating

Overall importance ratings were also assigned to each tract because we believe that decision makers need aggregated data to evaluate the large numbers of factors in trade-off decisions. As a result, we feel that the decision maker should be given a set of ratings representing major points of view. For example, in the consideration of wilderness designation, one might develop overall ratings for wilderness quality, timber resources, geologic resources, recreational potential, ecologic value, and social-system impact. As questions develop in considering the trade-offs between these factors, the decision maker is likely to seek greater detail. In regard to mineral resources, favorability and certainty ratings and the assessment form constitute a source of greater detail.

In our method the resource assessment team assigns each tract overall importance ratings ranging from 1^- to 4^+. The rating is recorded on the form and reflects the importance of the tract in meeting future energy and mineral resource needs.

The first step in creating the overall rating is a group decision on criteria that must be considered in generating a rating for each tract. The following generalized set of criteria, which was established by our team for the FS RARE II applications, is an example of the output of an assessment team.

1. High favorability for strategic resources enhances the importance of the tract.

These resources include oil and gas, uranium, chromium, niobium, tantalum, manganese, sheet mica, mercury, cobalt, tin, nickel, platinum-group metals, gold, and silver.

2. A tract with high favorability for several resources is generally more important than a tract favorable for only one resource.

3. The degree of certainty is used in assigning tracts to categories of importance. Thus, a tract with a favorability of 4 but a certainty of only 1 might be given an importance rating of 2 or perhaps 1, whereas another tract with a favorability of 4 and a certainty of 4 might be assigned a general importance rating of 3 or even 4, depending on the particular resource.

4. The overall supply of each resource in the region and the nation also should be considered. Thus, tracts with coal resources are less important than those with oil and gas because the nation has an adequate domestic supply of coal for its future needs.

5. Large tracts are more important than small tracts because they probably contain larger amounts of resources.

6. The economics of extracting the resources from a given tract should be considered to the extent possible. For instance, poor minability as related to complex structure, depth of overburden, and so forth, would make a tract less important.

7. The possible use of a tract for transmission corridors (coal-slurry pipelines, oil and gas pipelines, electric transmission lines, etc.) or for hydroelectric facilities increases the overall importance of the tract.

The criteria were labeled either as high or medium in importance by the team, but no attempt was made to assign numerical weights that indicate relative importance of each criterion because no simple model formulations were discovered that could relate the criteria to the tract-importance rating.

1.4 Assessment Form

To document the resource ratings assigned to each tract and to present the information supporting the ratings, the assessment form shown in Fig. 2 was created. The form consists of three sections: location information, comparative ratings, and supporting information. Any other ratings available for the tract, in this case FS and DOE, are recorded on the form and act as additional input to the rating process.

As discussed above, once individual resource ratings are derived, an overall rating is determined from considerations of the total set of individual resource ratings, a predetermined set of criteria, and supporting information. The supporting information section of the form is relatively unstructured, and the team is free to record any reference or supporting statements that would aid in environment/resource trade-offs and that would also allow a reader of the form to understand the basis for the team rating. Assessment forms created for the 63 tracts within the Idaho-Wyoming-Utah thrust belt and the 72 tracts within the central Appalachian thrust belt are contained in an accompanying report, *Data Report: Resource Ratings of the RARE II Tracts in the Idaho-Wyoming-Utah and the Central Appalachian Thrust Belts*, ORNL/TM-6885. However, to illustrate the range of information contained by the forms in this report, a subset of forms has been included in Appendix III.

ENERGY AND MINERAL RESOURCE EVALUATION – RARE II TRACTS

TRACT NO: 04170 TRACT NAME: Red Mountain ECOREG: 3112 WAR: 19

NATIONAL FOREST: Caribou STATE/COUNTY: Idaho, Bear Lake/Caribou

ACREAGE (GROSS): 13,800 ACREAGE (NET): 13,800 100 N/G: 100 LATITUDE: 42°27' LONGITUDE: 111°07'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/3	4	4		Stratigraphic and structural traps compounded by thrusting; similar to Canadian Rockies Foothills Belt
URANIUM	3/1	1	1		
COAL	1/3	1	1		
GEOTHERMAL	3/2	1			
CRITICAL MINERALS	3/2	1			Copper – red bed type deposits
OVERALL RATING (WEIGHTED)	3^+		4		

NAMES OF CRITICAL MINERALS PRESENT: Cu

COMMENTARY AND SUMMARY: Several major and several lesser oil and/or gas fields are located in the southern part of the Absaroka Belt in Wyoming and Utah. Most production is from Jurassic-Triassic reservoirs, but more recent deeper discoveries are in Upper Paleozoic rocks (Phosphoria) and even more recently in Lower Paleozoic rocks. The Rocky Mountain Oil and Gas Association estimates that Rare II tracts in the Absaroka belt contain nearly 3.3 billion barrels of oil and over 12.5 trillion cubic feet of gas. The major part of the Southeast Idaho phosphate resource is in this thrust belt, with much of it in the Rare II tracts. Not only are the phosphate rock resources important for the phosphorus, but there is a significant near-future potential for vanadium, uranium by-product production. The Mt. Pisgah gold district in Bonneville County may have significant potential for Carlin-type gold deposits (Rare II tracts 04160, 04161, and 04162). DOE, moderate corridor conflict (R-45).

GEOLOGY: Absaroka thrust belt (includes terrain westward to surface trace of the Paris-Bannock thrust complex). Includes (as secondary structures) the Crawford, Meade, Medicine Lodge, Sheep Mountain, Skyline, and many smaller thrust faults. Rocks exposed at the surface include sedimentary rocks from Cambrian to Tertiary in age along with some Tertiary and Quaternary volcanics. Several small igneous intrusions of Tertiary Age have been mapped in the Idaho part of the Absaroka Belt, chiefly in the vicinity of the Mt. Pisgah gold district.

REFERENCE/CITATION: USFS, 1978, RARE II DES, ID, UT, and WY Suppls.; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments, of Ten Alternatives-RARE II Lands; Powers, 1977, WGA Gdbk 29; Blackstone, 1978, Tectonic map of the Overthrust Belt: WGS; RMOGA, 1978, Estimates of Undiscovered Recoverable Hydrocarbon Resources (RARE-II); White and Williams, 1975, USGS Circ. 726; NOAA, 1977, Geothermal Energy Resources of the Western U.S.; USGS, 1945, Min. Res. Mo. Valley Region, Pts. 1,2,3; ERDA, 1976, NURE-Prelim. Rpt.; Armstrong and Oriel, 1965, AAPG Bull., v. 43; British Sulfur Corp., Ltd., 1964, A World Survey of Phosphate Deposits: Woodalls Ltd. (Printers), London; Gulbrandsen, 1966, Geochim. Cosmochim. Acta, v. 3, p. 769-778; Brobst and Pratt, 1973, USGS Prof. Paper 820; Worl and Others, 1974, USGS MR-60; Kinkel and Peterson, 1962, USGS MR-13; RMAG, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, CO; Bond and Others, 1978, Geologic Map of Idaho: IBMG; Ross, C.P., 1941, IBMG Pamph. 57, pt. 111; Mansfield, 1927, USGS Prof. Paper 152; Leonard and Others, 1978, USGS OFR 78-360; USGS, 1964, Mineral and Water Resources of Idaho: 88th U.S. Congress; Vine, 1959, USGS Bull. 1055-1.

Fig. 2. RARE II tract assessment form.

2. RARE II APPLICATIONS

2.1 Wilderness and RARE II

Wilderness became a significant issue with the passage of the Wilderness Act in 1964, by which Congress established the National Wilderness Preservation System (NWPS) to preserve areas in their natural state for the future use and enjoyment of the American people. The act defines wilderness as

> ...an area of undeveloped Federal land retaining its primeval character and influence ... and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunties for solitude or a primitive and unconfined type of recreation; (3) has at least 5,000 acres of land or is of sufficient size as to make practical its preservation and use in an unimpaired condition.

Congress further specified that within wilderness there will be no roads, no timber harvesting, no structures or installations, and no use of motorized vehicles or landing of aircraft. These stipulations plus subsequent administrative interpretations of the act essentially preclude significant resource exploration or development in wilderness areas.

Subsequent to passage of the act, the federal agencies named in the act began assessments of their lands for possible wilderness designation. The slowness with which the FS was proceeding on designation under their unit-planning process and the controversy surrounding their lands prompted them to initiate the Roadless Area Review and Evaluation (RARE) Program in 1972. Because of public dissatisfaction with RARE, the FS began a second evaluation in 1977, called RARE II. This systematic nationwide assessment is intended to identify roadless areas within national forests; to assess the wilderness, environmental, and resource values in each area; and to designate each area as wilderness, nonwilderness, or for further planning. An important goal of the RARE II program is the quick release of lands without wilderness attributes for developmental activities such as recreation, wildlife-habitat improvement, timber harvesting, road building, and resource extraction. The intent is to keep the number of tracts in the further planning category to a minimum.

In June 1978 the FS published a draft environmental statement (DES) describing ten alternatives that represent a range of options and perspectives relative to wilderness designation of roadless tracts (USDA 1978). Supporting data for the DES are found in a group of supplements accompanying the statement. Many of the basic geologic resource data found in the supplements were supplied to the FS by other agencies such as USGS and DOE.

As of this time, public response to the DES has been collected, and the FS has prepared a final environmental statement based on this public input. The final statement was issued in January 1979 and will recommend wilderness, nonwilderness, or further-planning status for the tracts.

The RARE II process being followed by FS is a unique attempt to incorporate public input into a national planning effort. The assessment method and results discussed in this report are a direct response to this call for input. We have attempted to create a vehicle for a rapid but relatively comprehensive assessment of one set of values identified by the FS as being important, that of geologic resources.

Two separate areas were assessed. First, 63 tracts in the controversial Idaho-Wyoming-Utah thrust belt were evaluated because of their high potential for oil and gas. Next, an area with roughly similar structural geology in the central Appalachians was assessed as a check on the method. These applications are discussed in detail in Sects. 2.3 and 2.4. Before these applications are discussed, however, resource assessment as handled by the FS in the RARE II planning process is described.

2.2 Geologic Resources and RARE II

The recent creation of DOE within the federal government symbolizes a growing awareness of our society's dependence on energy. A logical outgrowth of this awareness is the concern that restrictions placed on the orderly development of energy resources by environmentally oriented programs such as RARE II may jeopardize the economic or military security of the nation at some future date. As a result, the FS assessed the following energy resources: oil and gas, coal, uranium, and geothermal resources.

In addition to energy resources, our society has a critical dependence on a number of other minerals. These minerals, many of which are highly energy related, are known as the "critical minerals" (Table 1).

Table 1. Minerals deemed critical for U.S. industry

(Exclusive of petroleum, natural gas, coal, and uranium)

Antimony[a]	Fluorine[a]	Potassium[a]
Asbestos[a]	Germanium[a]	Rubidium
Bauxite and aluminum ore[a]	Gold[a]	Scandium[a]
Barite	Graphite[a]	Selenium
Bentonite	Ilmenite and rutile[a]	Silver
Beryllium[a]	Indium[a]	Strontium[a]
Bismuth[a]	Iron ore	Sulfur
Boron	Lead	Tantalum[a]
Cadmium[a]	Lithium[a]	Tellurium
Cesium[a]	Manganese[a]	Thorium
Chromium[a]	Mercury	Tin[a]
Cobalt[a]	Mica[a]	Tungsten
Columbium (niobium)[a]	Nickel[a]	Vanadium
Copper	Phosphorus	Zinc[a]
Diamonds[a]	Platinum-group metals[a]	Zirconium[a]

[a]About 50% or more of U.S. demand is imported.

Source: From reports of the U.S. Geological Survey and the U.S. Bureau of Mines; modified from U.S. Department of Agriculture, 1978. *RARE II, Draft Environmental Statement, Roadless Area Review and Evaluation*, U.S. Forest Service, Washington, D.C.

The 45 minerals shown in Table 1, in addition to the energy minerals oil and gas, uranium, and coal, are considered critical for U.S. industry. For the purpose of this report, all 45 minerals are lumped together as critical minerals and are so evaluated. Although much of the domestic demand for these materials can be supplied from U.S. sources, we import over 50% of more than one-half of the minerals in the tabulation. A high possibility exists that some of these high-import materials occur in favorable geologic environments in the United States; thus, these minerals could be produced in larger quantities domestically if given proper economic incentives. In contrast, materials such as bauxite, chromium, cobalt, gold, manganese, nickel, platinum, tantalum, and tin are generally considered highly strategic because we import most of our supply and because no significant amounts of geologically favorable terrain are believed to exist in the United States.

The presence of critical minerals is thus an additional factor in the determination of the importance of a tract. A tract rich in both energy resources and critical minerals is considered to be more important than a tract possessing only energy resources.

Because resource data for RARE II tracts are scarce and costly to generate, the first step in developing our assessment was to analyze the data in the state and region supplements of the FS DES. This analysis showed that the simple yes/no format used to record the presence or potential of mineral resources was inadequate for making comparisons and distinctions among tracts. Subsequently, a tape containing detailed tract data was obtained from the FS. Attempts to use the tape proved to be impractical because the organization of the tape made extraction of data both time consuming and costly.

We then turned to the RARE II data supplied to the FS by USGS and DOE. Much of this information was final resource ratings or estimates derived from more detailed data but generally supplied without furnishing the supporting data.

For example, the data given to the FS by the USGS as a basis of the FS evaluation were "in the process of being published" by the USGS and would not be available until after the DES review period.* Consequently, of all the mineral- and energy-resource data gathered especially for the RARE II effort, convenient access to only two summaries was available: the yes/no tables contained in the DES state supplements and the DOE data supplied to the FS.

Because the basic data supporting these two summaries were not documented, it was impossible to test the soundness of the evaluations contained in the summaries. For instance, the DES may list a "yes" for the presence of oil and gas in a particular tract, and DOE may call this tract "very important" with high potential for oil and gas. But it is impossible to know the basis for this decision from the documents supplied. What occurrence model was used in the judgment? What is the geology of the tract? What degree of confidence is associated with the assessment? Without such knowledge, the relative comparison of tracts must be very gross and is likely to be impossible for tracts that are quite similar.

The evaluation of critical minerals in tract comparisons is even worse. Many minerals are lumped under a single yes/no column in each supplement. Clearly, some of these minerals are more important than others to our technological society. Knowledge of this relative importance is essential in comparing tracts but is lost in the aggregation of data contained in the supplements.

The importance of resource data to wilderness decisions and the inadequate way in which resource data are handled in the RARE II process are largely responsible for our care in assigning and documenting ratings. The following applications assess the same basic set of energy resources considered by the FS with the exception of noncritical minerals. Assessment forms containing detailed supporting data are in our supplemental data report (Voelker et al. 1979).

*We have since received the USGS maps prepared for the RARE II evalation of the Idaho-Wyoming-Utah thrust belt. This material is discussed in detail in Sect. 3.2.

2.3 Idaho-Wyoming-Utah Thrust Belt Application

2.3.1 Description of the Idaho-Wyoming-Utah thrust belt

The Idaho-Wyoming-Utah thrust belt was selected for study because it is considered to be the most controversial of all the areas affected by RARE II. The region has a high potential for energy and mineral resources as well as for wilderness.

The Idaho-Wyoming-Utah thrust belt, as considered in this report, is shown in Fig. 3. It is bounded on the north by the Snake River volcanic plain, on the east by a line projected northward along and beyond the trace of the crest of the Moxa arch, on the south by the North Flank fault of the Unita Mountains, and on the west by the Wasatch fault. The area comprises about 23,700 sq miles, or 15 million acres. The FS has identified 63 RARE II tracts in the area, totaling about 3.1 million acres.

The Idaho-Wyoming-Utah thrust belt consists of a west-thickening wedge of Paleozoic and Mesozoic rocks that were thrust eastward from latest Jurassic to Eocene time. From a regional standpoint, this thrust belt is a small segment of the continent-long Cordilleran thrust and fold belt that stretches from Alaska to Mexico. Although the thrust structures are numerous and quite complex in detail, for the purposes of this report we have divided the thrust belt into four areas (Fig. 3), which, from east to west, are:

(1) Footwall, located between the Moxa arch and the trace of the Prospect-Darby thrust,

(2) Prospect-Darby thrust sheet, which extends westward to the trace of the Absaroka thrust,

(3) Absaroka thrust sheet, which is the largest division and extends westward to the trace of the Paris-Bannock thrust, and

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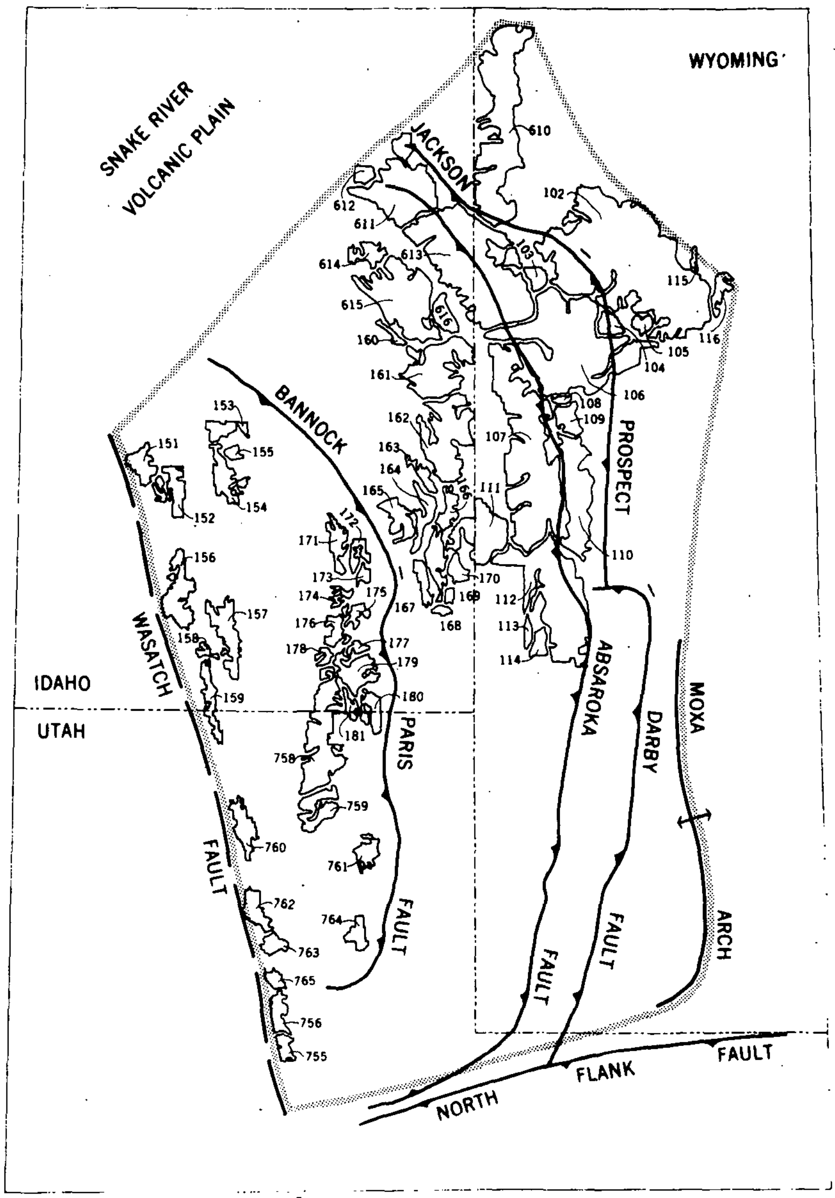

Fig. 3. RARE II tracts in the Idaho-Wyoming-Utah thrust belt.

(4) Paris-Bannock thrust sheet, which extends westward to the Wasatch fault.

Strictly speaking, the Gros Ventre Mountains and the Grand Tetons are not part of the Idaho-Wyoming-Utah thrust belt, but their mineral resources were nevertheless assessed.

2.3.2 Oil and gas

The Idaho-Wyoming-Utah thrust belt is one of the most important current onshore regions for oil and gas exploration as a result of significant recent discoveries (*Oil Gas J.* 1976–1978). This thrust belt is a small part of the continent-long Cordilleran hingeline and overthrust system. Major oil and gas reserves within this system occur in Alaska, the Canadian foothills, and eastern Mexico.

Overthrust structures throughout the world are important exploration targets because the same oil-bearing zones can be repeated several times in vertical sequence by the thrusting process. Powers (1977) estimates that the entire Idaho-Wyoming-Utah thrust belt comprising about 15 million acres (Fig. 3) may contain from 0.6 to 3 billion barrels of recoverable oil, and from 4 to 12 trillion cubic feet (TCF) of recoverable gas. This estimate compares closely with the estimate published by the *Oil and Gas Journal* (March 13, 1978) of 0.2 to 3 billion barrels of oil and "up to 20 TCF" of gas for the same size area. On March 10, 1978, the Rocky Mountain Oil and Gas Association (RMOGA 1978) released more optimistic estimates: just the 63 RARE II tracts used in this study, which comprise less than 40% of the Idaho-Wyoming-Utah thrust belt, contain 1 to 6 billion barrels of oil and 4 to 40 TCF of gas. Moreoever, the RMOGA released oil and gas estimates for *each* of the 63 RARE II tracts. Our analysis of the RMOGA tract estimates indicates that average figures of oil and gas per acre were extrapolated from the better-known parts of the eastern side of the thrust belt and applied to the western tracts. Estimates by RMOGA give the reader a false impression as to RMOGA's confidence in these estimates, which is discussed in more detail in Sect. 3.2.

A favorability of 4 was assigned to all tracts except the West Slope Tetons (04610), which was assigned a favorability of 2 (Tables 2 and 3; Fig. 4). From a structural standpoint, tract 04610 displays none of the thrust faults that are so prevalent in the other 62 tracts (Fig. 3). In addition, late Tertiary normal faulting and erosion of the Tetons block have drastically reduced the potential for any stratigraphic or structural traps to maintain significant oil and gas accumulations that may have existed in the past.

The certainty pattern illustrated by Fig. 4 and Table 3 demonstrates to a large degree the concentration of oil and gas exploration wells within the thrust belt. Because the westernmost tracts have not been explored, the level of certainty decreases from east to west. Both the lower level of certainty and the smaller size of the western tracts tend to reduce their overall importance. The most important tracts for oil and gas are 04102, 04110, 04161, 04613, and 04615 (Fig. 4; Table 2).

2.3.3 Uranium

Uranium occurs in a variety of rocks and geologic environments, and the whole Idaho-Wyoming-Utah thrust belt has some uranium potential. Consequently, a favorability of at least 2 was assigned to each of the 63 tracts (Table 2). A lack of geochemical data on the most favorable uranium-bearing rocks, however, resulted in a certainty-of-occurrence rating of 1 for a majority of the tracts. Tracts having particularly favorable host rocks, such as extensive outcrops of Tertiary rocks or the Phosphoria Formation, were usually assigned a favorability of 3.

Maps and data from the National Uranium Resource Evaluation (NURE) Program (ERDA 1976) indicate that only tract 04115 is partly within an area containing "possible" or "probable" uranium resources. However, the tract is so small (5290 acres) and so close to the boundary between the "probable-possible" resource category and the "no-potential" resource category that it was given a rating of only 2/1. Tract 04102 lies partly within an area identified by NURE (ERDA 1976) as having "speculative" uranium resources. Because this is the NURE estimate for the lowest likelihood of uranium resources, tract 04102 was also given a rating of 2/1. Tract 04613 was the only tract assigned a favorability of 4. This rating was based largely on the areally extensive outcrops of phosphate rock, the uranium-rich coal, and the Madison limestone. Although no uranium deposits are known from the Madison limestone in the Idaho-Wyoming-Utah thrust belt, this unit is quite productive from nearby areas of Wyoming and Montana. Based on the relatively diverse

Table 2. RARE II tract evaluation for the Idaho-Wyoming-Utah thrust belt

Tract number and name	Oil and gas[a]	Uranium[a]	Coal[a]	Geothermal[a]	Critical minerals[a]	Acreage (thousands)	Overall rating[b]
04102 Gros Ventre	4/4	3/1	4/4	3/2	4/4	433	4+
04103 Munger Mountain	4/3	2/1	4/3	3/2	4/2	13	3
04104 Monument Ridge	4/4	3/1	4/3	2/2	3/2	17	4-
04105 Jenny Creek	4/4	3/1	4/4	2/2	1/3	11	3-
04106 Grayback	4/3	3/1	4/4	3/2	4/3	272	4
04107 Salt River Range	4/3	2/1	4/4	2/2	4/3	256	4
04108 Deadman	4/3	2/1	4/4	2/2	2/1	6	2+
04109 N. Fork Sheep Creek	4/3	2/1	4/4	2/2	3/2	21	3
04110 S. Wyoming Range	4/4	2/3	4/3	2/2	3/3	91	4-
04111 Gannet Spring Creek	4/3	2/1	4/3	3/2	2/1	66	3+
04112 Commissary Range	4/3	3/2	4/3	2/2	4/4	178	4+
04113 Nugent Park West	4/3	2/1	1/3	2/2	2/1	7	2+
04114 Hams Fork Ridge	4/4	3/2	4/1	2/2	4/4	14	4
04115 Bacon Ridge	4/4	2/1	2/1	2/2	1/3	5	3-
04116 Gypsum Creek	4/3	3/1	2/1	3/2	3/2	17	2+
04151 West Mink	4/1	2/1	1/4	2/2	2/2	20	1+
04152 Scout Mountain	4/1	2/1	1/4	2/2	2/2	32	1+
04153 Toponce	4/1	2/1	1/4	2/2	2/2	17	1+
04154 Bonneville Peak	4/1	2/1	1/4	2/2	2/2	32	1+
04155 North Pebble	4/1	2/1	1/4	2/2	2/2	6	1+
04156 Elktown Mountain	4/1	2/1	1/4	3/2	2/2	45	1+
04157 Oxford Mountain	4/1	2/1	1/4	3/2	2/1	42	1+
04158 Deep Creek	4/1	2/1	1/4	2/2	2/1	5	1+
04159 Clarkston Mountain	4/1	2/1	1/4	2/2	2/1	19	1+
04160 Pole Creek	4/4	2/1	1/4	2/2	4/2	9	3+
04161 Caribou City	4/4	2/1	4/2	2/2	4/4	93	4
04162 Stump Creek	4/2	2/1	4/2	3/2	2/1	103	3
04163 Schmid Peak	4/2	2/2	1/3	2/2	4/4	11	3
04164 Dry Ridge	4/3	2/2	1/3	2/2	4/4	23	3+
04165 Huckleberry Basin	4/3	2/2	1/3	3/2	4/4	30	4
04166 Sage Creek	4/3	2/2	1/3	2/2	4/4	17	3+
04167 Meade Peak	4/3	2/3	1/3	3/2	4/4	42	4
04168 Hell Hole	4/2	3/1	1/4	2/2	4/4	6	3+
04169 Telephone Draw	4/3	3/1	1/3	3/2	3/2	5	3
04170 Red Mountain	4/3	3/1	1/3	3/2	3/2	14	3+
04171 Soda Point	4/2	2/1	1/4	2/2	2/1	74	2-
04172 Sherman Peak	4/2	2/1	1/4	2/2	2/2	15	2-
04173 Stauffer Creek	4/1	2/1	1/4	2/2	2/2	8	2-
04174 Williams Creek	4/2	2/1	3/1	3/2	2/1	11	2
04175 Liberty Creek	4/2	2/1	1/3	3/2	2/3	17	2
04176 Mink Creek	4/1	2/1	2/3	3/2	2/2	16	2
04177 Paris Peak	4/1	2/1	1/3	2/2	2/3	9	2+
04178 Station Creek	4/1	2/1	1/2	2/2	2/2	9	2
04179 Worm Creek	4/1	2/1	1/3	2/2	2/3	42	2+
04180 Swan Creek Mountain	4/1	2/1	1/3	2/2	2/3	21	2+
04181 Gibson	4/1	2/1	1/3	2/2	2/2	11	2
04610 West Slope Tetons	2/1	2/1	1/4	2/2	4/4	177	1
04611 Garns Mountain	4/4	3/2	4/4	2/2	4/4	115	4+
04612 Moody Creek	4/4	2/1	1/3	2/2	3/2	9	3
04613 Palisades	4/4	4/3	4/4	3/2	4/4	247-DOE 155-FS	4+
04614 Bald Mountain	4/4	3/2	3/2	2/2	4/4	15	4
04615 Bear Creek	4/4	3/2	3/3	3/2	4/4	79	4+
04616 Poker Peak	4/4	3/1	1/4	3/2	4/1	19	4
04755 Farmington	4/2	2/1	1/4	2/2	2/2	12	1+
04756 Francis	4/2	2/1	1/4	2/2	2/2	16	1+
04758 Mount Naomi	4/2	2/2	3/1	2/2	2/2	84	2
04759 Mount Logan	4/2	2/1	1/4	2/2	2/1	42	1+
04760 Wellsville Mountain	4/1	2/1	1/4	3/2	4/3	24	3+
04761 Mollens Hollow	4/2	2/1	1/4	2/2	2/1	17	2-
04762 Willard	4/1	2/1	1/4	2/2	4/4	17	3-
04763 Lewis Peak	4/1	2/1	1/4	3/2	4/1	12	2+
04764 Upper South Fork	4/2	2/1	1/4	2/2	4/2	12	2
04765 Burch Creek	4/1	2/1	1/4	3/2	2/1	8	1+

[a]Upper number represents favorability of the area for occurrence of the resource; lower number represents certainty that the resource is present.

[b]1 to 4+.

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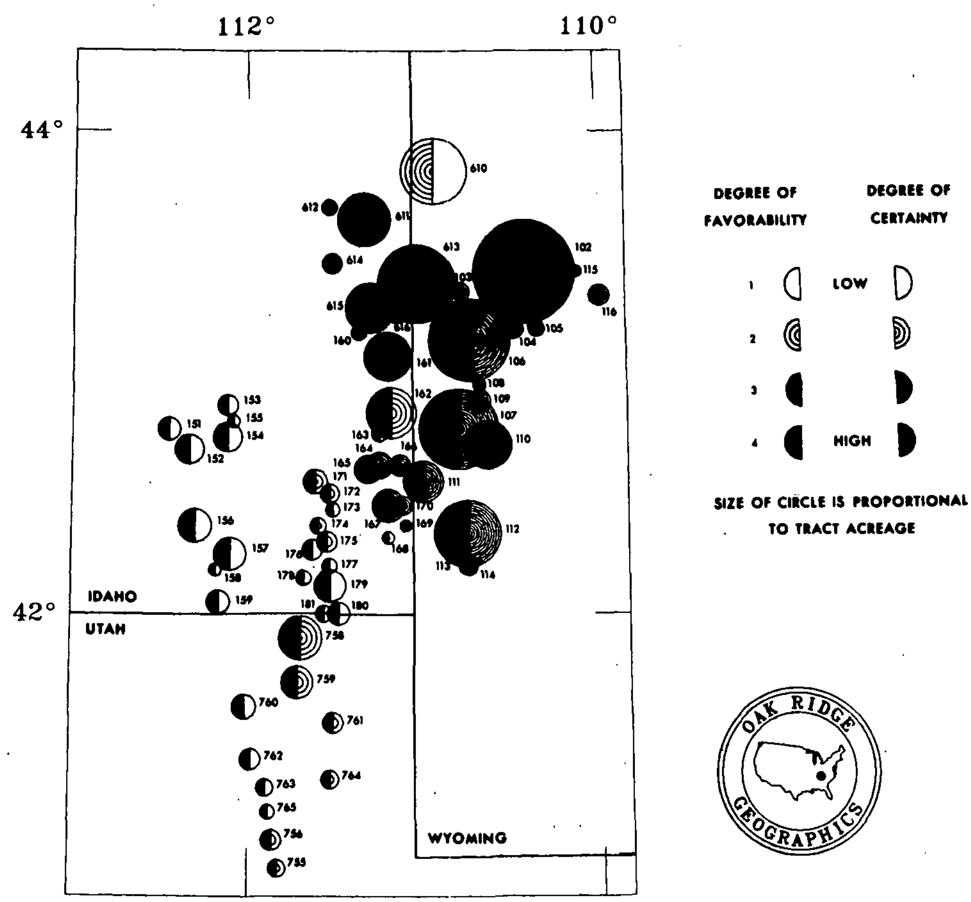

Fig. 4. Ratings of oil and gas in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

Table 3. Distribution of oil and gas ratings among Idaho-Wyoming-Utah tracts

ORNL rating	Number of tracts	Acres (thousands)
2/1	1	177
4/1	20	395
4/2	13	420
4/3	15	972
4/4	14	1157

geology of the remaining 60 tracts and the limited amount of geologic data available, most of these tracts are also given ratings of 2/1. The distribution of uranium ratings for the 63 tracts is summarized in Table 4 and displayed graphically in Fig. 5.

Table 4. Distribution of uranium ratings among Idaho-Wyoming-Utah tracts

ORNL rating	Number of tracts	Acres (thousands)
2/1	41	1376
2/2	5	170
2/3	2	133
3/1	9	794
3/2	5	401
4/3	1	247

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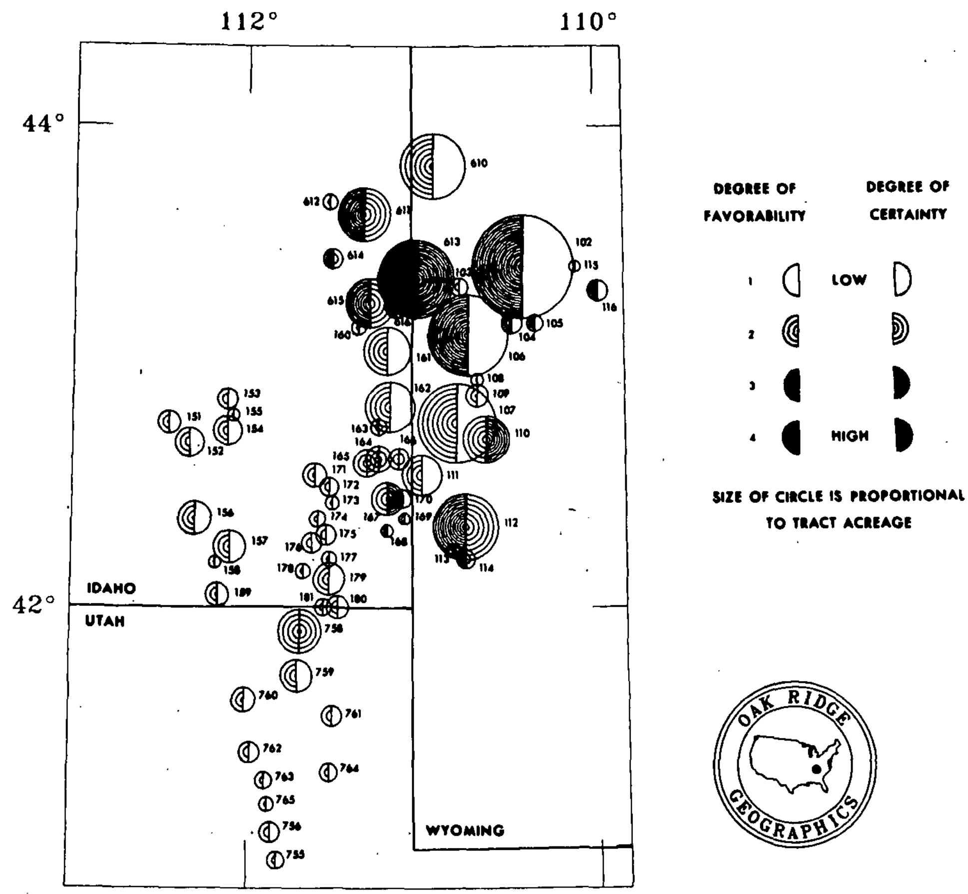

Fig. 5. Ratings of uranium in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

2.3.4 Coal

Only a few RARE II tracts contain outcrops of minable coal and lignite of Cretaceous and Tertiary age. The coal ranges from subbituminous to bituminous in rank and is of variable quality. Most of the coal occurs in the upper plates of the eastern thrust sheets, mainly in Wyoming but partly in Idaho; some coal also occurs in tracts near the western edge of the Green River basin in Wyoming (tracts 04102, 04105–04109, 04611, and 04613). Lignite occurs in Teritary rocks in the western part of the thrust belt.

The distribution of coal is fairly well known, and the tonnage underlying a RARE II tract can be roughly estimated. One can compare the area of any RARE II tract overlying a coalfield with the total area of the field and multiply this ratio by the total tonnage of coal in the field. The estimate is rough because it is not known whether or not the coal is uniformly distributed throughout the field. Based on this method, we estimate the coal resources under RARE II tracts considered in this report to be a maximum of 40 million tons in Wyoming (Glass et al. 1975), 10 million tons in Idaho (Kiilsgaard 1964), and none in Utah (Dow 1945), which is about 0.001% of the coal resources of the United States (Averitt 1975). Because only 16 tracts are given a favorability of 4 and 42 are given a favorability of 2 or less (Table 5), the thrust belt is considered to be relatively unimportant for coal.

Table 5. Distribution of coal ratings among Idaho-Wyoming-Utah tracts

ORNL rating	Number of tracts	Acres (thousands)
1/4	25	698
1/3	14	263
1/2	1	9
2/1	2	22
4/1	1	14
4/2	2	196
4/3	5	365
4/4	8	1361

However, Table 5, which summarizes the coal results of Table 2, also shows that the acreage of tracts with a favorability of 4 (1,936,000) is twice as large as the acreage of tracts with a favorability of 2 or 1 (992,000). This contradiction is caused by the concentration of coal in the large eastern tracts (Fig. 6). Coal does not underlie most of the acreage of the tracts, but if it underlies any part of a tract, the whole tract is rated accordingly.

In the development of the overall rating, high favorability and certainty for coal rarely led to a high overall rating for a tract, which is caused primarily by two factors: (1) the coal resources of the tracts comprise little of the country's resource base, as noted above, and (2) the complex structural geology of the thrust belt would make mining difficult and expensive.

2.3.5 Geothermal energy

The contribution that geothermal energy will make to the nation's energy requirements is certain to increase in the near future. However, although estimates of geothermal resources have differed by several orders of magnitude (White and Williams 1975), most researchers agree that geothermal energy will furnish only a small part of the nation's energy requirements by the year 2000.

The Idaho-Wyoming-Utah thrust belt is structurally distinct and possibly hydrologically and thermally distinct from the Yellowstone National Park "known geothermal resource area." Although the potential for geothermal power is enormous in the Yellowstone area, the thrust belt has a low potential.

The assignment of favorability/certainty values for geothermal resources within the RARE II tracts is particularly difficult because of the seemingly dispersed nature of the resource. Because the geothermal industry is still in its infancy, the resource assessment considered neither the technical feasibility nor the economics of geothermal development. As a result, the favorability was based on USGS data (White and Williams 1975), a geothermal resources map prepared by the National Oceanic and Atmospheric Administration (NOAA) in 1977 (NOAA 1977), and the abundance or absence of such features as hot springs, earthquakes, and relatively recent intrusive and extrusive igneous rocks that are commonly considered essential for a geothermal resource. These features are particularly evident in tracts 04162, 04175, and 04176. Based on proximity to Yellowstone National Park, a certainty of 2 was assigned to all tracts. In assigning an overall tract-importance rating, the geothermal resource was the least important of all the energy and mineral resources evaluated. The distribution of geothermal "favorability/certainty" values for the 63 tracts is shown in Table 2 and summarized in Table 6.

Table 6. Distribution of geothermal energy ratings among Idaho-Wyoming-Utah tracts

ORNL rating	Number of tracts	Acres (thousands)
2/2	42	1606
3/2	21	1515

ORNL-DWG 78-20225

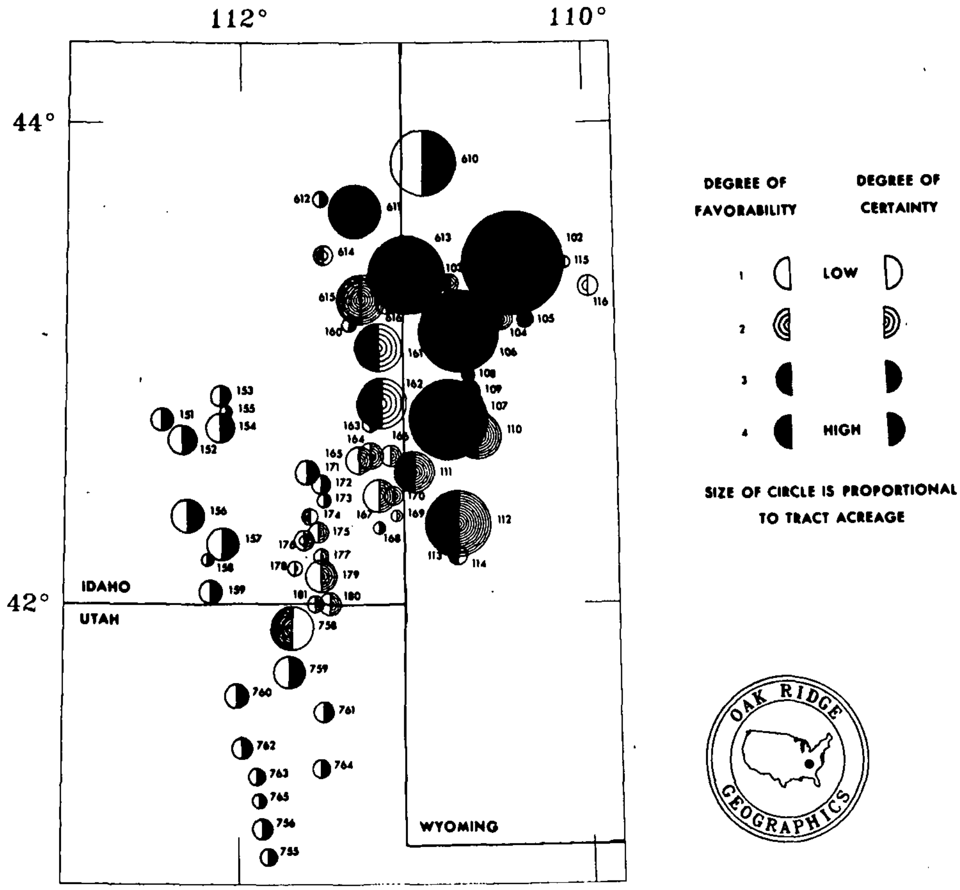

Fig. 6. Ratings of coal in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

A graphic display of the geothermal ratings is shown in Fig. 7.

2.3.6 Critical minerals

The economic and strategic importance of critical minerals has guided our evaluation of these resources in the Idaho-Wyoming-Utah thrust belt. The chief critical mineral deposits present in the RARE II lands of the thrust belt are phosphorus, gold, copper, and asbestos. Phosphorus occurs in the phosphate rock resources of the Northwest Phosphate Region (Idaho, Montana, Utah, and Wyoming). The identified phosphate resource of this region is more than one-half of that of the United States as a whole (Cathcart and Gulbrandsen 1973) and amounts to nearly 800 million tons of contained phosphorus. Not only does most of this resource lie within the Idaho-Wyoming-Utah thrust belt area, but a significant part lies within the RARE II tracts of the belt. Nearly one-half of the tracts in the thrust belt have outcrops of phosphate-bearing rocks (Voelker et al. 1979). Furthermore, most of these are the larger tracts in the eastern and northern part of the thrust belt (Fig. 3).

Although the phosphate resources are of importance in their own right as a major component of mineral fertilizer, the western U.S. phosphorites are also important for their content of

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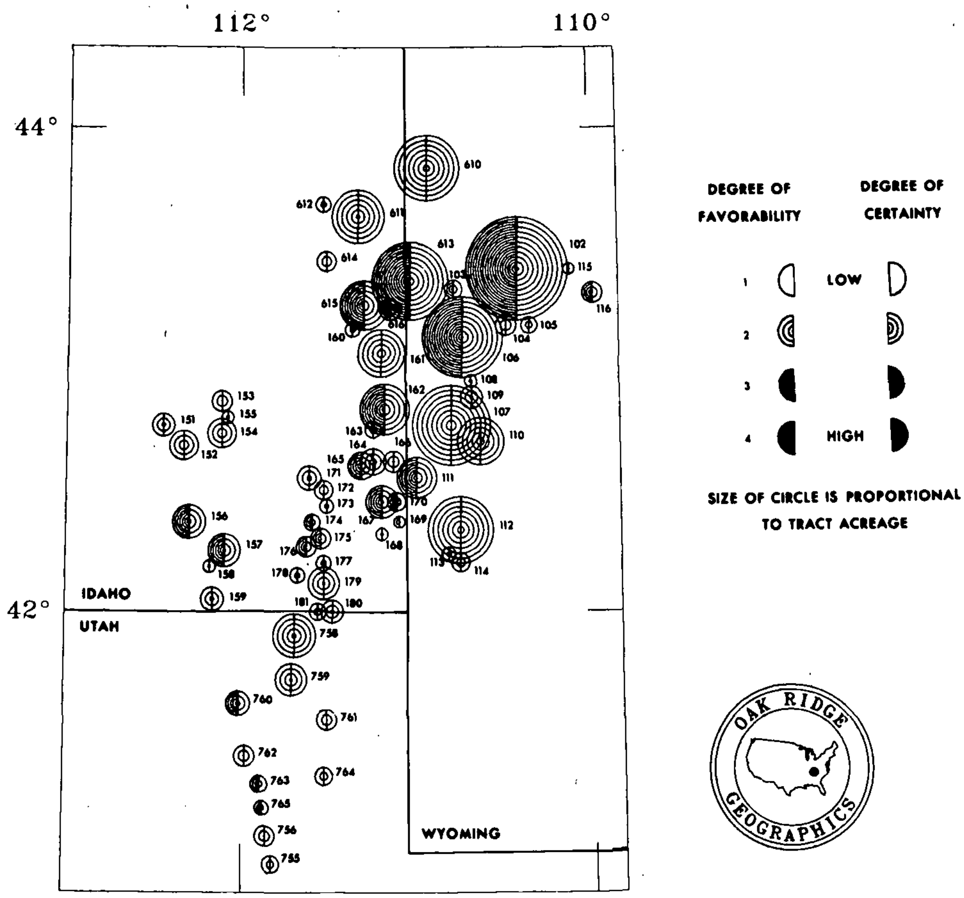

Fig. 7. Ratings of geothermal energy in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

minor elements, the most significant of which are vanadium, fluorine, uranium, cadmium, chromium, molybdenum, and zinc. These elements very likely may be recovered in the not too distant future as by-products; vanadium has been recovered for some years, and it is anticipated that, by 1982, all phosphoric acid plants in North America will have installed uranium recovery circuits. In this regard, chromium is of special interest because it occurs in amounts averaging about 0.3% (Gulbrandsen 1966). The low-grade occurrence of chromium is likely to be of considerable significance in the not too distant future, considering the projected demands for chromium, the lack of domestic conventional ores, and the unstable political nature of the regions from which we draw most of our imports. However, the precise habitat of chromium in the phosphate rock is not well known (Gulbrandsen 1979), and much research is needed, not only to determine whether or not the chromium can be recovered economically but also to ensure that excess soluble chromium salts are not being discharged to the environment during fertilizer manufacturing.

The importance of gold as a critical mineral should not be underestimated either industrially or economically. The Mount Pisgah gold district in Bonneville County, Idaho, reportedly produced as much as 60,000 oz of gold, mostly in the 1870s and chiefly from placers. Bedrock occurrences are reported to be in pyritic quartz veins, but the geological potential of the district has not been adequately assessed, particularly for fine-grained, Carlin-type deposits. Much of this district lies within RARE II tracts (04160, 04161, 04615, and 04616) in the northern part of the Idaho segment of the thrust belt area. However, because of the lack of adequate new data, the certainty of gold occurrence is low, although the favorability is considered to be high.

Copper, some lead, and minor quantities of zinc and the precious metals occur in several types of deposits throughout the western part of the Idaho-Wyoming-Utah thrust belt region. The favorability for the occurrence of large, economic grade deposits is relatively low, using current exploration models.

Asbestos and/or talc (Chidester and Shride 1962) has been reported on or near tracts 04610 in western Wyoming and 04763 north of Ogden, Utah. The deposits are small, and the general nature of their geologic occurrence does not indicate a potential for large, readily available resources.

The nature of our critical minerals rating is obviously very complex — much more complex than that for a single resource. The diverse nature of the geologically favorable environments in which the various resources can occur and the methods used in the search for their presence are the major factors of this complexity. Goals in future rating procedures may well have to include separate ratings for some, if not all, of the critical minerals. The distribution of the various combinations of favorability and certainty of critical minerals in the RARE II tracts of the Idaho-Wyoming-Utah thrust belt is shown in Table 7. Note the large acreage that has been given a 4/4 rating. This acreage is revealed in Fig. 8 to be concentrated in large tracts in the northeast portion of the region. Except for several tracts having copper potential, the smaller tracts to the southwest are of less value for critical minerals.

Table 7. Distribution of critical minerals ratings among Idaho-Wyoming-Utah tracts

ORNL rating	Number of tracts	Acres (thousands)
4/4	16	1502
4/3	3	552
4/2	3	34
4/1	2	31
3/4		
3/3	1	91
3/2	6	83
3/1		
2/4		
2/3	4	89
2/2	14	323
2/1	12	400
1/4		
1/3	2	16
1/2		
1/1		
Total	63	3121

2.3.7 Overall tract importance rating

The overall ratings assigned by the team to each tract are listed in Table 2. One can appreciate the high overall resource potential (importance) of the thrust belt by aggregating and displaying the ratings in Table 2 in several different ways. The overall importance rating of each tract is shown in Fig. 9 by the amount of black in each circle. The frequency distribution of the overall ratings is shown in Fig. 10. The distribution is essentially flat, with approximately the same number of tracts appearing in each category. The large number of tracts appearing in categories 3 and 4 highlights the importance of the thrust belt. In most other regions of similar size in the country, the preponderance of tracts will most likely occur in categories 1 and 2, with relatively few entries in categories 3 and 4. The importance is further emphasized in Fig. 11, in which the acreage in category 4 is shown to be greater than all the other categories combined. Most tracts fall into category 4 by virtue of the

ORNL-DWG 78-20226

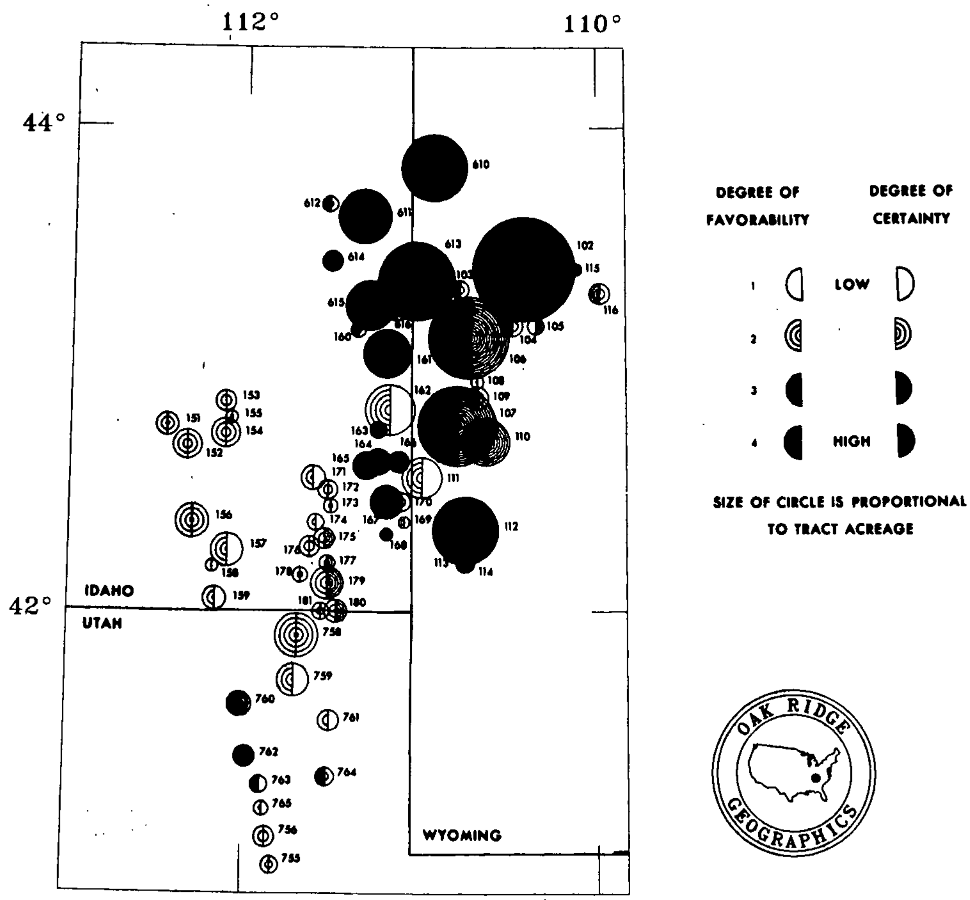

Fig. 8. Ratings of critical minerals in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

multiple occurrence of valuable resources and the fact that large size can usually be equated to larger quantities of resources. A quick scan of Figs. 4, 6, and 8 shows a cluster of darkly shaded tracts, usually including tracts 04102, 04106, 04107, 04112, 04161, 04611, 04613, and 04615. These same tracts appear as highly important in the overall rating (Fig. 9).

2.4 Central Appalachian Thrust Belt Application

2.4.1 Description of the central Appalachians

The central Appalachians studied in the second application are shown in Fig. 12. The region lies within a 330- by 100-mile belt paralleling the regional geologic structure and encompasses large parts of Virginia, West Virginia, North Carolina, and Tennessee. The area comprises approximately 33,000 sq miles, or about 21,100,000 acres, and contains 72 RARE II tracts totalling about 610,000 acres. When compared with Fig. 3, Fig. 12 illustrates the relatively small size of the central Appalachian tracts.

The central Appalachians include three relatively distinct northeast-trending physiographic provinces, which correspond roughly to geologic/structural provinces (Fenneman 1946). Along the southeast side is the Blue Ridge province, which consists largely of Precambrian igneous and metamorphic rocks and smaller amounts

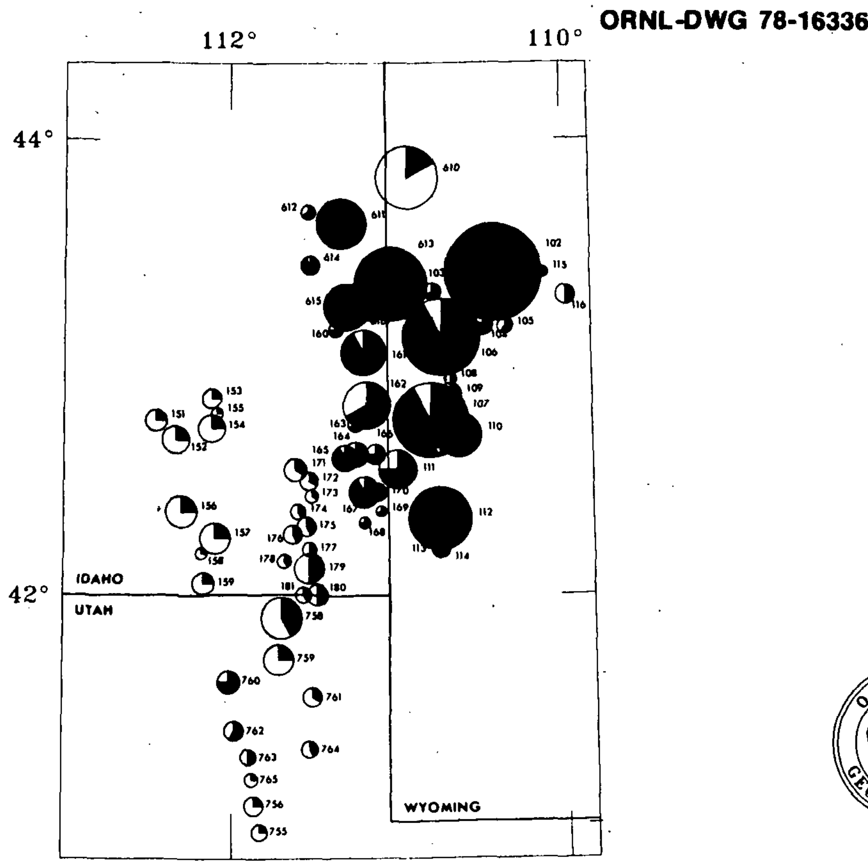

Fig. 9. Relative importance of the 63 RARE II tracts evaluated in the Idaho-Wyoming-Utah thrust belt. The last 3 digits of Table 2 tract numbers are listed.

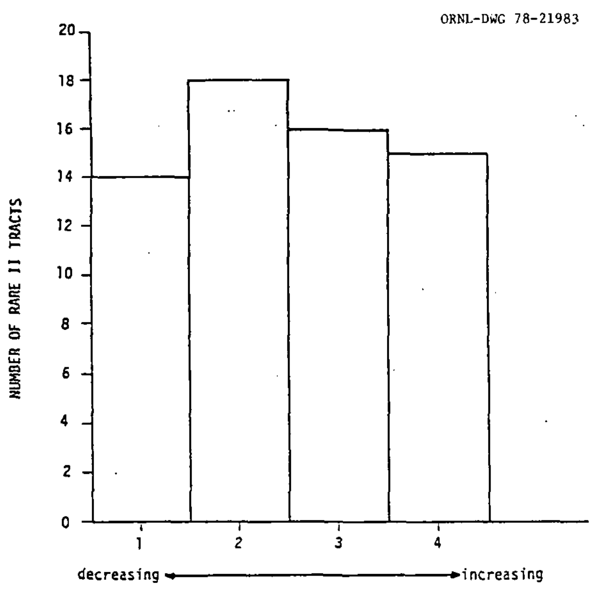

Fig. 10. Total number of tracts in each importance category for RARE II tracts evaluated in the Idaho-Wyoming-Utah thrust belt.

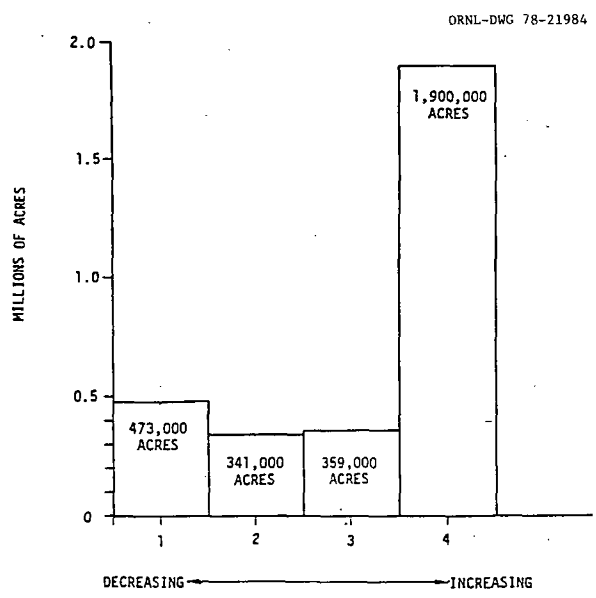

Fig. 11. Total acreage allotted to each importance category for the RARE II tracts evaluated in the Idaho-Wyoming-Utah thrust belt.

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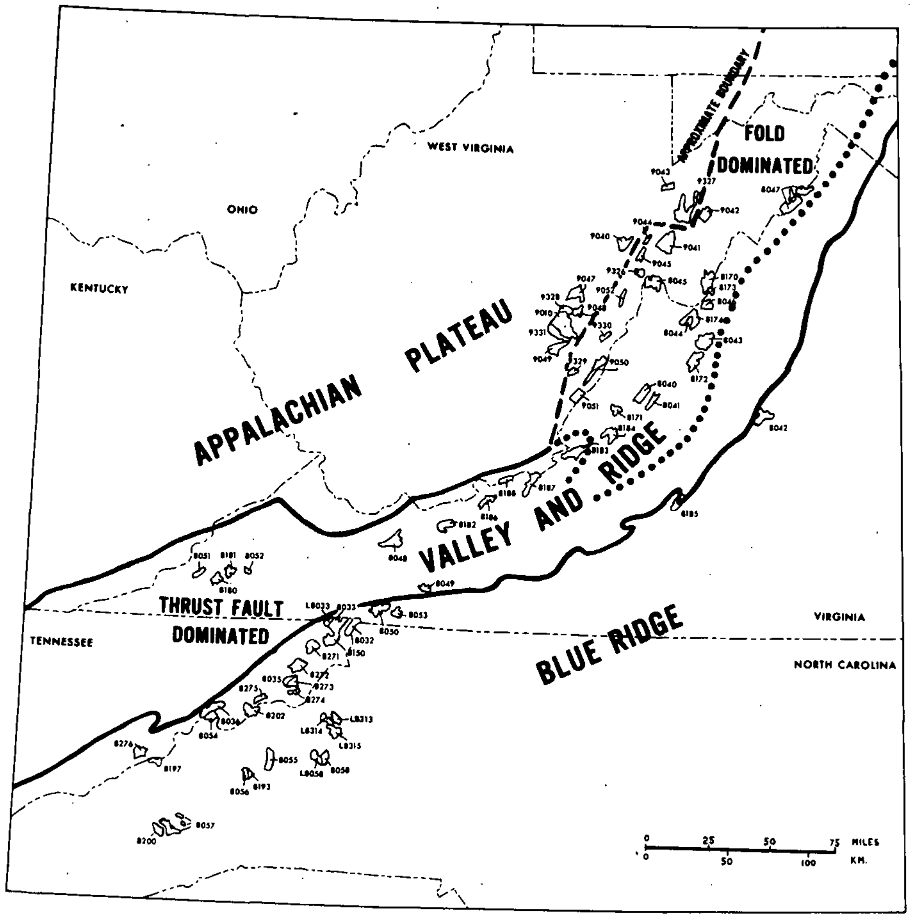

Fig. 12. RARE II tracts in the central Appalachian thrust belt.

of Paleozoic sedimentary rocks. Fifteen tracts are located in the metamorphic and igneous eastern part of the province, and fourteen are located in the sedimentary rocks on the western edge. Adjacent to the Blue Ridge to the northwest is the Valley and Ridge province, which consists of Lower and Middle Paleozoic sedimentary rocks. Thirty-four tracts are located in this province. Immediately northwest of the Valley and Ridge is the Appalachian Plateau province, which consists of Middle and Upper Paleozoic sedimentary rocks. Nine tracts are included in this province.

All three provinces have been deformed as a result of late Paleozoic compression directed to the northwest (Harris and Milici 1977). The compression has formed abundant folds and thrust faults, particularly in the Valley and Ridge. In general, thrust faults are the dominant structures at the surface in the southern and eastern parts of the province, whereas the northern and western segments are characterized by large fold structures with only nominal faulting. These parts of the province are informally called thrust fault–dominated and fold-dominated, respectively, in this report. Eleven tracts are located in the thrust-dominated area, and twenty-three tracts are located in the fold-dominated area. In the Appalachian Plateau, the compressional deformation is much less severe, although large folds and areally extensive thrust sheets have been recognized. To the east, the intensity of deformation increases, and metamorphic effects are widespread, especially in the Blue Ridge.

2.4.2 Oil and gas

In 1859 oil was first discovered in the United States within the Appalachian Plateau of Pennsylvania. Since then oil and gas exploration and production have been concentrated in the Appalachian Plateau, with some in the fold-dominated part of the Valley and Ridge, both in and north of the area considered in this report. On the other hand, little exploration for oil and gas has been conducted in the thrust fault–dominated part of the Valley and Ridge, and virtually none in the Blue Ridge (USGS 1974, 1975).

As a result of the long history of oil and gas production from the Appalachian Plateau, this province is considered very favorable for continued discoveries. The region contains many hydrocarbon-source rocks (i.e., organic shales and limestones) and a broad spectrum of reservoirs that range from the porous sands in classic anticlines, fault traps, shoestring sands, or stratigraphic traps to dolomitic and fracture porosities in carbonate rocks. In short, the region as a whole is broadly favorable geologically in numerous formations of a variety of ages. Indeed, many of the concepts developed to explain the accumulation of petroleum originated in late-nineteenth-century studies in the Appalachian region.

Because of these considerations, all Plateau tracts were assigned a favorability of 4 (Fig. 13). The certainty of occurrence was rated as 2 because of the distance to known fields and the uncertain extrapolation to tracts from structures known to contain oil and gas.

The rocks of the Valley and Ridge are similar to those of the Appalachian Plateau: sedimentary rocks that act as hydrocarbon sources and reservoirs. The fold-dominated part of the Valley and Ridge contains several anticlines known to produce hydrocarbons, and the thrust faults at depth may have vertically stacked productive units. However, the productive Pennsylvanian rocks are not present, and there has been little exploration of potentially favorable Lower Paleozoic rocks.

Although the older Paleozoic rocks may have originally contained the abundant organic material to form oil and gas, the very age of the rocks, in addition to the tectonic activity and metamorphism to which they have been subjected, mitigates against retention of large quantities of hydrocarbons. The fracturing and later thrust faulting would permit leakage to the surface because earlier concentrations of oil and gas were heated by the compression and metamorphism. Because of this history such recoverable hydrocarbons yet trapped in the province are most likely gas.

As a result of these considerations, favorability and certainty vary throughout the province. Two tracts, 09044 and 09045, are rated 4/4 because they overlie a known gas field from which there is production (Patchen et al. 1978). One tract, 08051, is rated 4/3 because it lies close to a gas-producing anticline (Patchen et al. 1978). Eleven other tracts are rated 4/2 because they are near gas-producing anticlines. All of these tracts are in the western parts of the Valley and Ridge province. As tracts get closer to the Blue Ridge, both favorability and certainty drop. For instance, tract 08185 on the boundary between the Valley and Ridge and Blue Ridge is rated 2/1.

ORNL-DWG 79-7227

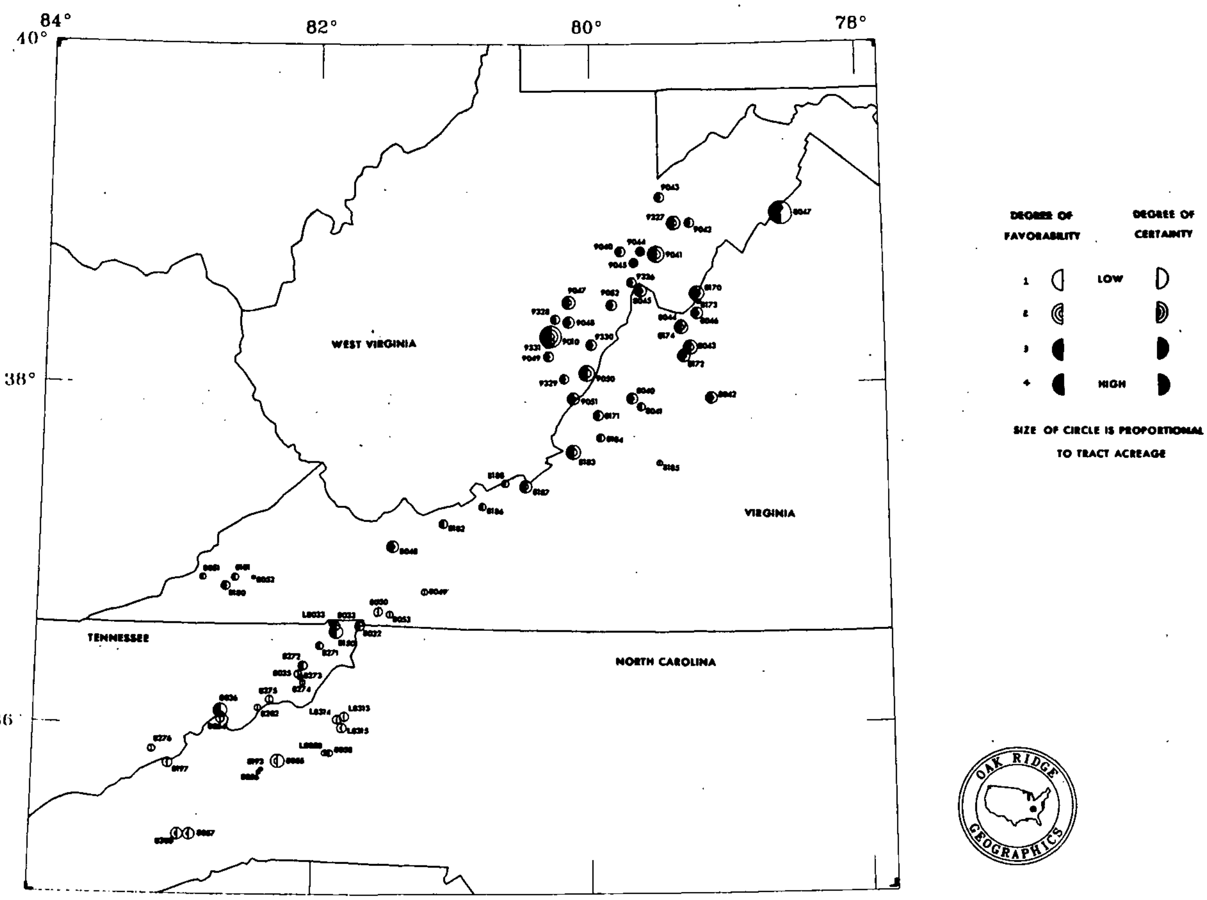

Fig. 13. Ratings of oil and gas in the central Appalachian thrust belt.

The Blue Ridge consists of Precambrian metamorphic and igneous rocks and Cambrian sedimentary rocks that almost certainly contain no oil or gas. However, the Blue Ridge may be a set of extensive, west-directed thrust sheets, emplaced over sedimentary rocks similar to those in the Valley and Ridge (Harris 1976). If so, potential exists for gas at depth below the Blue Ridge. Also, recent data (Price 1977) have shown that fluid hydrocarbons can exist at high temperatures so that the metamorphism of the Blue Ridge may not have driven off or destroyed any existing oil and gas. Because of these two developing theories, we have cautiously rated the favorability of the tracts with metamorphic and igneous rocks at the surface as 2 and have rated as 3 the tracts in the sedimentary rocks at the western edge of the province. Because of the lack of data on actual occurrence, however, certainty was rated as 1 except for tract 08042, which is closer to gas-bearing rocks and therefore was rated 2.

The ratings for oil and gas are summarized in Table 8 for the 72 tracts. Overall, about one-third of both the tracts and the acreage is highly favorable (4/2 or higher). On the other

Table 8. Distribution of oil and gas ratings among tracts in the central Appalachians

ORNL ratings	Number of tracts	Acres (thousands)
2/1	22	112
3/1	8	97
3/2	19	174
4/2	20	200
4/3	1	15
4/4	2	12

hand, the tracts make up only a small part of the favorable acreage in the central Appalachians so that the ratings for oil and gas did not justify raising overall importance to 4. Complete rating and acreage information for each tract is listed in Table 9.

2.4.3 Uranium

Exploration for uranium in the eastern United States has been limited (ERDA 1976). Because the known deposits occur in igneous, sedimentary, and metamorphic rocks and because these rock types are common in the central Appalachians, all RARE II tracts were assigned a favorability of at least 2 (Table 9). The favorability was increased if the tract contained one or more particularly favorable rock types such as karst breccia, sandstone, conglomerate, and granite.

The tracts most likely to contain uranium deposits are in the Blue Ridge, where granitic gneisses, granites, and Lower Paleozoic sandstones and conglomerates are common. Three tracts in the Blue Ridge in North Carolina, where uranium has been found (Bryant and Reed

Table 9. RARE II tract evaluation for the central Appalachian thrust belt

Tract number and name	Oil and gas[a]	Uranium[a]	Coal[a]	Geothermal[a]	Critical minerals[a]	Acreage (thousands)	Overall rating[b]
08033 Beaverdam Creek	3/1	2/1	1/4	2/1	4/4	5	3-
L8033 Beaverdam Creek	3/1	2/1	1/4	2/1	3/2	2	2-
08272 Big Laurel Branch	3/1	2/1	1/4	2/1	4/4	6	3
08276 Devil's Backbone	2/1	2/2	1/4	2/1	3/2	4	2-
08271 Hickory Flat Branch	3/1	2/1	1/4	2/1	4/4	5	3
08150 Iron Mountain	3/1	2/1	1/4	2/1	4/4	14	3
08036 Jennings Creek	3/1	2/2	1/4	2/1	3/2	15	2+
08274 Laurel Fork	2/1	3/2	1/4	2/1	2/3	2	2-
08202 Nolichucky	2/1	2/2	1/4	2/1	3/2	3	2
08273 Pond Mountain Addition	2/1	3/2	1/4	2/1	3/2	2	3-
08035 Pond Mountain	2/1	2/2	1/4	2/1	4/4	4	3-
08032 Rogers Ridge	3/1	2/2	1/4	2/1	4/4	7	3
08275 Unaka Mountain	2/1	2/2	1/4	2/1	2/2	5	1+
08055 Balsam Cone	2/1	2/2	1/4	2/1	4/3	14	3+
08054 Big Creek	2/1	2/2	1/4	2/1	3/1	6	2-
08056 Craggy Mountain Extension	2/1	2/2	1/4	2/1	3/1	1	2+
08193 Craggy Mountain WSA	2/1	2/2	1/4	2/1	3/1	1	2+
L8315 Harper Creek	2/1	4/4	1/4	2/1	2/1	7	3+
08058 Linville Gorge Extension	2/1	3/2	1/4	2/1	3/2	4	2+
L8058 Linville Gorge Extension	2/1	3/2	1/4	2/1	3/2	3	2+
L8314 Lost Cove	2/1	4/4	1/4	2/1	2/1	6	3+
08200 Middle Prong	2/1	3/2	1/4	2/1	3/3	10	3-
08057 Shining Rock Extension	2/1	3/2	1/4	2/1	4/3	10	3
L8313 Upper Wilson	2/1	4/2	1/4	2/1	2/1	7	3
08197 Wildcat	2/1	2/2	1/4	2/1	3/2	7	2
08183 Barbours Creek	3/2	2/1	1/4	2/1	3/2	16	3-
08048 Beartown	3/2	2/1	1/4	2/1	3/1	11	2+
08181 Big Stoney	4/2	2/2	4/4	2/1	2/1	4	2+

Table 9. (continued)

Tract number and name	Oil and gas[a]	Uranium[a]	Coal[a]	Geothermal[a]	Critical minerals[a]	Acreage (thousands)	Overall rating[b]
08180 Devils Fork	4/2	2/2	4/4	2/1	2/1	6	2+
08184 Hoop Hole	3/2	2/1	1/4	2/1	3/2	5	2+
08182 Kimberling Creek	3/2	2/1	1/4	2/1	2/1	6	1+
08050 Lewis Fork	2/1	2/2	1/4	2/1	3/1	6	1+
08049 Little Dry Run	2/1	2/1	1/4	2/1	3/3	3	2
08052 Little Stoney	4/2	2/2	3/4	2/1	2/1	1	2+
08053 Little Wilson Creek	2/1	2/2	1/4	2/1	2/1	4	1+
08186 Mill Creek WSA	3/2	2/1	1/4	2/1	3/3	4	2
08187 Mountain Lake WSA	3/2	2/1	1/4	2/1	3/2	12	3-
08188 Peters Mountain WSA	3/2	2/1	1/4	2/1	3/2	4	2
08051 Roaring Branch	4/3	2/2	4/4	2/1	2/1	3	2+
08185 Thunder Ridge	2/1	3/1	1/4	2/1	2/1	3	1+
08047 Big Schloss	3/1	2/1	1/4	2/1	2/1	41	1+
08043 Crawford Mountain	3/2	2/1	1/4	2/1	2/1	15	1+
08171 Dolly Anne	3/2	2/1	1/4	2/2	2/1	8	1+
08172 Elliott Knob	3/2	2/1	1/4	2/1	2/1	12	1+
08173 Head of Dry River	3/2	2/1	1/4	2/1	3/1	1	1+
08045 Laurel Fork	3/2	2/1	1/4	2/1	3/2	11	2-
08046 Little River	3/2	2/1	1/4	2/1	3/2	11	2-
08174 Ramseys Draft Addition	3/2	2/1	1/4	2/1	3/2	13	2-
08044 Ramseys Draft Study Area	3/2	2/1	1/4	2/1	3/2	7	2-
08041 Rich Hole	3/2	2/1	1/4	2/1	2/2	5	1+
08040 Rough Mountain	3/2	2/1	1/4	2/1	3/3	9	2
08042 St. Mary's	3/2	2/1	1/4	2/1	3/2	11	2-
08170 Dry River	3/2	2/1	1/4	2/1	3/2	17	2
09010 Cranberry	4/2	2/2	3/4	2/1	2/2	36	3
09040 Cheat Mountain	4/2	2/1	4/4	2/1	2/1	8	2+
09041 Seneca Creek	4/2	2/1	1/4	2/1	2/1	21	2
09042 North Mountain Hopeville	4/2	2/1	1/4	2/1	3/2	7	2
09043 Canaan Loop	4/2	2/1	4/4	2/1	2/1	7	2+
09044 Laurel Fork North	4/4	2/1	1/4	2/1	2/1	6	3
09045 Laurel Fork South	4/4	2/1	1/4	2/1	2/1	6	3
09047 Gauley Mountain	4/2	2/2	2/4	2/1	2/2	13	2+
09048 Tea Creek Mountain	4/2	2/2	2/4	2/1	2/2	10	2+
09049 Falls of Hills Creek	4/2	2/2	2/4	2/1	2/2	8	2+
09050 Middle Mountain	4/2	2/1	1/4	2/1	3/2	19	2+
09051 Little Allegheny Mountain	4/2	2/1	1/4	2/1	2/1	11	2-
09052 Little Mountain	4/2	2/1	1/4	2/1	2/1	8	2-
09326 East Fork of Greenbrier	4/2	2/1	1/4	2/1	2/1	7	2
09327 Dolly Sods Roaring Plain	4/2	2/1	4/4	2/1	2/1	14	3-
09328 Turkey Mountain	4/2	2/2	3/4	2/1	2/2	16	3-
09329 Spice Run	4/2	2/1	1/4	2/1	2/1	6	2-
09330 Marlin Mountain	4/2	2/1	1/4	2/1	3/2	9	3·
09331 Cranberry Addition	4/2	2/2	3/4	2/1	2/3	10	3·

[a]Upper number represents favorability of the area for occurrence of the resource; lower number represents certainty that the resource is present.

[b]1 to 4+.

1966), were assigned a favorability of 4. The two closest to the deposit, L8314 and L8315, were assigned a certainty of 4, and L8313 was judged to have a certainty of 2. Two tracts, 08273 and 08274 in the Blue Ridge in Tennessee, are within the Walnut Mountain uranium district (Butler and Stansfield 1968) and were rated 3/2. The remaining 24 tracts in the Blue Ridge and the 12 in the Precambrian crystalline rocks were rated 2/2, and the 12 in the sedimentary rocks to the west were rated 2/1.

The tracts in the Valley and Ridge and Plateau provinces are considered less favorable for uranium. No tract was rated above 2/2.

The rating pattern is graphically portrayed in Fig. 14, whereas Table 10 summarizes the ratings among the 72 tracts. Overall, only five tracts totalling 24,000 acres were assigned a favorability of 3 or 4, which indicates the low potential for uranium in the central Appalachians. As uranium exploration continues, however, new models for accumulation will no doubt be developed, and perhaps areas that are considered

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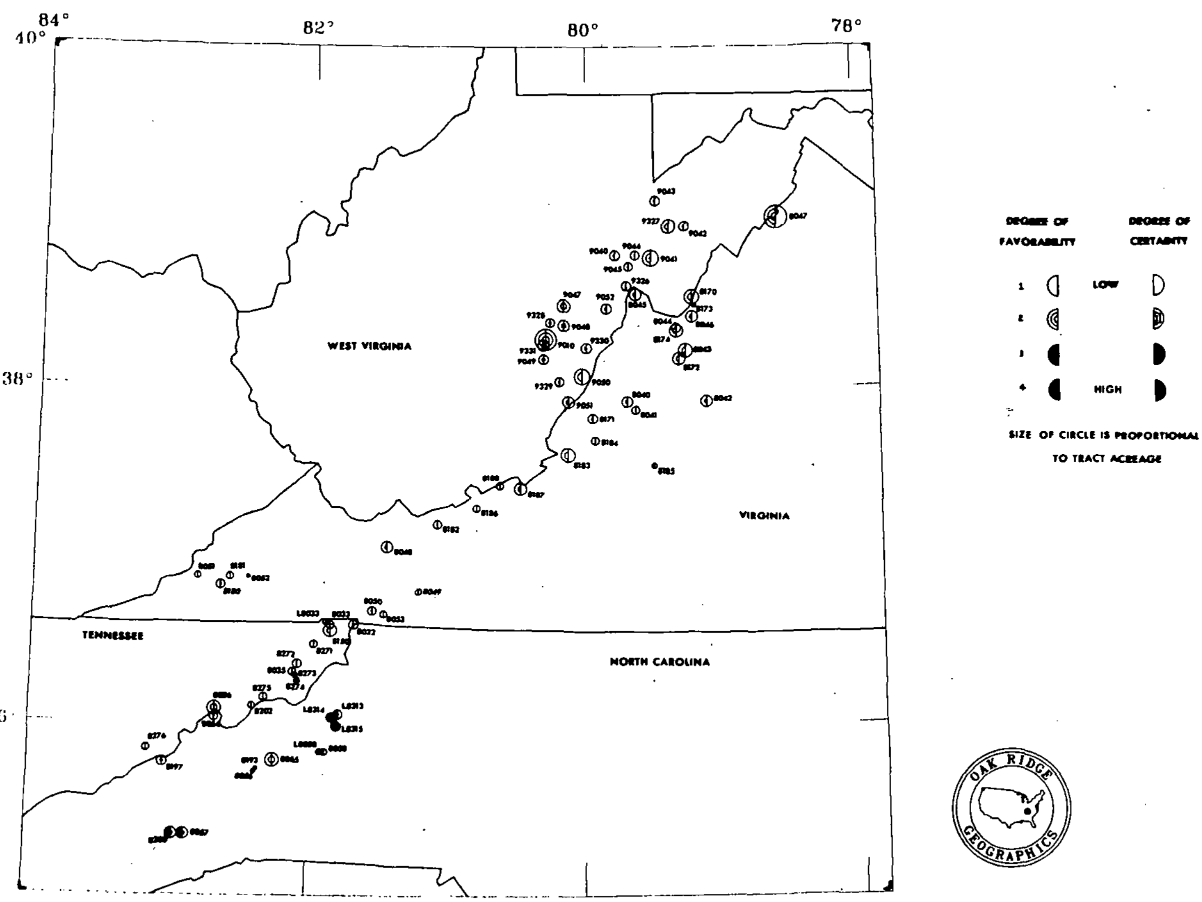

Fig. 14. Ratings of uranium in the central Appalachian thrust belt.

Table 10. Distribution of uranium ratings among tracts in the central Appalachians

ORNL rating	Number of tracts	Acres (thousands)
2/1	39	405
2/2	28	205
3/2	2	5
4/2	1	7
4/4	2	13

unfavorable now will become exploration targets in the future.

2.4.4 Coal

Bituminous coal is a major resource of the central Appalachians. The coal occurs mainly in the Appalachian coalfield, which lies in the Appalachian Plateau province and part of the thrust fault-dominated segment of the Valley and Ridge province in rocks of Carboniferous age. Only six tracts (08051, 08010, and 08181 in Virginia and 09040, 09043, and 09327 in West Virginia) lie within the coalfield (Trumbull 1960). Each tract was assigned a favorability/certainty rating of 4/4 (Table 9). Seven other tracts (08052 in Virginia and 09010, 09047, 09048, 09049, 09329, and 09331 in West Virginia) lie near the edge of the coalfield within less favorable environments for minable coal (Trumbull 1960) and were assigned favorabilities of 2 or 3. Yet because these tracts contain coal, although of poor quality or small tonnage, the certainty of coal occurrence is 4 (Table 9). The other 59 tracts lie in areas that are known not to contain coal and were therefore assigned a 1/4 rating. The coal rating pattern is displayed in Fig. 15.

The majority of tracts and the majority of acreage are unfavorable for coal, as shown in Table 11. Because the nation has a large coal reserve and little of this coal underlies RARE II acreage, a high tract rating for coal had little effect on the overall importance rating of a tract.

Table 11. Distribution of coal ratings among tracts in the central Appalachians

ORNL rating	Number of tracts	Acres (thousands)
1/4	59	483
2/4	3	31
3/4	4	54
4/4	6	42

2.4.5 Geothermal energy

The current tectonic setting of the central Appalachians is characterized by minor earthquakes, a shallow geothermal gradient, and no apparent significant recent faults that penetrate to the present land surface. In addition, the youngest igneous activity may be over 45 million years old. Compared with other regions of high heat flow, recent volcanism, and active faults, the central Appalachians are not a favorable base for geothermal resources (AAPG 1976a,b). However, hot, dry rock at depth may have some potential. All 72 tracts were assigned a favorability of 2. Only two tracts were assigned a certainty of 2, based on the occurrence of hot springs in or near the tract (08171 and 08040). The remaining 70 tracts were assigned a certainty of 1. The predominant use of a 1 certainty indicates a basic lack of understanding of the nature, occurrence, and extent of geothermal resources.

The pattern of ratings is graphically displayed in Fig. 16, and the various combinations of favorability/certainty ratings are tabulated in Table 12.

2.4.6 Critical minerals

The critical or strategic nature of certain mineral resources is a major factor in our evaluation of the RARE II tracts in the central Appalachians. The general category of critical minerals as used in this report has been discussed in Sect. 2.2; the materials included in this category are listed in Table 1. Those minerals that have been produced or are likely to occur in the central Appalachians are:

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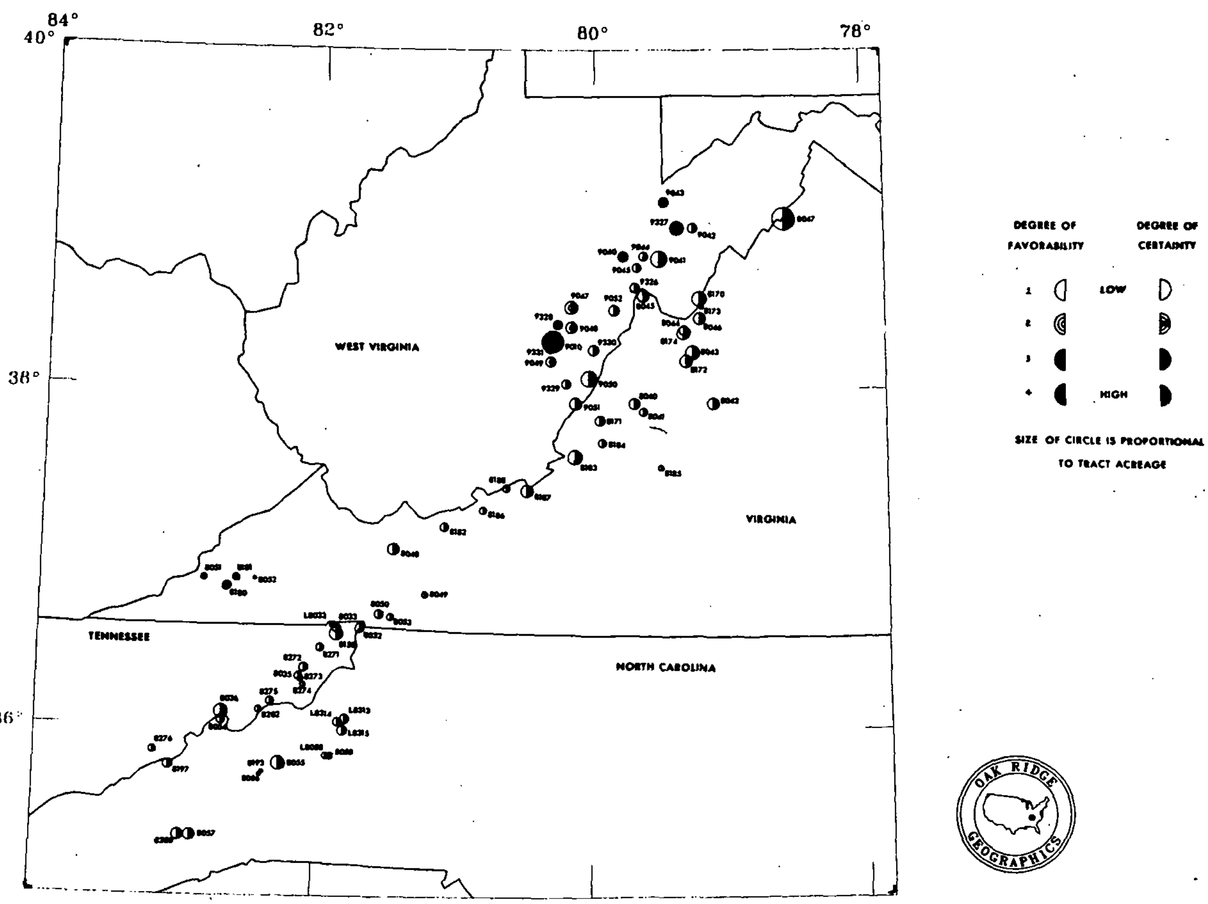

Fig. 15. Ratings of coal in the central Appalachian thrust belt.

Asbestos	Fluorite	Phosphate minerals
Barite	Gold	Sulfur
Bauxite	Iron	Tin
Cadmium	Manganese	Titanium
Copper	Mica (sheet)	Zinc

A known resource potential for critical minerals does not occur in many of the RARE II tracts in the central Appalachians for the most part. However, a high certainty of resource occurrence is generally nearby, usually as a result of the tract's being along the regional strike from favorable areas. As mentioned previously, the central Appalachians span three major physiographic/geologic provinces. Although many critical minerals may occur in more than one province, a significant potential is commonly restricted to only one or sometimes two provinces because of the variety of geologic factors that affect favorability. For example, titanium potential seems to be limited largely to ilmenite-apatite-rutile concentrations in Precambrian anorthosites and to ilmenite-zircon paleoplacers in Precambrian and early Cambrian clastic rocks, all in the Blue Ridge (Herz and Eilertsen 1968).

ORNL-DWG 79-7230

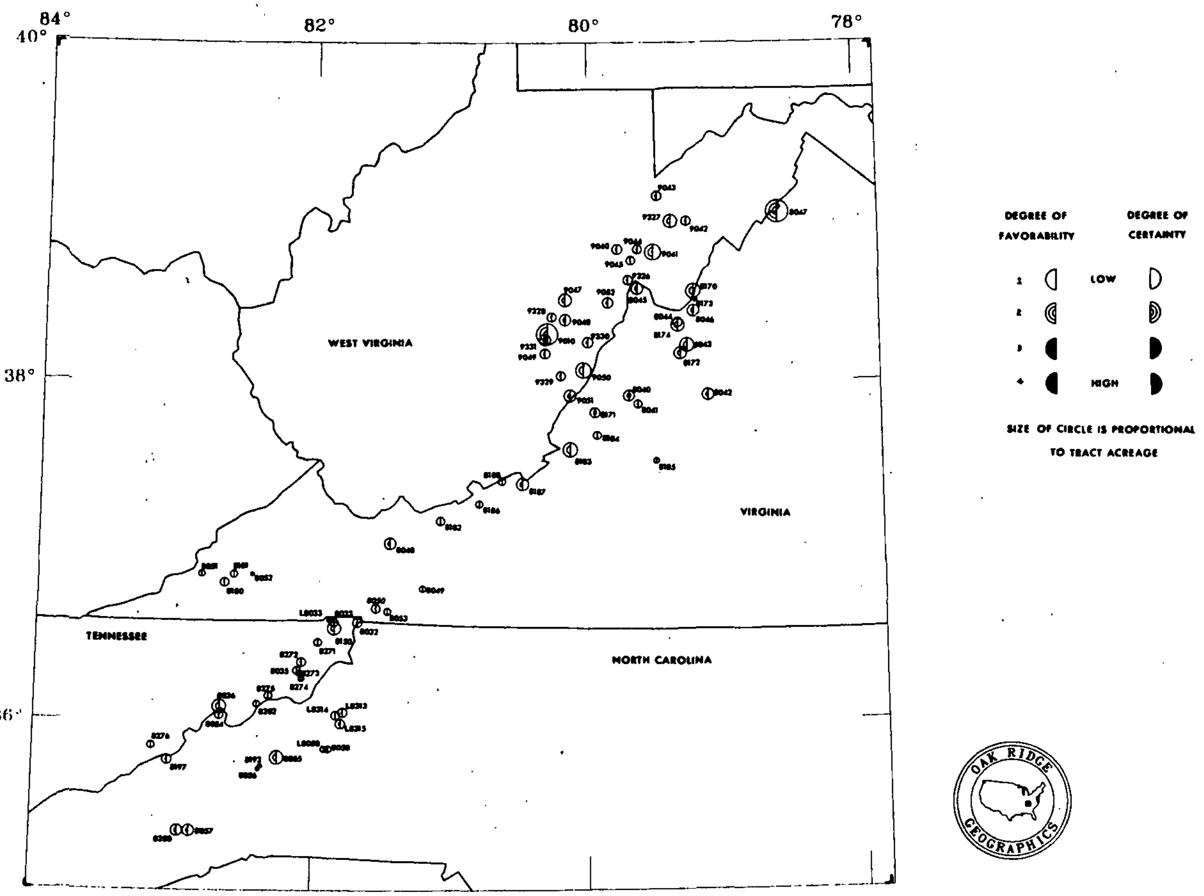

Fig. 16. Ratings of geothermal energy in the central Appalachian thrust belt.

Table 12. Distribution of geothermal ratings among tracts in the central Appalachians

ORNL rating	Number of tracts	Acres (thousands)
2/1	70	594
2/2	2	17

Zinc and its associated cadmium by-product are two of the most important critical minerals in the central Appalachians. According to Wedow and others (1973), more than one-half of our domestic zinc production comes from districts producing from the Cambro-Ordovician dolomitic rocks of the Valley and Ridge. These favorable rocks are exposed in most of the thrust plates in the Valley and Ridge and also underlie the Appalachian Plateau. It was the development of a new model, unrelated to the classic Appalachian thrust structures, that spurred exploration of the zinc potential at depth in the flat-lying rocks west of the Valley and Ridge province. Eventually this exploration led to the discovery and development of the new large Central Tennessee–Southern Kentucky zinc district in the 1960s and 1970s.

Barite, bauxite, manganese ore, and lesser amounts of phosphate resources occur sporadically in the clay residues from weathering of Paleozoic carbonate rocks, chiefly in the Valley and Ridge. Residual concentrations of iron ores also occur in small limonite deposits, usually associated with manganese ore. Iron ores have also been developed in the stratiform sedimentary deposits, which are typified by extensive hematite ores of the Birmingham region of Alabama. Except for the residual concentrations of ore that are limited to the current land surface, most favorable rock units and associated ores project westward beneath the Appalachian Plateau.

Copper, zinc, and sulfur have been recovered from massive sulfide deposits in the Appalachian region. Present models for this type of ore deposit essentially limit the occurrence to the crystalline metamorphic rocks of the Blue Ridge and Piedmont provinces. Poorly known occurrences of disseminated copper have also been reported in gneissic rocks from these provinces.

Low-grade copper resources, locally associated with uranium, are scattered through Upper Devonian and Carboniferous red beds in parts of the Valley and Ridge. Although the potential for any significant development seems small, few areas have been adequately explored.

Tin has long been known in small quantities throughout the Blue Ridge–Piedmont province of the Appalachian region. One of the most prominent occurrences is the Irish Creek prospect in Virginia. Relatively little modern prospecting has been attempted for tin in this area, but it is likely that tin deposits may occur in some of the RARE II tracts with the same general geologic environment, such as tract 08042.

Sheet mica, which is of strategic importance to the electronics industry, occurs in many of the metamorphic units of the Blue Ridge. Of the many mica districts in the Appalachian region, the Spruce Pine district is the most important. Sheet mica has been produced from mines and prospects that occur within some of the RARE II tracts in this area, and the certainty of occurrence for additional deposits in the same general area is high.

The distribution of favorability/certainty ratings is shown in Table 13.

Table 13. Distribution of critical mineral ratings among tracts in the central Appalachians

ORNL rating	Number of tracts	Acres (thousands)
2/1	24	216
2/2	7	83
2/3	2	12
3/1	6	25
3/2	21	183
3/3	4	26
4/3	2	24
4/4	6	41

No favorability values of 1 have been assigned to tracts in the central Appalachians because the number of minerals is so great (45) that there is generally a minimum potential for at least one mineral in any tract. Ratings for central Appalachian tracts are graphically displayed in Fig. 17.

2.4.7 Overall tract importance rating

The overall ratings assigned by the team to each tract in the central Appalachians are listed in Table 9. No tract was assigned an overall importance rating greater than 3^+, and only 22 of the 72 tracts were rated above the rating scale midpoint of 2^+. The areal distribution of tract importance as measured by the area of black within each circle is shown in Fig. 18. The distribution of overall importance rating by number of tracts and acreage, respectively, is shown in Figs. 19 and 20.

In general, the most important tracts are evenly distributed throughout the three provinces (Fig. 18), but the resources that make the tracts important are different for each province (Sect. 2.5.). In contrast, about two-thirds of both numbers of tracts are acreage were assigned overall importance ratings of 1 and 2.

ORNL-DWG 79-7228

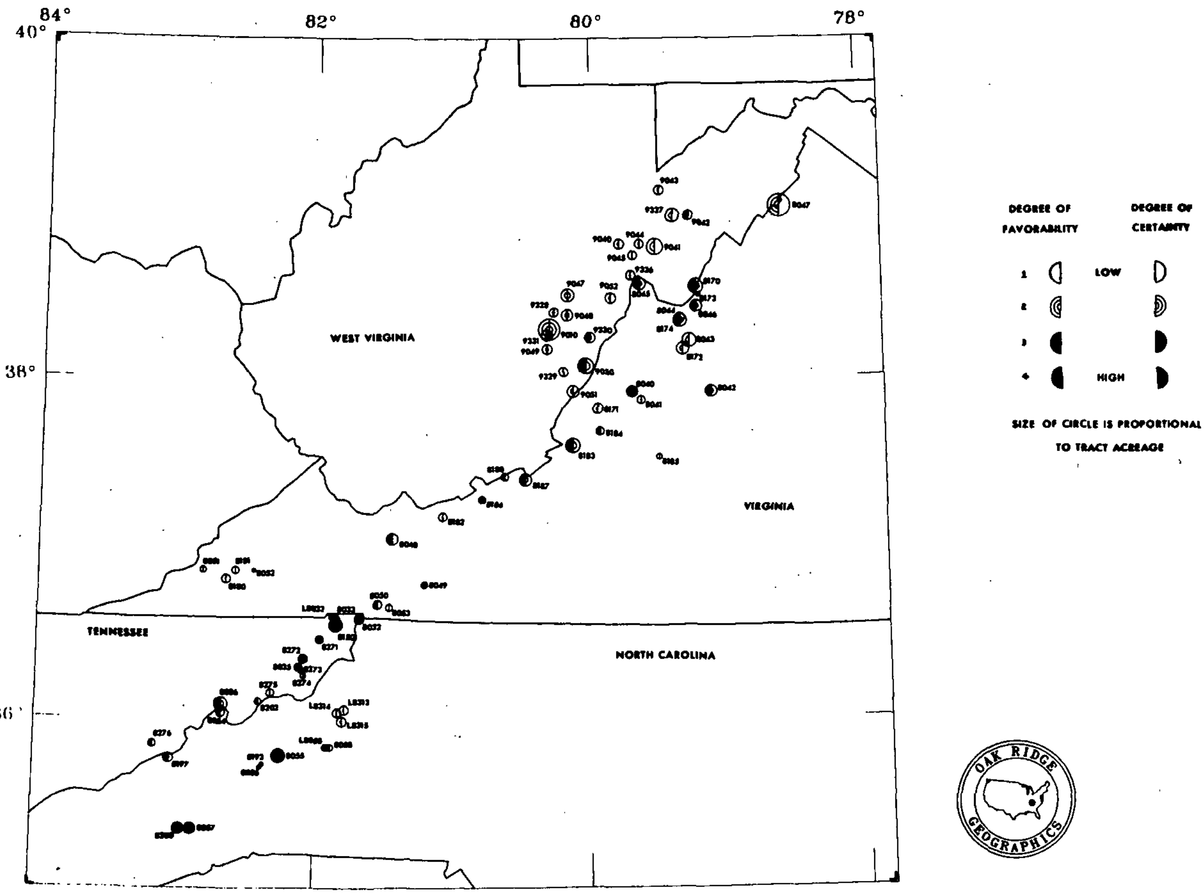

Fig. 17. Ratings of critical minerals in the central Appalachian thrust belt.

The frequency distributions shown in Figs. 19 and 20 are skewed toward the low rankings, as might be expected for undisturbed portions of a developed region with a long history of resource production. However, it cannot be concluded definitely that the undeveloped areas have no mineral resources. Exploration has bypassed these areas for more favorable areas elsewhere. As new resource-occurrence models are proposed and accepted in the future, the favorability of these areas may increase significantly.

2.5 Comparison of Results for the Two Regions

The Idaho-Wyoming-Utah thrust belt includes 63 RARE II tracts comprising about 3.1 million acres, whereas the central Appalachians include 72 tracts comprising about 610,000 acres. Based on our ratings, RARE II tracts in the Idaho-Wyoming-Utah thrust belt are much more important from a mineral- and energy-resource standpoint than are RARE II tracts in the central Appalachians.

Oil and gas are the most important resources in the Idaho-Wyoming-Utah thrust belt, followed by the phosphate resources and associated

ORNL-DWG 79-7226

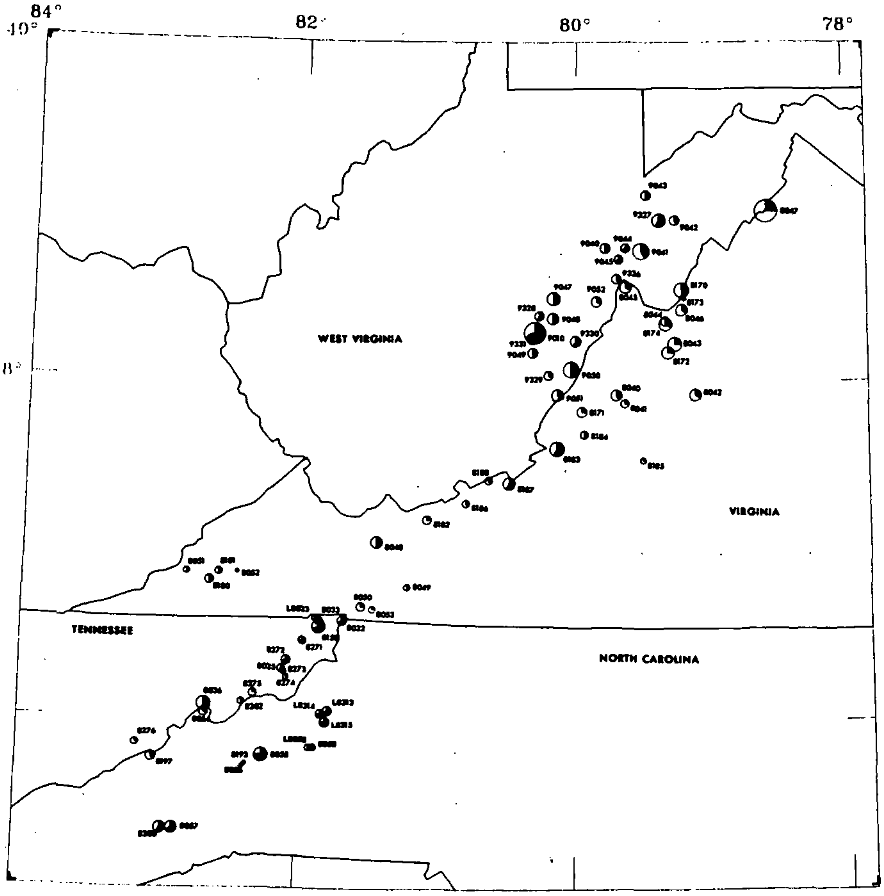

Fig. 18. Relative importance of 72 RARE II tracts evaluated in the central Appalachian thrust belt. The black portion of the circle is proportional to the importance.

uranium and metals in the Phosphoria Formation. Scattered and small occurrences of other critical minerals such as gold, copper, lead, talc, asbestos, and antimony have increased the importance of some tracts, but in general, this region is not known for its metal production. Geothermal potential and coal reserves did not raise the importance of any tract appreciably, inasmuch as these resources are more abundant elsewhere.

The central Appalachians considered in this report include parts of three physiographic provinces that largely correspond to structural provinces. The most important resources in the Appalachian Plateau province are oil, gas, and coal. In the Valley and Ridge province, the important critical minerals are zinc, lead, manganese, copper, and barite. Small amounts of bauxite and phosphate rock have also been mined. In the Blue Ridge, the most important resources are copper, zinc, and mica.

The difference in the overall resource importance of the two regions (compare Figs. 9, 10, and 11 with Figs. 18, 19, and 20) is due

ORNL-DWG 79-10305

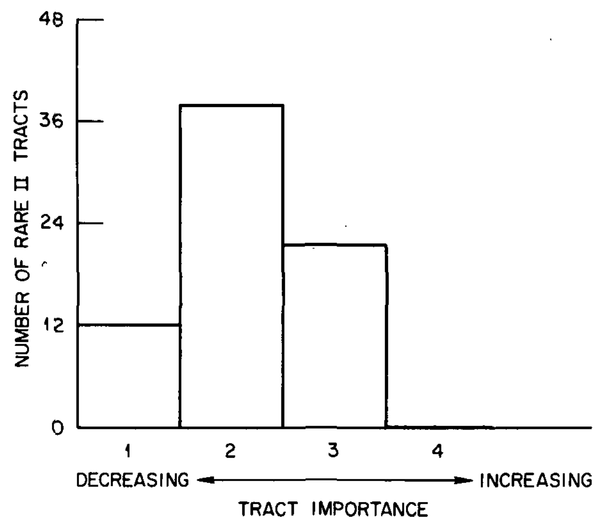

Fig. 19. Total number of tracts in each importance category for RARE II tracts evaluated in the central Appalachian thrust belt.

ORNL-DWG 79-10306

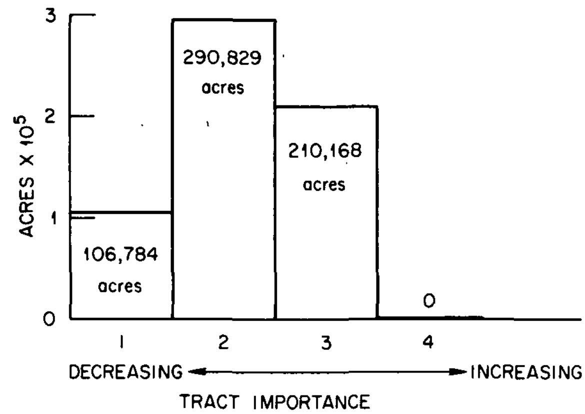

Fig. 20. Total acreage allotted to each importance category for the RARE II tracts evaluated in the central Appalachian thrust belts.

largely to the high oil and gas favorability of the Idaho-Wyoming-Utah thrust belt. High favorability for oil and gas occurs uniformly over this region, whereas only the Appalachian Plateau in the central Appalachians has high favorability for oil and gas. Similarly, the phosphate resources (including reserves) in the Idaho-Wyoming-Utah thrust belt are quite large from a national standpoint and are exposed in many RARE II tracts. Because one-third of the Idaho-Wyoming-Utah region qualifies as roadless and is being considered by the RARE II process, it follows that tracts within this region contain a large percentage of the total resource potential of the region and must be considered quite important. In contrast, coal and zinc are perhaps the most important resources in the central Appalachians, but because the tracts are small and scattered, it can be inferred that only a small percentage of these resources occur in RARE II tracts. RARE II tracts in the central Appalachians thus must be considered less important as a base for future mineral-resource production.

3. EVALUATION OF THE METHOD

3.1 Accuracy and Reliability

It is impossible to check the accuracy of a resource-assessment method without extensive exploration and development. At best, the results can be tested only for reasonableness and, to a limited degree, for reliability.

Reasonableness is the subjective judgement by knowledgeable persons that, from their experience, the method results "make sense." We have made several presentations to resource experts and have obtained several formal reviews. Although each interchange brought us new data and understanding, our basic ratings have not been challenged.

Reliability refers to the replicability of method results under various situations. Thus, one can check for replicable rating distributions for each resource when the method is applied to roughly similar geologic environments, when the method is applied by two different groups to the same region, or when the method is applied to a region that is assessed by other, independent methods. In addition, it is possible to check the consistency with which the assessment team applies its own decision rules within a given region.

Money and time constraints limited our ability to conduct thorough reliability checks for all of the situations above, and more work in this area is planned for the future. For instance, it was not possible to have two different groups assess the same region. Such a test would check one of the basic assumptions underlying the method, namely, that the procedure and the interactions within the assessment team cause all pertinent resource models to be identified and correctly applied by the group.

Local geologic anomalies preclude the selection of two regions having completely identical geologic environments for significant resources such as oil and gas. We were able to select two regions with gross structural similarities, however, to see if the method produced consistent ratings for those portions of the regions having similar local geologic environments. A statistical analysis of the ratings in the regions selected showed that the distribution of rating values for oil and gas correlated closely with the proportion of each region having similar geologic environments (Scheffler 1979). Nine of 23 Appalachian tracts assigned favorabilities of 4 all occur on the Appalachian Plateau, which contains a broad spectrum of the various types of reservoirs normally associated with the occurrence of oil and gas (Sect. 2.4.2). Similar conditions occur in a much greater proportion of the Idaho-Wyoming-Utah tracts.

Although ratings by other organizations were reviewed in our assessment and therefore may have influenced our results to a small extent, we feel that it is useful to compare these ratings. The comparison is a particularly good way to show the strengths and weaknesses of the various approaches to resource assessment. The comparison is discussed in Sect. 3.2.

Because tracts are considered individually by our method, the possibility exists that rating inconsistencies among tracts can result from the method. To test internal consistency, we analyzed our overall importance ratings statistically, using multiple linear regression. Overall rating (dependent variable) was regressed against acreage, favorability, and certainty for all resources (multiple independent variables). Although additional criteria such as the strategic importance and supply of individual resources or the proposed use of a tract as a transmission corridor are considered by the team in assigning the importance rating, the factors above are dominant and lend themselves to statistical checks because they are numerical entities. For the combined eastern-western tract population, R^2 was 0.80. The western tracts as a group were rated slightly more consistently than the eastern tracts: $R^2 = 0.88$ for the west and 0.69 for the east. These results show high levels of consistency, considering that a number of criteria were not brought into the analysis.

To determine the effect of additional criteria, we investigated the 13 western tracts in which the predicted rating differed from the observed rating by more than one standard error. Six of these tracts were found to have proposed energy corridors, four had gas pipelines, and one had a hydro-project conflict. The computer underrated five of these tracts. A similar check of eastern tracts showed much the same thing. Scheffler (1979) has discussed the various tests performed and the results.

3.2 Comparisons with Other Rating Systems

Comparisons of rating systems can be based on attributes of the methods such as efficiency and cost, or they can be based on differences in output or on the accuracy of the output. The ultimate measure of accuracy is the actual volume of mineral resources in the ground. This volume, however, cannot be known until an area is fully developed. Furthermore, minable volume is constantly changing: varying with current economics, available technology, demand, and so forth. Thus, it is impossible to compare rating systems on the basis of accuracy. The following discussion compares the effectiveness of our method with other methods used or developed for the RARE II program and applied to the Idaho-Wyoming-Utah thrust belt and their results.

The USGS has now released open-file, mineral-resource assessments of RARE II tracts in Idaho (Leonard 1978), Wyoming (Pearson 1978), and Utah (Bromfield 1978). An unpublished map of the oil and gas potential of the Idaho-Wyoming-Utah thrust belt (Powers 1977; updated July 1978) also has been released. In the USGS assessments, all mineral resources, with the exception of coal, oil and gas, and construction materials, were combined in a single map, and areas of high, moderate, and low potential were identified. A problem in interpreting the USGS assessment is immediately apparent. Except for the separate oil and gas assessment map, the reader is unable to determine which specific minerals and geologic environments account for the high- and moderate-potential areas. More importantly, the decision maker is unable to distinguish between tracts of equal favorability, even though the minerals believed to occur in one tract may be more critical or strategic and far less abundant than such minerals in another tract.

Other difficulties with the open-file documents are apparent inconsistencies among evaluators in assigning the three resource-potential categories and the unavailability of sufficient data to support the ratings shown on the maps. For example, tract 04613 (the Palisades) lies in Idaho and Wyoming. The mineral-resource-potential ratings, compiled by Leonard (1978) for Idaho and by Pearson (1978) for Wyoming, however, show that areas of high and low potential along the state boundary in Idaho adjoin areas of low potential in Wyoming. Thus, a broad band of high potential in Idaho abruptly ends at the Wyoming state line. Because the structural trend of the tract is northwest, it is unlikely that the north-trending resource-potential boundary was agreed upon by both authors. It is much more likely that the boundary reflects a fundamental difference in what each author considers important from a mineral-resource standpoint. This disagreement would be quite bewildering to the decision maker who does not grasp the complexities of mineral-resource assessment. Unfortunately, a basic disagreement among resource specialists can result in a loss of confidence by both the decision makers and the public in the assessment method used by USGS for this study. An approach that identified conceptual differences and forced their resolution would be more desirable than the independent-evaluator approach used by the USGS in these 1978 open-file documents.

A direct comparison of the results of the USGS and ORNL assessments for mineral resources is not especially useful because we assigned a single favorability rating to each tract and the USGS mapped favorability without regard to tract boundaries. However, to some extent, our mineral-resource overlay maps can be compared with the USGS rating maps to determine what minerals or rock units the USGS deemed important. There is good correlation between areas with outcrops of the Phosporia Formation on our maps and high-potential areas on the USGS maps. For other areas, however, we can only speculate on the minerals or rock units used by the USGS to determine areas of high- and moderate-mineral-resource potential. In contrast, we have mapped favorable geology for a few tracts considered to be unimportant by the USGS. Our high oil and gas ratings compare very closely with USGS ratings, except for three tracts along the west side of the thrust belt that were rated low by the USGS. We assigned certainty ratings of 1 to these three tracts.

A comparison of the overall importance rating for the 63 RARE II tracts is shown in Fig. 21, based on rating systems developed separately by ORNL, DOE, and the Forest Service. In general, each rating system clearly shows the high importance of energy- and mineral-resource potential on RARE II tracts in the Idaho-Wyoming-Utah thrust belt. Inasmuch as the basic geologic data available to each rating group were the same, similar aggregate results are not surprising. However, some differences are apparent because the methods used to determine the overall tract importance differed for each rating system. The Forest Service presented its energy- and mineral-resource data in a yes/no format and did not assign overall importance ratings to individual tracts.

Many of the energy- and mineral- resource data supplied to the Forest Service were prepared by both federal agencies and industry. In presenting these data, the Forest Service used a "yes" to indicate that the resource was present in the tract or that the tract had a high potential to contain the resource. As in the case of the USGS and DOE assessments, the Forest Service, except in a few cases, did not support its ratings with backup data; thus the reader has no way of determining the basis of the yes/no statement. For example, mineral-resource data were supplied to the Forest Service by the USGS, and yet 10 of the 63 tracts that were considered by the USGS to have a high potential for critical minerals were

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Forest Service Ratings	DOE Ratings 4	3	2	1	
Yes	30 tracts	24 tracts	2 tracts		56 tracts
No		1 tract	5 tracts	1 tract	7 tracts
	30 tracts	25 tracts	7 tracts	1 tract	

Forest Service Ratings	ORNL Ratings 4	3	2	1	
Yes	15 tracts	16 tracts	17 tracts	8 tracts	56 tracts
No			1 tract	6 tracts	7 tracts
	15 tracts	16 tracts	18 tracts	14 tracts	

DOE Ratings	ORNL Ratings 4	3	2	1	
4	15 tracts	13 tracts	2 tracts		30 tracts
3		2 tracts	15 tracts	8 tracts	25 tracts
2		1 tract	1 tract	5 tracts	7 tracts
1				1 tract	1 tract
	15 tracts	16 tracts	18 tracts	14 tracts	

Fig. 21. Comparison of evaluations prepared by ORNL, the Forest Service, and DOE for 63 RARE-II tracts in the Idaho-Wyoming-Utah thrust belt.

assigned a "no" by the Forest Service (tracts 04103, 04111, 04612, 04616, 04162, 04168, 04167, 04178, 04154, and 04758 in Idaho). Combined, these tracts total 334,000 acres. Moreover, seven tracts totaling 191,000 acres that the USGS did not consider to have a high-mineral-resource potential were assigned a "yes" by the Forest Service (tracts 04116, 04179, 04758 in Utah and tracts 04755, 04759, 04762, and 04764; tract 04179 had a small part designated as high potential by the USGS). In all, the Forest Service disagreed with 17 tract assessments prepared by the USGS, which is 27% of the total tracts in the Idaho-Wyoming-Utah thrust belt. No explanation of this discrepancy was offered by the Forest Service in their DES.

For purposes of comparison, we have arbitrarily assigned an importance of "4" to tracts with a "yes" for any commodity and an importance of "1" to tracts that had a "no" for all commodities. For this reason, the Forest Service overall tract importance ratings are somewhat higher than the DOE and ORNL ratings in Fig. 21 and thus are not strictly comparable to them except in a very general manner.

The DOE assessed oil and gas, uranium, coal, and hydro potential for each tract on a scale of 1 to 4. Critical minerals were not evaluated. All tracts were then assigned an overall rating, which was simply the highest individual resource rating. As a result, DOE tract-importance ratings are generally higher than ORNL ratings. In fact, DOE considers 55 of the 63 tracts to be either "very important" (4) or "important" (3). In contrast, ORNL assigned only 31 of the 63 tracts an importance rating of 3 and 4. The ORNL approach allows better discrimination between tracts and results in a wider spread of overall importance ratings.

Results of the DOE assessment, especially the oil and gas assessment, rely heavily on inputs by the USGS and the Rocky Mountain Association of Petroleum Geologists (RMOGA 1978). Although we agree with the assessments by industry, the USGS, and DOE that the thrust belt is quite favorable for oil and gas, we believe that tract distinctions can be made that are based on the certainty of resource occurrence, which decreases to the west. For example, individual tract estimates for oil and gas were compiled by RMOGA from data gathered by numerous companies, which were then forwarded to DOE and the Forest Service. We evaluated these data by grouping the tracts according to major thrust belt and plotting various gas-to-oil-to-acreage relationships (Figs. 22 and 23). The results show clearly that all tracts within the westernmost thrust plate (Bannock thrust) were assigned a fixed value for oil of about 600 bbl/acre and a fixed value of gas of about 6 million cubic feet per acre. Because oil and gas estimates for tracts in the more easterly thrust plate show considerable scatter when plotted, we conclude that RMOGA was much less confident about their own estimates for the western tracts, which is to be expected because exploration has barely begun, even in the eastern part of the thrust belt.

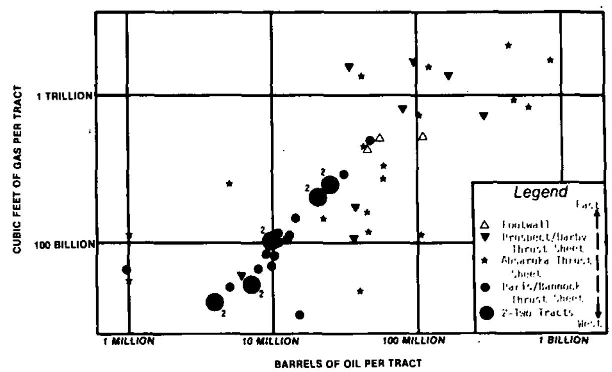

Fig. 22. Rocky Mountain Oil and Gas Association (RMOGA 1978) estimates of oil and gas per tract in the Idaho-Wyoming-Utah thrust belt. Tracts are separated according to major thrust sheet (see Fig. 3).

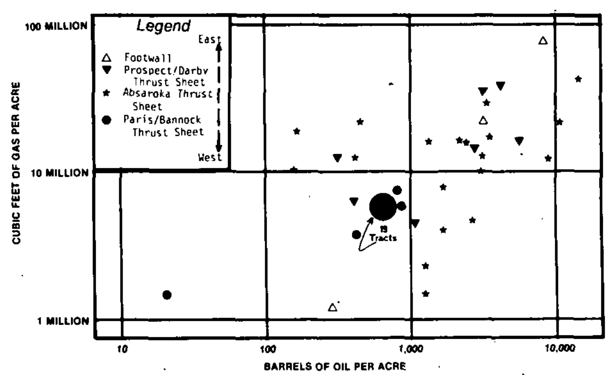

Fig. 23. Rocky Mountain Oil and Gas Association (RMOGA 1978) estimates of oil and gas per acre in the Idaho-Wyoming-Utah thrust belt. Tracts are separated according to major thrust sheet (see Fig. 3).

The Forest Service, as well as decision makers and the public, however, should understand that the *certainty of oil and gas occurrence* for the western tracts of the Idaho-Wyoming-Utah thrust belt is very low, even though all assessments agree that the environment for their occurrence is equally favorable.

Finally, a rapid-assessment method developed by the USGS (Singer 1978) in Alaska deserves mention. This method is a leading example of methodological development going on in the area of rapid resource assessment. In this approach, deposit "types" for well-explored deposits similar to incompletely explored and undiscovered deposits in Alaska are characterized by physical, chemical, and mineralogical features and associated rock types. Log normal distribution models of tonnages and average grades are constructed for each deposit type. Next, favorable areas for the occurrence of mineral deposits are plotted on 1:1,000,000 scale maps. The Alaskan group's concept of favorability is similar to our own, but no ratings are assigned to areas. Instead, the number of deposits likely to occur within the favorable area is subjectively estimated and presented in a probabilistic form to show the degree of certainty held by the investigator. Finally, both the total grade and tonnage are determined by applying the estimated number of deposits to the resource models. In general, this method is not applicable to relatively small areas because the quantitative estimates are unreliable. In addition, if grade and tonnage numbers are estimated for an area, decision makers may tend to ignore the fact that these numbers are *only* resource estimates and not reserves, as seems to be the case with the RMOGA data.

In conclusion, most mineral-resource-rating systems used in the RARE II program provide no data to support the ratings, do not discriminate between many areas with similar potential or favorability, and — above all — inspire little confidence by the public in the decision-making process. The ORNL rating system has been developed in an attempt to overcome these inadequacies.

4. SUMMARY AND CONCLUSIONS

This report describes a rapid resource-assessment method and its application in rating the energy- and mineral-resource potential of 63 RARE II tracts in the controversial Idaho-Wyoming-Utah thrust belt and 72 RARE II tracts in the central Appalachian thrust belt.

The assessment method is a holistic group approach in which a team of experts interprets existing data to produce subjective resource ratings for each tract. The collective judgment and personal knowledge of the team and of its invited experts are used to (1) adopt appropriate resource-occurrence models, (2) interpret and supplement available data, (3) extrapolate available data to tracts being evaluated, and (4) rate the resource potential of the tracts. Individual resources are assigned unique dual ratings, which indicate both the favorability of the geologic environment of a given tract for a specific resource category and the degree of certainty that the resource is actually present on the tract being evaluated.

In addition to the dual ratings, overall importance ratings are synthesized from the dual ratings of individual resource categories according to a set of predetermined criteria. In the application discussed, the dominant criteria in the assignment of overall ratings included (1) the presence of strategic resources such as oil and gas and uranium or critical minerals such as chromium, cobalt, manganese, platinum, and tin; (2) the relation of tract resources to overall national supplies; (3) the favorability/certainty rating; (4) the size of a tract; and (5) proposed or planned uses of a tract such as transmission corridors or hydrologic projects.

The method adopted gives the following advantages over other assessment procedures commonly employed in rapid resource assessment.

1. The dual-rating system gives the decision maker additional information for making difficult trade-off decisions between tracts.

2. The overall importance rating gives the decision maker a means of identifying that subset of tracts having the highest overall resource importance when such things as supply and strategic value are considered.

3. The systematic procedure, which is centered on strong team interaction, results in greater efficiency and output consistency.

4. The personal knowledge of experts is incorporated into the rating process.

5. Favorability is based on the geologic environment and allows all tracts to be assessed. Certainty indicates the amount of supporting data available to the specialist in making an assessment.

6. Overlays that show favorable areas for individual resources allow tracts to be subdivided for different uses, which gives the decision maker another option in trade-off deliberations.

7. The assessment form documents and allows subsequent review of the rating process.

Application of the method to two regions that have broad structural similarities but distinctive local geologic environments tested the original design concepts and demonstrated the advantages listed above. However, several weaknesses also were revealed:

1. Assignment of a single favorability/certainty rating to the long list of critical minerals considered in the assessment proved to be difficult. A future modification of the method will organize critical minerals into three or four logical groups that contain minerals likely to occur together, such as base metals or certain ferro-alloy metals. Each group will then be assigned a separate favorability/certainty rating.

2. The information contained in the various entries on the assessment form proved to be somewhat redundant. The format will be modified in future applications until a more optimum arrangement is found.

3. We experienced difficulty in explaining the concepts of favorability and certainty to individuals unfamiliar with resource-development concepts. Unless we can improve our definitions

of favorability and certainty further, our communication with some people may be limited to the overall-importance rating, to which everyone seems to be able to relate.

4. Given their preference, decision makers would ask for grade-tonnage estimates from a resource assessment because, transformed into economic terms, such estimates offer a single criterion for decision making. However, no assessment method can produce accurate grade-tonnage estimates for small, relatively unexplored, and undeveloped tracts, and one must resort to various indications of favorability or potential. Such favorability estimates are supported by whatever resource-occurrence data are available.

Traditional wilderness studies that have programs of field-data collection intended to produce new data should provide better estimates than methods that rely on existing data. However, time limitations and the need to assess large acreages preclude the use of traditional assessment procedures in many land-use decisions. In light of this and the serious competition for lands with high-resource potential, our method presents a needed assessment tool.

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APPENDIX I

Design Criteria

The following criteria have guided the implementation of the assessment method:

1. The method should be based on recognized principles governing small group interaction. Those factors inducing feelings of trust, recognition, and involvement should be incorporated into the design, and those factors encouraging conflict, isolation, and nonsharing should be eliminated. Particular interaction goals include:

1. making each member feel essential to the success of the team,
2. fostering a sense of group unity and loyalty,
3. creating a series of realistic, limited, short-term objectives that can be achieved,
4. maintaining the best possible communications,
5. working intensely as a group for short periods,
6. looking for early signs of conflict or withdrawal and identifying and resolving the associated problem quickly and collectively, and
7. creating an atmosphere in which individual differences of opinion are accepted and the right to such opinions is protected; a strong individual is not allowed to dominate the group during consensus formation.

2. The method should be basically a subjective evaluation that represents a team consensus. The ratings derived from this process should integrate all available tract information and should conform to criteria established by the team in advance of the exercise.

3. Each tract assessment (rating) should be documented and justified on an evaluation form and should list supporting information such as references to published documents, personal experience, and interpretations of team members.

4. All data except those that are proprietary or that pertain to national security should be used.

5. When available, other ratings should be used to check the rating decision.

6. The favorability rating of a tract should be interpreted from regional favorability and adjusted by tract geology and occurrence data that is extrapolated to the tract.

7. A second rating that reflects the certainty of resource occurrence should be created. Certainty is thus the direct evidence (data) of the actual presence of the resource in the tract or data that can be extrapolated to the tract through consideration of local geology.

8. An overall importance rating should be created for each tract.

The method that has evolved in response to these goals is described in Appendix II.

APPENDIX II

Method Procedure

The following sequence of steps constitute the procedure developed from the design criteria in Appendix I. It has been modified to reflect the experience gained in two applications.

1. Team Formation. A core team of three people is selected to manage the assessment. To ensure continuity, the same team is made responsible for each step of the procedure. Team members are selected for their ability to work within a group and for their expertise. At least two members of the team should have broad experience in resource evaluation. The third member handles administrative functions and documents the decision process.

2. Data Collection and Transformation. The first few weeks of an assessment are spent on data collection, the first days on a survey of available data. This survey consists of library and bibliographic searches and contacts with knowledgeable individuals. A reference list is compiled, and reports are ordered. Overlays showing occurrence data are prepared for each resource along with an overlay of gross geologic features. As reports arrive, pertinent information is added to the overlay maps. We have found that a scale of 1:500,000 is most appropriate for large regions. An assessment form is prepared for each tract, and the tract description is entered. Also during this period, experts familiar with the region and the commodities being evaluated are identified. Several of these individuals are invited to participate in upcoming data-synthesis and resource-rating sessions. The data-collection period requires a minimum of three to four weeks.

3. Data Synthesis and Illustration. A two-day work session is conducted in which the team and the invited experts determine and delineate favorable areas for each resource on a series of overlays. The purpose of this intensive session is to synthesize the personal knowledge of invited experts and the information gathered by the team. During the session, areal and point source data are recorded on the overlays, and descriptive information is added to the assessment forms. During the few days after data synthesis, the team prepares for the rating session; questions raised in the synthesis session are resolved, missing data are collected, and models of resource accumulation are expanded.

4. Rating. A two- to three-day rating session is conducted by the core team and by the invited experts at the point in the session where their speciality is discussed. Invited experts who do not participate in the synthesis session are supplied the materials created during step 3.

A mental picture of a rating session would be helpful. Five people are likely to be involved in the rating process at any time. They work around a table full of maps, overlays, notes, and published documents and have a degree of isolation to avoid interruptions. They move from tract to tract rapidly and avoid lengthly diversions in conceptual matters. If conceptual differences or questions of procedure cannot be resolved adequately in a reasonable time, the rating session is discontinued until a later date.

Once all tracts have been rated for a given resource, the resulting pattern is reviewed, and a number of small adjustments are made. Such iteration improves the consistency and accuracy of the total rating set because a better understanding of the region and of its resource patterns evolves in the course of rating, which can be used to adjust individual ratings.

If it is necessary to select one or more portions of a region for special consideration, as in the case of exploration planning or wilderness designation, it is useful to supply the decision maker with a rating of overall tract importance, which allows him to identify tracts with the highest resource value. Using this overall importance rating, the decision maker is in an excellent position to compare resource values against other uses in reaching a final selection. After agreeing on a set of criteria for determining overall tract importance, the team assigns an importance rating to each tract. We have found that it is possible for the team to differentiate each of 4 levels into positive (+) and negative (-) categories. For example, a very valuable tract can be rated 4-, 4, or 4+. As in the case of individual resource rating, a rapid review of the total importance-rating pattern allows the team to make small changes and thereby improve the total set and ensure consistency.

5. Documentation. The primary method of documentation is the assessment form. The form is completed as the process proceeds and is essentially finished after the rating session. A brief report accompanying the tract assessment forms describes the process, the assumptions and criteria used, and the significance of the final rating patterns. Section 2, RARE II Applications, illustrates the type of information found in such a report.

APPENDIX III

Selected Western and Eastern Evaluation Forms

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 04102 TRACT NAME: Gros Ventre ECOREG: 3/12 WAR:.24

NATIONAL FOREST: Bridger-Teton STATE/COUNTY: Wyoming, Teton/Sublette

ACREAGE (GROSS): 435,320 ACREAGE (NET): 432,600 100 N/G: 99 LATITUDE: 43°25' LONGITUDE: 110°25'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/4	4	4		Stratigraphic and structural traps compounded by thrusting; similar to Canadian Rockies Foothills Belt
URANIUM	3/1	1	2		SS-type deposits; SE part of tract
COAL	4/4	1	1		Shafts; subbituminous
GEOTHERMAL	3/2	1			
CRITICAL MINERALS	4/4	4			
OVERALL RATING (WEIGHTED)	4^+		4		

NAMES OF CRITICAL MINERALS PRESENT: P(U, V, F, Zn, Cd, Cr)

COMMENTARY AND SUMMARY: Part of the large La Barge hydrocarbon complex with the associated Greater Big Piney Gas Area is located in the central part of the Footwall Belt. Numerous smaller oil and/or gas fields also occur along nearly the entire length of the belt and include a recent major gas discovery in Teton County in a roaded salient extending deep into Rare II tract 4102. Over 200 million barrels of oil and nearly 15 trillion cubic feet of gas have been estimated by the Rocky Mountain Oil and Gas Association for Rare II tracts in this belt. The Permian Phosphoria Formation contains part of the region's large phosphate resources.

GEOLOGY: Footwall Belt of the Jackson-Prospect-Darby fault system (extends eastward to the crest of the Moxa Arch and its northward projection). Surface rocks are largely Tertiary in age, except in the north where the Gros Ventre, West Slope of the Tetons, and several smaller satellite Rare II tracts contain the entire regional stratigraphic sequence from Precambrian through Cenzoic.

REFERENCE/CITATION: USFS, 1978, RARE II DES, ID, UT, and WY Suppls.; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments, of Ten Alternatives-RARE II Lands; Powers, 1977, WGA Gdbk 29; Blackstone, 1978, Tectonic Map of the Overthrust Belt: WGS; RMOGA, 1978, Estimates of Undiscovered Recoverable Hydrocarbon Resources (RARE-II); White and Williams, 1975, USGS Circ. 726; NOAA, 1977, Geothermal Energy Resources of the Western U.S.; USGS, 1945, Min. Res. Mo. Valley Region, Pts 1, 2, 3; ERDA, 1976, NURE-Prelim. Rpt.; Armstrong and Oriel, 1965, AAPG Bull., v. 43; British Sulfur Corp., Ltd., 1964, A world survey of phosphate deposits: Woodalls Ltd. (Printers), London; Gulbrandsen, 1966, Geochim. Cosmochim. Acta, v. 3, 769-778; Brobst and Pratt, 1973, USGS Prof. Paper 820; Worl and Others, 1974, USGS MR-60; Kinkel and Peterson, 1962, USGS MR-13; RMAG, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, CO; Love and Others, 1955, Geologic Map of Wyoming: USGS; Glass and Others, 1975, Energy Resources Map of Wyoming: WGS; Sheldon, 1965, USGS Prof. Paper 1313-B; Clabaugh and others, 1946, USGS Mo. Basin Studies No. 9; USGS, 1964, MR-42; Chidester and Worthington, 1962, USGS MR-31; Love, 1961, USGS Prof. Paper 424-C; Chidester and Shride, 1962, USGS MR-17.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 04152 TRACT NAME: Scout Mountain ECOREG: 3130 WAR: 17

NATIONAL FOREST: Caribou STATE/COUNTY: Idaho, Bannock

ACREAGE (GROSS): 34,480 ACREAGE (NET): 32,300 100 N/G: 94 LATITUDE: 42°41' LONGITUDE: 112°20'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/1	1	2		Stratigraphic and structural traps compounded by thrusting; similar to Canadian Rockies Foothills Belt
URANIUM	2/1	1	1		
COAL	1/4	1	1		
GEOTHERMAL	2/2	1			
CRITICAL MINERALS	2/2	1			
OVERALL RATING (WEIGHTED)	1+		2		

NAMES OF CRITICAL MINERALS PRESENT: Base and precious metals?

COMMENTARY AND SUMMARY: Petroleum exploration has not been as intensive in the Paris-Bannock thrust belt as in the more easterly thrust structures; however, several holes showing some oil and gas have been completed in the past. The Rocky Mountain Oil and Gas Association estimates that over 300 million barrels of oil and approximately three trillion cubic feet of gas occur in Rare II tracts in this belt. Phosphate resources are minor in comparison with the more easterly belts. Some potential for disseminated gold and base metals in the Precambrian and Lower Paleozoic strata is also present.

GEOLOGY: Paris-Bannock thrust belt (includes terrain between Paris-Bannock fault on east and the Wasatch fault and its northward projection on the west). The Wasatch fault is the major east boundary fault of the Basin and Range structural province and is generally normal in character, usually having a steep westward dip. Bedrock includes strata from the younger Precambrian, all Paleozoic systems, and Tertiary and Quaternary deposits. Tertiary and Quaternary volcanic rocks and similar age gravels locally cover the older rocks and structures.

REFERENCE/CITATION: USFS, 1978, RARE II DES, ID, UT, and WY Suppls.; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments, of Ten Alternatives-RARE II Lands; Powers, 1977, WGA Gdbk 29; Blackstone, 1978, Tectonic map of the Overthrust Belt: WGS; RMOGA, 1978, Estimates of Undiscovered Recoverable Hydrocarbon Resources (RARE-II); White and Williams, 1975, USGS Circ. 726; NOAA, 1977, Geothermal Energy Resources of the Western U.S.; USGS, 1945, Min. Res. Mo. Valley Region, Pts. 1,2,3; ERDA, 1976, NURE-Prelim. Rpt.; Armstrong and Oriel, 1965, AAPG Bull., v. 43; British Sulfur Corp., Ltd., 1964, A World Survey of Phosphate Deposits: Woodalls Ltd. (Printers), London; Gulbrandsen, 1966, Geochim. Cosmochim. Acta, v. 3, p. 769-778; Brobst and Pratt, 1973, USGS Prof. Paper 820; Worl and Others, 1974, USGS MR-60; Kinkel and Peterson, 1962, USGS MR-13; RMAG, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, CO; Bond and Others, 1978, Geologic Map of Idaho: IBMG; Ross, C.P., 1941, IBMG Pamph. 57, pt. 111; Mansfield, 1927, USGS Prof. Paper 152; Leonard and Others, 1978, USGS OFR 78-360; USGS, 1964, Mineral and Water Resources of Idaho: 88th U.S. Congress; Vine, 1959, USGS Bull. 1055-1.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 04162 TRACT NAME: Stump Creek ECOREG: 3112 WAR: 22

NATIONAL FOREST: Caribou STATE/COUNTY: Idaho, Caribou

ACREAGE (GROSS): 103,640 ACREAGE (NET): 103,200 100 N/G: 100 LATITUDE: 42°50' LONGITUDE: 111°11'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/2	4	4		Stratigraphic and structural traps compounded by thrusting; similar to Canadian Rockies Foothills Belt
URANIUM	2/1	1	1		
COAL	4/2	1	1		Teton basin field
GEOTHERMAL	3+/2	1			
CRITICAL MINERALS	2/1	1			Possible extension of Mt. Pisgah gold-bearing formations
OVERALL RATING (WEIGHTED)	3		4		

NAMES OF CRITICAL MINERALS PRESENT:

COMMENTARY AND SUMMARY: Several major and several lesser oil and/or gas fields are located in the southern part of the Absaroka Belt in Wyoming and Utah. Most production is from Jurassic-Triassic reservoirs, but more recent deeper discoveries are in Upper Paleozoic rocks (Phosphoria) and even more recently in Lower Paleozoic rocks. The Rocky Mountain Oil and Gas Association estimates that Rare II tracts in the Absaroka belt contain nearly 3.3 billion barrels of oil and over 12.5 trillion cubic feet of gas. The major part of the Southeast Idaho phosphate resource is in this thrust belt, with much of it in the Rare II tracts. Not only are the phosphate rock resources important for the phosphorus, but there is a significant near-future potential for vanadium, uranium by-product production. The Mt. Pisgah gold district in Bonneville County may have significant potential for Carlin-type gold deposits (Rare II tracts 04160, 04161, and 04162). DOE, moderate corridor R-45 conflict.

GEOLOGY: Absaroka thrust belt (includes terrain westward to surface trace of the Paris-Bannock thrust complex). Includes (as secondary structures) the Crawford, Meade, Medicine Lodge, Sheep Mountain, Skyline, and many smaller thrust faults. Rocks exposed at the surface include sedimentary rocks from Cambrian to Tertiary in age along with some Tertiary and Quaternary volcanics. Several small igneous intrusions of Tertiary Age have been mapped in the Idaho part of the Absaroka Belt, chiefly in the vicinity of the Mt. Pisgah gold district.

REFERENCE/CITATION: USFS, 1978, RARE II DES, ID, UT, and WY Suppls.; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments, of Ten Alternatives-RARE II Lands; Powers, 1977, WGA Gdbk 29; Blackstone, 1978, Tectonic map of the Overthrust Belt: WGS; RMOGA, 1978, Estimates of Undiscovered Recoverable Hydrocarbon Resources (RARE-II); White and Williams, 1975, USGS Circ. 726; NOAA, 1977, Geothermal Energy Resources of the Western U.S.; USGS, 1945, Min. Res. Mo. Valley Region, Pts. 1,2,3; ERDA, 1976, NURE-Prelim. Rpt.; Armstrong and Oriel, 1965, AAPG Bull., v. 43; British Sulfur Corp., Ltd., 1964, A World Survey of Phosphate Deposits: Woodalls Ltd. (Printers), London; Gulbrandsen, 1966, Geochim. Cosmochim. Acta, v. 3, p. 769-778; Brobst and Pratt, 1973, USGS Prof. Paper 820; Worl and Others, 1974, USGS MR-60; Kinkel and Peterson, 1962, USGS MR-13; RMAG, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, CO; Bond and Others, 1978, Geologic Map of Idaho: IBMG; Ross, C.P., 1941, IBMG Pamph. 57, pt. 111; Mansfield, 1927, USGS Prof. Paper 152; Leonard and Others, 1978, USGS OFR 78-360; USGS, 1964, Mineral and Water Resources of Idaho: 88th U.S. Congress; Vine, 1959, USGS Bull. 1055-1.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 04758 TRACT NAME: Mount Naomi ECOREG: 3112 WAR: 19

NATIONAL FOREST: Wasatch/Caribou STATE/COUNTY: Utah/Idaho, Cache/Franklin

ACREAGE (GROSS): 84,000 ACREAGE (NET): 83,800 100 N/G: 100 LATITUDE: 41°54' LONGITUDE: 111°42'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/2	4	3		Stratigraphic and structural traps compounded by thrusting; similar to Canadian Rockies Foothills Belt
URANIUM	2/2	1	1		
COAL	3/1	4	1		
GEOTHERMAL	2/2	1			
CRITICAL MINERALS	2/2	4			
OVERALL RATING (WEIGHTED)	2		3		

NAMES OF CRITICAL MINERALS PRESENT: Base metals?

COMMENTARY AND SUMMARY: Petroleum exploration has not been as intensive in the Paris-Bannock thrust belt as in the more easterly thrust structures; however, several holes showing some oil and gas have been completed in the past. The Rocky Mountain Oil and Gas Association estimates that over 300 million barrels of oil and approximately three trillion cubic feet of gas occur in Rare II tracts in this belt. Phosphate resources are minor in comparison with the more easterly belts. Some potential for disseminated gold and base metals in the Precambrian and Lower Paleozoic strata is also present.

GEOLOGY: Paris-Bannock thrust belt (includes terrain between Paris-Bannock fault on east and the Wasatch fault and its northward projection on the west). The Wasatch fault is the major east boundary fault of the Basin and Range structural province and is generally normal in character, usually having a steep westward dip. Bedrock includes strata from the younger Precambrian, all Paleozoic systems, and Tertiary and Quaternary deposits. Tertiary and Quaternary volcanic rocks and similar-age gravels locally cover the older rocks and structures.

REFERENCE/CITATION: USFS, 1978, RARE II DES, ID, UT, and WY Suppls.; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments, of Ten Alternatives-RARE II Lands; Powers, 1977, WGA Gdbk 29; Blackstone, 1978, Tectonic Map of the Overthrust Belt: WGS; RMOGA, 1978, Estimates of Undiscovered Recoverable Hydrocarbon Resources (RARE-II); White and Williams, 1975, USGS Circ. 726; NOAA, 1977, Geothermal Energy Resources of the Western U.S.; USGS, 1945, Min. Res. Mo. Valley Region, Pts. 1, 2, 3; ERDA, 1976, NURE-Prelim. Rpt.; Armstrong and Oriel, 1965, AAPG Bull., v. 43; British Sulfur Corp., Ltd., 1964, A World Survey of Phosphate Deposits: Woodalls Ltd. (Printers), London; Gulbrandsen, 1966, Geochim. Cosmochim. Acta, v. 3, p. 769-778; Brobst and Pratt, 1973, USGS Prof. Paper 820; Worl and Others, 1974, USGS MR-60; Kinkel and Peterson, 1962, USGS MR-13; RMAG, 1972, Geologic Atlas of the Rocky Mountain Region: Denver, CO; Stokes and Madsen, 1961, Geologic Map of Utah-Northeast Quarter: UGMS; USGS, 1964, Mineral and Water Resources of Utah: 88th U.S. Congress; White, 1962, USGS MR-20.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 08170 TRACT NAME: Dry River ECOREG: 2214 WAR: 16

NATIONAL FOREST: George Washington STATE/COUNTY: West Virginia, Pendleton

ACREAGE (GROSS): 16,660 ACREAGE (NET): 16,135 100 N/G: 97 LATITUDE: 38°32' LONGITUDE: 79°13'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	3/2	1			
URANIUM	2/1	1			
COAL	1/4	1			
GEOTHERMAL	2/1	1			
CRITICAL MINERALS	3/2	1			Mineral-bearing rocks closer to surface
OVERALL RATING (WEIGHTED)	2				

NAMES OF CRITICAL MINERALS PRESENT: Possible copper; possible iron, zinc, lead, barite, fluorite, cadmium at depth

COMMENTARY AND SUMMARY: This tract is in the fold-dominated part of the Valley and Ridge province. The rocks are quite favorable for oil and gas, although some hydrocarbons may have been driven off by heat from metamorphism and igneous activity in the nearby Blue Ridge, heat that also made gas more common than oil throughout the province. These hydrocarbons are produced in several places in the province in the study area. Sandstone units may be favorable for uranium. The rocks are too old to contain coal. Hot dry rock at depth may have some potential for geothermal energy. The Devonian Oriskany Sandstone at the surface may contain critical minerals manganese, iron, and zinc, and the Silurian Clinton Formation may contain iron. Critical minerals for which the subsurface rocks may be favorable include zinc, lead, cadmium, fluorite, and barite (Ordovician carbonates). Little exploration has occurred for any commodity, except oil and gas for which exploration has been moderate.

GEOLOGY: Surface rocks are Upper Devonian shales and sandstones on NW flank of a major syncline tract.

REFERENCE/CITATION: All resources — Stose and Ljungstedt, 1932, Geol. Map of W. Va.; USGS and USBM, 1968, USGS Prof. Paper 580; Miller and Others, 1970, Mineral Res. of the TVA Region; Brobst and Pratt, 1973, USGS Prof. Paper 820; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments of Ten Alternatives — RARE II Lands; USFS, 1978, RARE II DES, So. Appal. Suppl. Oil and Gas — Vlissides and Quirin, 1963, Oil and Gas Fields of the U.S.; Cardwell, 1971, AAPG Mem. 15; USGS, 1974 and 1975, Maps of Appal. Oil and Gas Production; Miller and Others, 1975, USGS Circ. 725; Harris and Milici, 1977, USGS Prof. Paper 1018; Patchen and Others, 1978, AAPG Bull. 62: 1399–1441. Uranium — ERDA, 1976, NURE Preliminary Report. Coal — Trumbull, 1960, Coal Fields of the U.S. Geothermal — AAPG, 1976a and b, Geothermal Gradient Map and Subsurface Temperature Map of North America.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: L8180 TRACT NAME: Devils Fork ECOREG: 2214 WAR: 18

NATIONAL FOREST: Jefferson STATE/COUNTY: Virginia, Scott

ACREAGE (GROSS): 5,887 ACREAGE (NET): 4,750 100 N/G: 81 LATITUDE: 36°49' LONGITUDE: 82°39'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/2	1			Pine Mountain overthrust has trapped gas in Wise County. Tract is on SE border of Appalachian Gas and Oil Field (USGS 1974, 1975)
URANIUM	2/2	1	2		
COAL	4/4	1	2		Tract is within Appalachian coal field
GEOTHERMAL	2/1	1			
CRITICAL MINERALS	2/1	1			
OVERALL RATING (WEIGHTED)	2^+				

NAMES OF CRITICAL MINERALS PRESENT: Possible copper, iron, zinc, lead, cadmium, fluorite, and barite at depth

COMMENTARY AND SUMMARY: This tract is in the thrust-fault-dominated part of the Valley and Ridge province. The rocks are quite favorable for oil and gas, although some hydrocarbons may have been driven off by heat from metamorphism and igneous activity in the nearby Blue Ridge, heat that also made gas more common than oil throughout the province. These hydrocarbons are produced in several places in the province in the study area. Exploration overall has been fairly meager. This tract has unusually *high favorability because of its location with respect to a gas-producing anticline.* Sandstone units may be favorable for uranium but little exploration has occurred. This tract is located within the Appalachian coal field and overlies minable, thick, high-quality coal. Hot dry rock at depth may have some potential for geothermal energy, but little exploration has taken place. The surface rocks probably contain no critical minerals. The subsurface rocks may be favorable for copper (Upper Devonian red beds); zinc (Devonian Oriskany sandstone); iron (Silurian Clinton Formation); and zinc, lead, cadmium, fluorite, and barite (Cambro-Ordovician carbonates); little exploration has been performed.

GEOLOGY: Surface rocks are synclinally folded Lower Pennsylvanian sandstones and shales in the Upper plate of the Pine Mountain overthrust.

REFERENCE/CITATION: All resources — Milici and Others, 1963, Geol. Map of Va.; Gooch and Pharr, 1959, Mineral Indus. and Res. of Va.; USGS and USBM, 1968, USGS Prof. Paper 580; Miller and Others, 1970, Mineral Res. of the TVA Region; Brobst and Pratt, 1973, USGS Prof. Paper 820; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments of Ten Alternatives — RARE II Lands; USFS, 1978, RARE II DES, So. Appal. Suppl. Oil and Gas — Vlissides and Quirin, 1963, Oil and Gas Fields of the U.S.; Cardwell, 1971, AAPG Mem. 15; USGS, 1974 and 1975, Maps of Appal. Oil and Gas Production; Miller and Others, 1975, USGS Circ. 725; Harris and Milici, 1977, USGS Prof. Paper 1018; Patchen and Others, 1978, AAPG Bull. 8. Uranium — ERDA, 1976, NURE Preliminary Report. Coal — Trumbull, 1960, Coal Fields of the U.S. Geothermal — AAPG, 1976a and b, Geothermal Gradient Map and Subsurf. Temp. Map of N. Am. Critical Minerals — Lesure, 1957, V.P.I. Bull., Eng. Expt. Sta. series 118; Worl and Others, 1968, Fluorite Deposits of the U.S.; Lesure and Others, 1978, U.S.G.S. Bull. 1397c.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: L8315 TRACT NAME: Harper Creek ECOREG: 2214 WAR: 19

NATIONAL FOREST: Pisgah STATE/COUNTY: North Carolina, Avery/Caldwell

ACREAGE (GROSS): 7,163 ACREAGE (NET): 7,138 100 N/G: 99.6 LATITUDE: 35°59' LONGITUDE: 81°49'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	2/1	1			
URANIUM	4/4	1			
COAL	1/4	1			
GEOTHERMAL	2/1	1			
CRITICAL MINERALS	2/1	1			
OVERALL RATING (WEIGHTED)	3+				

NAMES OF CRITICAL MINERALS PRESENT: Uranium

COMMENTARY AND SUMMARY: This tract is within the Grandfather Mountain Window of the Blue Ridge province. Potential for gas may exist at depth below the basal Blue Ridge Thrust (Harris 1976). If the Brevard Zone, nearby to the southeast, is the root zone of the west-directed thrusting (Bryant and Reed 1970), the potential is very slight, and little exploration has occurred. Uranium has been reported as occurring on the tract (Bryant and Reed 1966), but none has been mined. The rocks are too old for coal. Hot dry rock at depth may have some potential as a source of geothermal energy, but little exploration has taken place. Other than uranium, no critical minerals are known to occur in the tract, but mica, tin, rare earths, and others could occur in pegmatites in the gneiss. Little exploration has been performed.

GEOLOGY: Surface rock is the Precambrian Wilson Creek gneiss.

REFERENCE/CITATION: All resources — N.C. Dept. Conserv. and Develop., Div. Min. Res., 1959, Geol. Map of N.C.; USGS and USBM, 1968, USGS Prof. Paper 580; Miller and Others, 1970, Mineral Res. of the TVA Region; Bryant and Reed, 1970, USGS Prof. Paper 615; Brobst and Pratt, 1973, USGS Prof. Paper 820; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments of Ten Alternatives — RARE II Lands; USFS, 1978, RARE II DES, So. Appal. Suppl. Oil and Gas — Vlissides and Quirin, 1963, Oil and Gas Fields of the U.S.; Cardwell, 1971, AAPG Mem. 15; USGS, 1974 and 1975, Maps of Appal. Oil and Gas Production; Miller and Others, 1975, USGS Circ. 725; Harris and Milici, 1977, USGS Prof. Paper 1018; Patchen and Others, 1978, AAPG Bull. 8. Uranium — Bryant and Reed, 1966, USGS Circ. 521; ERDA, 1976, NURE Preliminary Report. Coal — Trumbull, 1960, Coal Fields of the U.S. Geothermal — AAPG, 1976a and b, Geothermal Gradient Map and Subsurface Temperature Map of North America. Critical Minerals — Lesure, 1968, USGS Prof. Paper 577; Oriel, 1950, N.C. Dept. Conserv. and Devel., Div. Min. Res., Bull. 60.

ENERGY AND MINERAL RESOURCE EVALUATION — RARE II TRACTS

TRACT NO: 09047 TRACT NAME: Gauley Mountain ECOREG: 2211 WAR: 18

NATIONAL FOREST: Monongahela STATE/COUNTY: West Virginia, Webster/Randolph/Pocahontas

ACREAGE (GROSS): 13,320 ACREAGE (NET): 12,890 100 N/G: 97 LATITUDE: 38°29' LONGITUDE: 80°10'

INDIVIDUAL TRACT RESOURCE RATINGS	ORNL	USFS	DOE	USGS	REMARKS
OIL AND GAS	4/2	4			
URANIUM	2/2	1	1		
COAL	2/4	4	3		
GEOTHERMAL	2/1	1			
CRITICAL MINERALS	2/2	4			
OVERALL RATING (WEIGHTED)	2^+		3		

NAMES OF CRITICAL MINERALS PRESENT: Possible copper, iron, lead, zinc, cadmium, fluorite, and barite at depth

COMMENTARY AND SUMMARY: This tract is in the Appalachian Plateau province. The rocks are favorable for oil and gas, which are produced throughout the province in the study area. Sandstone units may be favorable for deposits of uranium. This tract is situated on the edge of the Appalachian coal field. Coal underlies part of the tract but is thin and of low quality. Hot dry rock at depth may be favorable as a source of geothermal energy. The surface rocks probably contain no critical minerals, but older rocks at depth may be favorable for copper (Upper Devonian red beds); zinc and lead (Devonian Oriskany Sandstone); iron (Devonian Helderberg Limestone and Silurian Clinton Formation); and zinc, cadmium, lead, fluorite, and barite (Ordovician carbonates). Little exploration has occurred for any resources, except for oil, gas, and coal in the immediate area.

GEOLOGY: Surface rocks are Upper Mississippian and Lower Pennsylvanian shales and sandstones, mostly flat-lying but with occasional folds and faults.

REFERENCE/CITATION: All resources — Stose and Ljungstedt, 1932, Geol. Map of W. Va.; USGS and USBM, 1968, USGS Prof. Paper 580; Miller and Others, 1970, Mineral Res. of the TVA Region; Brobst and Pratt, 1973, USGS Prof. Paper 820; DOE, 1978, Energy Res. Assessments of RARE II Lands; DOE, 1978, Energy Res. Assessments of Ten Alternatives — RARE II Lands; USFS, 1978, RARE II DES, So. Appal. Suppl. Oil and Gas — Vlissides and Quirin, 1963, Oil and Gas Fields of the U.S.; Cardwell, 1971, AAPG Mem. 15; USGS, 1974 and 1975, Maps of Appal. Oil and Gas Production; Miller and Others, 1975, USGS Circ. 725; Harris and Milici, 1977, USGS Prof. Paper 1018; Patchen and Others, 1978, AAPG Bull. 62: 1399-1441. Uranium — ERDA, 1976, NURE Preliminary Report. Coal — Trumbull, 1960, Coal Fields of the U.S. Geothermal — AAPG, 1976a and b, Geothermal Gradient Map and Subsurface Temperature Map of North America.

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November 13, 1979

MEMORANDUM

TO: Burt Barnes

FROM: Mike Wright and Debbie Struhsacker

SUBJECT: Oakridge BLM Wilderness Survey Impact Report.

The ORNL report, "Energy Resources and the Bureau of Land Management Wilderness Program: Regional Energy Resource Compilation and Analysis", September 28, 1979, presents an oversimplified and unrealistic evaluation of the potential impact that the BLM Wilderness inventory may have on energy resource development. Most of the conclusions can not validly be drawn from the data examined. In the case of geothermal energy, conclusions and statements in the report are not at all supportive of development of this important energy source. Some examples are:

". . . geothermal energy is not expected to make a significant contribution to future energy needs" (p. 18).

"The rate of introduction of geothermal technology is expected to be low in the next 20 years." (p. 34)

" . . . If all BLM Roadless Areas are designated wilderness, short-term (1980-2000) impacts to exploration and possible development of geothermal resources will be minimal." (p. 34)

". . . electrical energy generated from hydroelectric and geothermal resources is largely used near the source"(p. 39).

None of these statements is correct. In the first place it is not the purpose of the subject report to determine what is or is not a significant contribution to U.S. energy needs. The conclusion regarding the role of geothermal energy is based upon an incorrect interpretation of Figure 2, p. 15. Each unit of geothermal energy brought on line will directly replace a unit of foreign petroleum that this country will not have to import. Each geothermal resource whose use is blocked because of designation of the area as wilderness will have a direct, unfavorable impact on this nation's effort to become energy self-sufficient. Moreover, we believe that invalid conclusions are drawn for the other energy resources as well.

Recommendations

We consider that if this report goes to the BLM in its present form that unsupportable statements such as the above will be taken as an official DOE position. This will create at the outset within the BLM an incorrect impression of the unimportance of energy resource development within the wilderness study areas. These negative effects would be very difficult to overcome in the future. This report should be considered by DOE to be an unacceptable representation of DOE's position as energy advocate for the U. S. We recommend considerable modification of the report before dissemination.

We believe that the majority of problems in this report result from drawing conclusions from the data as presently assembled. The current data compilation scale is 1:2,500,000, or about 1in. = 40 mi. At this scale, and because ORNL's work was initiated only a few months ago, there has been no detailed, tract-by-tract resource evaluation. Without such a detailed evaluation, conclusions regarding impact of a) ultimate inclusion of tracts in the wilderness inventory, and b) the effects of interim management policies on exploration and development in the 1980-1993 time frame absolutely cannot be drawn. They are little better than guesses, and should not be used to make DOE policy statements.

We have several other general comments on the report as follows:

Lack of Internal Consistency

The major conclusion of this report, as stated in the introduction, is that the BLM inventory will have little effect upon oil, gas, coal and uranium needs (p. 1). However, in the body of the text there are several statements to the contrary:

1) "If all BLM Roadless Areas are designated wilderness, our future potential for uranium resources could be reduced significantly" (p. 26).

2) ". . . geothermal resource development will be the most severely impaired if all Roadless Areas become wilderness (p. 18).

3) ". . . the conflicts with [geothermal] and Roadless Areas appear greater than with other resources . . . the short-term (1980-2000) impacts to exploration and possible development of geothermal resources will be minimal" (p. 34).

Identification of Areas Recommended for Immediate Study

Figure 1 (p. 4) shows regions with the greatest conflict between proposed wilderness areas and regions of existing and potential energy resources. These areas were defined by:

1) Identification of regions with densely spaced roadless areas (Fig. 4, p. 21)

2) Preparation of a simplified Geologic Terrain Map (Fig. 3, p. 19) showing four geologic settings.

3) Designation of the potential for occurrence of oil and gas, coal, uranium, geothermal, and oil shale (high, moderate and low) in each geologic environment (Table 4, p. 20).

Our interpretations of overlays of Figures 3 and 4, and consideration of the criteria listed in Table 4 produces different regions meriting immediate evaluation than some of the areas shown on Figure 1. For example:

1) According to Table 4, large sedimentary basins are the geologic terrain most important for energy resources, since they have high potential for everything but geothermal. However, not all clusters of roadless areas in large sedimentary basins have been designated as regions needing immediate study (Figure 1). Why not?

2) The entire Cordilleran fold and thrust belt is indicated as a high priority area. However, according to Table 4, this geologic setting has low potential for oil shale, geothermal, uranium and coal, and only moderate potential for oil and gas. Moreover, Figure 4 shows a fairly sparse population of Roadless Areas in this region. Based on this information, why is this belt important?

<u>Potential of BLM Lands</u>

According to Table 3 (p. 17), the western U. S. produced 16 quads of energy in 1977, or roughly 25% of our domestic energy production. ORNL estimates that only 3 quads were produced from western BLM lands (p. 14). Can this figure be documented? From these values they conclude that:

> ". . . BLM lands produce less than 5 percent of the domestic energy supply, yet they occupy more than 9 percent of the land area . . . According to these percentages BLM lands presently do not contribute their share of national energy-resource needs." (p. 14)

The inference is made that this lack of production is due to lack of resource potential. Problems with exploration on and development of federal land have not been considered. The report fails to recognize that the energy resources of the west, now relatively undeveloped, will become increasingly important in the future. Inferences such as the above, based on the historic situation, are incorrect because this history cannot be projected into the future, even for the near future. Exploration of the BLM lands in the west must continue today in order that discoveries may be brought on line in timely fashion.

1) Based on the information shown in Figure 3 and 4, and Table 4, this report concludes " . . . a large part of the BLM lands lie in relatively unfavorable areas for many of the energy resources" (p. 18). Superposition of Figures 3 and 4 shows that most of the dense clusters of Roadless Areas occur in areas of "Cenozoic rifts and volcanic rocks", which according to Table 4 have low oil and gas, oil

shale and coal potential, low to moderate uranium potential and high geothermal potential. The area mapped as Cenozoic rifts and volcanic rocks is actually composed of extrusive and intrusive igneous rocks and sedimentary and metamorphic rocks of widespread age and distribution. Grouping these lithologies into one category, Cenozoic volcanic rocks, is a gross over-simplification. Evaluating the areas' energy potential with a blanket generalization of the resource potential of volcanic rocks is misleading. The varied rock types in this region have high quality and diverse energy resource potential. In addition there are many promising base and precious metals exploration targets in the area.

2) Furthermore, classification of geothermal potential in the four general geologic environments as shown in Table 4 is not correct. Failure to recognize the widespread, well known potential to the Madison group means that the geothermal potential of "Large Sedimentary Basins" should be changed from "low" to "moderate to high". Recent drilling for petroleum in the overthrust area of Idaho, Wyoming, and Utah has encountered hot fluids. Therefore the potential of the "Cordilleran Folded Thrust Belt" should be at least "moderate".

From the above we conclude that ORNL's method of designating critical areas for immediate study is not meaningful for geothermal resources. It would be far better to do a quick, tract-specific study, which ESL and the State Teams could support, to identify those tracts having important, immediate potential. These are the areas which would merit in-depth study and which could quickly be identified to the BLM as having geothermal importance. We recognize that this could create problems with ORNL's proposed detailed study methods, which call for in-depth study of all resources in regions which include a large number of tracts.

Mike (DS)
Mike Wright
Associate Director

Debbie
Debbie Struhsacker
Associate Geologist

MW,DS:srm

cc: Nichols
Minck
Ann Wiggins

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MEMORANDUM

October 22, 1979

TO: Burt Barnes

FROM: Mike Wright and Debbie Struhsacker

SUBJECT: Comments on the ORNL Resource Rating Method for Geothermal Resources.

The ORNL resource rating method is a big improvement over other methods with which we are familiar. We very much like several aspects including 1) the systematic approach, 2) the "working group" techniques for idea generations and conflict resolution, 3) the fact that emphasis is placed on documentation of how ratings were obtained, and 4) the dual rating system.

There are a few problems that we have identified in application of this method to geothermal resources. During a recent visit to ESL, ORNL personnel indicated willingness to modify their techniques, if appropriate, for rating geothermal resources. They are open to suggestions. Some general comments we have are given below. They are based on our discussions with the ORNL people and on Voelker, et al., 1979, A Systematic Method for Resource Rating with Two Applications to Potential Wilderness Areas, ORNL/TM-6739. Page numbers given below refer to this document.

Favorability Rating

Although generally a workable concept, the emphasis placed upon resource occurrence models in the Favorability Rating may present a problem in geothermal resource assessment. Occurrence models are not well established for some types of geothermal systems. Any adopted occurrence models with accompanying geothermal resource definitions and characteristics should reflect the viewpoint of at least several specialists in the field. Occurrence models should be carefully worked out with the ORNL group before application of the method. ESL can be of help in doing this.

Certainty Rating

Many areas of high geologic favorability for geothermal resources will have low certainty due to the infancy of the geothermal exploration industry and the attendant lack of widespread geothermal exploration. The certainty rating for geothermal resources will be low compared to that for most other resources for which exploration programs have been active for many years. In the case of geothermal energy, the lack of data, exploration activity and production should not be interpreted as lack of resource potential.

The parameters contributing to a certainty rating should be modified for geothermal analyses. The term "known resource district", as used in Certainty Rating #2 (page 5) may have limited applicability to geothermal sites since many high quality geothermal prospects are not known resources in a quantified production sense.

The types of supporting data used in deciding upon the certainty ranking should be altered to precisely fit geothermal exploration parameters. For example, thermal gradient and/or heat flow data should replace the assay criterion listed in Certainty Rating Number 3 (p. 5).

Overall Rating

This aspect of the Oak Ridge method presents serious problems in its application to geothermal resources. As an evaluation of the importance of a resource to the national energy budget, the rating system is strongly skewed in favor of oil and gas. Geothermal energy is not listed as a high-rated "strategic resource" in the overall rating scheme (p. 8). Moreover, geothermal energy is considered to be a relatively unimportant resource" ... which will furnish only a small part of the nation's energy requirements..." (p. 19). Thus a tract with high geothermal potential but low potential for other strategic resources could receive a low overall rating and be recommended for wilderness rather than preserved for exploration development. Many high quality geothermal exploration targets could be lost to wilderness status using this rating system.

General

Another aspect of resource rating on specific tracts that the ORNL system does not consider is the location of the tract relative to areas most favorable for resource occurrence, or alternatively how much of a specific tract is highly favorable. In our resource work on the RARE II areas we found that it was often possible to effectively remove a conflict by moving the boundary of the proposed wilderness area without disturbing the integrity of the area. Identification of such cases will be important in the BLM study as well, and can play an important role in conflict resolution.

Recommendations

1. Include geothermal resources (and other alternate energy resources

such as oil shale in the list of strategic resources.

2. The Overall Rating should not pit one resource against another. If a tract has good resource potential, it should remain non-wilderness regardless of what that resource is. The definition of "strategic resource" may change over the years. Curent "non-strategic" resources should remain available for future development.

3. The effects that boundary changes would have on a resource rating should be considered, and the DOE recommendations to the BLM should include boundary changes wherever significant conflict could be avoided thereby.

Mike Wright

Debbie Struhsacker

PMW, DS:ls

TO: Mike Wright

FROM: Debbie Struhsacker

SUBJECT: Oak Ridge National Laboratory's Resource Assessment Method

2. Summary of ~~Oak Ridge Method~~

   A. Use of Dual Rating System

(pp.3-5) 1. The Favorability Rating: "The favorability of any region for a particular resource is based on commonly accepted occurrence models. This concept applies to both known districts and unexplored areas of good geologic potential (i.c. elephant county).
   - Favorability rating is assigned on a regional scale and modified as need be to reflect local geologic conditions.

(pp.4-5) 2. Certainty Rating: Refers to the presence or absence of a resource in a tract. Certainty indicates the amount of supporting data available such as information on past or present production, assay results, detailed mineral investigations, etc.
   - These certainty data can be extrapolated from nearby mining districts, oil and gas fields, etc. to the tract in question.

(pp.7-8) B. Overall Tract Rating

The Overall rating emphasizes "the importance of the tract in meeting future energy and mineral resource needs". The overall rating considers the following:

- the great importance ~~high favorability~~ of strategic resources (geothermal is not listed as a strategic resource)
- the favorability and certainty ratings for a given resource
- the overall supply of each resource in the region and in the nation
- the economics and feasibility of extracting the resource.
- size of the tract (large tracts have greatest importance)