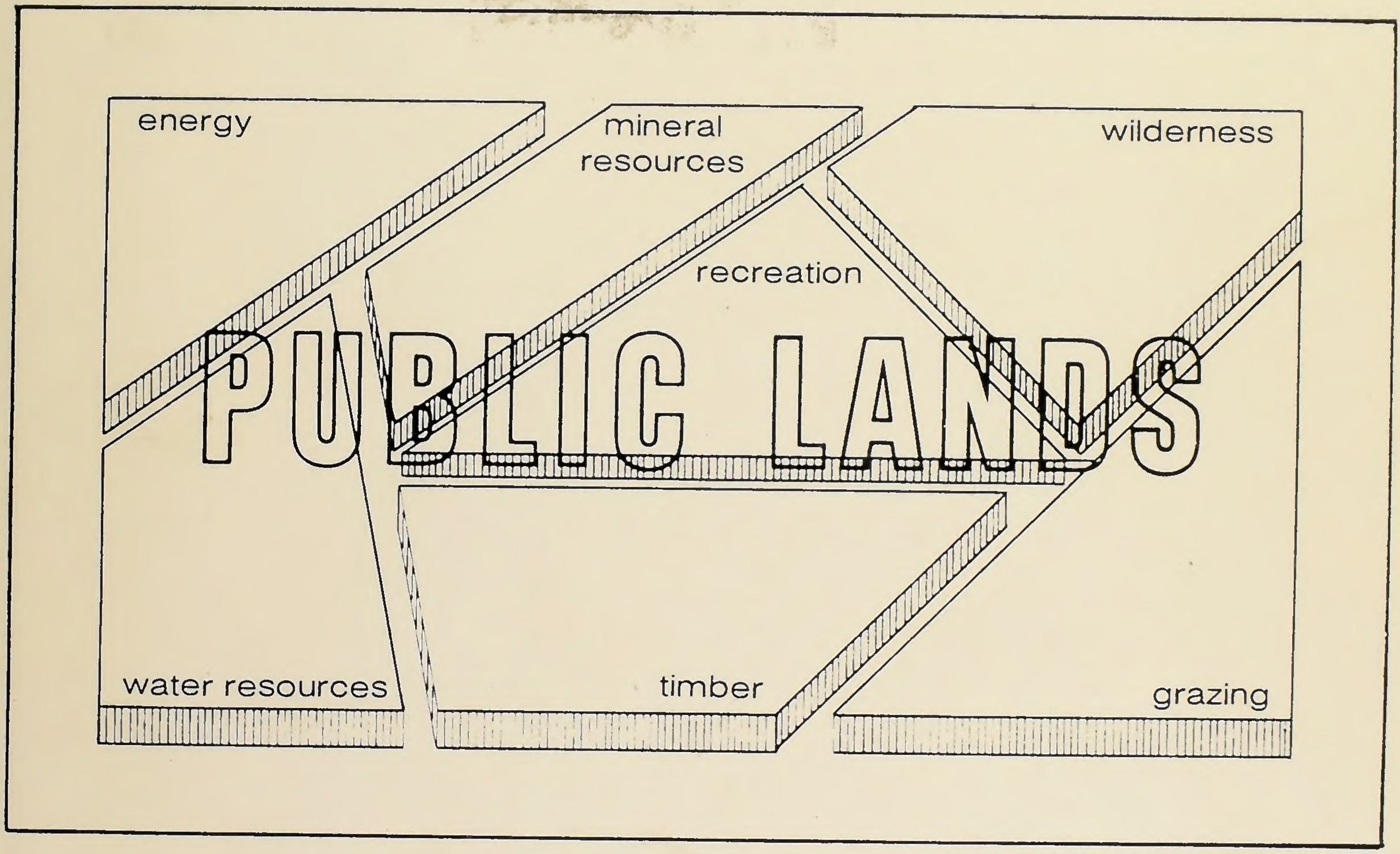
MINERAL-RESOURCE EVALUATION OF WILDERNESS STUDY AREAS



the Bureau of Land Management's Moab District, Utah

Volume II: San Juan Resource Area

Volume II

MINERAL-RESOURCE EVALUATION OF WILDERNESS STUDY AREAS ADMINISTERED BY THE BUREAU OF LAND MANAGEMENT

the MOAB DISTRICT, UTAH

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This volume contains evaluations of tracts in the San Juan Resource Area

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THE WILDERNESS REVIEW PROGRAM OF THE BUREAU OF LAND MANAGEMENT

In 1976 the Federal Land Policy and Management Act was passed by Congress (FLPMA; Public Law 94-579). This law provided the Bureau of Land Management (BLM) with a unified and comprehensive mandate for management of the public lands. In general, FLPMA stated that public lands will remain in Federal ownership and will be managed by the principles of multiple use and sustained yield (BLM, 1979). FLPMA directed the BLM to prepare an inventory of the public lands and their resources, including the identification of areas having wilderness characteristics (FLPMA, Section 603). Under FLPMA, wilderness preservation is part of BLM's multiple-use mandate, and wilderness values are recognized as part of the spectrum of resource values and possible uses that are considered in the land-use planning process. The BLM must report its wilderness recommendations to the President no later than October 21, 1991; the president must make final recommendations to Congress by October 21, 1993. Congress will then decide what areas will be designated "Wilderness."

The BLM Wilderness Program consists of three phases--an intensive inventory, detailed study, and reports with recommendations.

> <u>Phase I</u>- During Phase I (already completed), the BLM identified areas of 5,000 acres or more that possess wilderness characteristics based on general criteria established by Congress in the 1964 Wilderness Act. These areas are called Wilderness Study Areas (WSAs).
>
> <u>Phase II</u>- In Phase II, which is currently in progress, the BLM will use specified criteria (Federal Register, Dec. 19, 1980) to attempt to balance the need for wilderness with the needs for other resources and thus determine the "suitability" or "nonsuitability" of each WSA for wilderness recommendation. One criterion used to judge a WSA's "wilderness suitability" is mineral potential, and the BLM is required to consider the mineral values of a WSA in their suitability decision. **The mineral resource data provided in this report are designed to help satisfy this criterion.**
>
> <u>Phase III</u>- Phase III consists of reporting and forwarding to the President (through the Secretary of the Interior) all recommendations pertaining to the suitability or nonsuitability of each WSA for inclusion in the Wilderness Preservation System. By law, each WSA that is determined to be suitable for wilderness designation in Phase II must have a detailed mineral survey conducted by the U.S. Geological Survey and the U.S. Bureau of Mines. These mineral surveys, as well as environmental statements and other data, are submitted to the President with the BLM's final recommendations developed in Phase III.

THE WILDERNESS REVIEW PROCESS OF THE BUREAU OF LAND MANAGEMENT

In 1976 the Federal Land Policy and Management Act was passed by Congress (FLPMA; Public Law 94-579). This act provided the Bureau of Land Management (BLM) with a mandate and comprehensive authority for management of the public lands. In general, FLPMA states that public lands will remain in Federal ownership and will be managed on the principles of multiple use and sustained yield (Sec. 102(a)). FLPMA directs the BLM to prepare an inventory of the public lands and their resources, including the identification of areas having wilderness characteristics (FLPMA, Section 603). Under FLPMA, wilderness preservation is part of BLM's multiple-use mandate, and wilderness values are considered as part of the spectrum of resource values and uses that must be considered in the "balanced" planning process. The BLM must report its wilderness recommendations to the President no later than October 21, 1991; the President must then make final recommendations to Congress by October 21, 1993. Congress will then decide which areas will be designated "wilderness."

The BLM wilderness review consists of three phases—the inventory, wilderness study, and reports with recommendations.

> Phase I, Inventory (Phase I officially completed). The BLM identified areas of 5,000 acres or more that possess wilderness characteristics, based on general criteria established by Congress in the 1964 Wilderness Act. These areas are called Wilderness Study Areas (WSAs).
>
> Phase II. In Phase II, which is currently in progress, the BLM will use detailed criteria (Federal Register, Dec. 1982) to determine the suitability of each WSA for wilderness. Each WSA is studied for other resources and land uses to assess the "manageability" or "nonsuitability" of each WSA for wilderness designation. The evaluation used to judge a WSA's "wilderness suitability" is quality, uniqueness, and the BLM is required to consider the mineral values of a WSA in their suitability decisions. The mineral resource data provided in this report are designed to help satisfy this criterion.
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> Phase III. Phase III consists of reporting and forwarding to the President through the Secretary of the Interior, the recommendations pertaining to the suitability or non-suitability of each WSA for inclusion in the Wilderness Preservation System. By law each WSA that is recommended to be preserved for wilderness designation in Phase II must undergo mineral survey conducted by the U.S. Geological Survey and the U.S. Bureau of Mines. These mineral surveys, as well as environmental statements and other documents, are submitted to the President with the BLM's Final Recommendations developed in Phase III.

PART 1

INTRODUCTION

This report evaluates the energy- and mineral-resource potential and importance of WSAs in the BLM's Moab district in Utah. Volume I contains tracts numbered between 007 and 140A plus 233 in the Price River, San Rafael and Grand Resource Areas. Volume II contains tracts numbered between 164 and 229 plus two Instant Study Areas in the San Juan Resource Area. The energy minerals evaluated include oil, gas (and related resources such as oil-impregnated sandstone and oil shale), uranium, vanadium, coal, geothermal, and hydropower. The non-fuel minerals that were evaluated include copper, manganese, and potash. The minerals selected for study were specified by the BLM in the work contract with Oak Ridge National Laboratory. The rationale for selecting the three non-fuel minerals (copper, manganese, and potash), and not others, is based chiefly on their known occurrence and potential importance in the district. Other non-fuel minerals (e. g., titanium, zinc, and mercury) were not evaluated because (1) the district's geologic environment is clearly unfavorable for many of these minerals, (2) the BLM considers the information already available at the district office to be adequate for some of these minerals, and (3) sufficient time and funds were not available to properly evaluate the potential and importance of each mineral commodity.

The report is divided into three parts. Part 1 contains a descriptive and statistical overview of the study. Part 2 describes briefly the geologic setting of the district and provides an overview of the district's mineral-resource setting and potential. Part 3 is the main body of the report. It consists of individual WSA-evaluations, each 10 to 15 pages in length. For more information on the BLM's Wilderness Program in Utah and for detailed description of the wilderness characteristics of each WSA in Utah, the reader is referred to BLM (1980).

The method and criteria used to evaluate the mineral resources are described in the appendix. Briefly, each resource evaluated for a WSA is assigned a dual numerical rating on a scale of 1 to 4. As an example, a WSA might be assigned an oil and gas rating of f1/c2. The first rating (f1) is an estimate of the favorability (f) of the WSA's geologic environment to contain oil and gas accumulations of a volume specified in the appendix. In this example, the geologic environment is assigned the f1 rating because it is unfavorable for oil and gas accumulations. Ratings of f2, f3, or f4 correspond to increasing levels of geologic favorability. (For instance, a WSA assigned an f4 rating would be favorable for oil and gas accumulations exceeding 50 million barrels of oil, or if gas, 300 billion cubic feet as described in the appendix.) The second rating (c2 in the example above) is the degree-of-certainty (c) that the resource does or does not exist in the WSA. If little is known about the existence of the resource in the area, certainty ratings of c1 or c2 would be assigned to the WSA for that particular resource--regardless of the assigned favorability rating. In the example above, the c2 rating for oil and gas indicates that no direct data are available from within or very near the WSA to support or refute the existence of oil and gas in the area. To be assigned a c2 rating, however, the WSA must be within a petroliferous province (basin) with at least one producing, or formerly productive, oil and/or gas field (see appendix). Higher degrees of certainty (c3 and c4) indicate that direct data are available from within or near the WSA to either support or refute the existence of the resource in the area.

After each mineral resource being evaluated for a WSA has been assigned a favorability and certainty rating, the evaluation team derives a single-digit "overall importance rating" for the WSA on a scale of 1 (low importance) to 4 (high importance). The overall importance rating provides the land manager and staff with a summary judgment, based on predetermined criteria, of the cumulative importance of all the mineral values within the WSA (see appendix). The overall importance rating may be helpful to some land managers, whereas other land managers may draw different conclusions because of additional information available at the district office. An explanation of how the overall-importance rating is derived and why it is used is contained in the appendix.

The information in this report was obtained by a review of publicly available literature. Field studies have not been conducted. In the discussions that follow, the terms "WSA" and "tract" are used interchangeably.

DESCRIPTIVE AND STATISTICAL OVERVIEW

Forty (40) tracts in the Moab district totalling 1,627,369 acres were evaluated to determine their mineral-resource importance. The tracts are roughly equivalent to the units originally identified by the BLM in the Intensive Wilderness Inventory issued in November 1980 (BLM, 1980). Thirty (30) of the tracts are WSAs and Instant Study Areas containing a total of 1,067,502 acres that are now being evaluated by the BLM for wilderness suitability. These 30 WSAs are shown in figure 1 as unpatterned. The patterned area on figure 1 represents areas that the BLM has dropped from further wilderness consideration.

The number of WSAs and the exact boundaries of those WSAs being evaluated by the BLM for wilderness suitability have changed during the Wilderness Review Program. The size and location of the tracts are based on a May 1981 update of the BLM's "Final Decision on WSAs in Utah" (BLM, 1980). This update, which also includes all the intensive inventory units of November 1980, is reproduced with minor modifications in figure 1. The boundaries shown on this map may vary somewhat from boundaries shown on other maps (more recent or older) that have been issued by the BLM.

Table 1 lists the name and acreage of each of the 40 tracts evaluated for this study. The WSA acreage is differentiated from the acreage that has been dropped from the intensive inventory, but this study evaluated the entire acreage shown for each tract. Table 1 also shows the overall importance rating (OIR) assigned to each tract by the evaluation team. Figure 2 shows the areal distribution of all the tracts, with their assigned OIR. Relatively high mineral-importance is assigned to many of the tracts, which reflects the estimated potential of the Moab district to continue to supply large quantities of the resources for which the Colorado Plateau is noted (e.g., uranium, vanadium, oil, gas, and coal).

Tracts in the Moab district can be roughly grouped according their mineral importance on the basis of broad geologic features (fig. 2). These features (e.g., uplifts and depressions that developed throughout the district in the geologic past) have resulted in selective preservation and/or removal of rock units and structural features that are favorable for specific types of mineral resources.

The tracts lying along the Uncompaghre Plateau are considered to have the lowest mineral importance of all tracts in the district. Favorable strata for uranium, vanadium, copper, manganese, and coal have been removed by erosion, and oil-rich upper Paleozoic rocks were not deposited in the area. Tracts along the Monument Upwarp also have a low estimated mineral importance. The favorable Triassic and Jurassic strata for the "hard rock" minerals (uranium, vanadium, copper, and manganese), and the favorable Cretaceous coal-bearing rocks have all been eroded from the area. In addition, deep stream-incision of the Monument Upwarp has reduced the oil and gas potential of this area, which otherwise would have been a favorable region.

Tracts in the other three resource areas are more important for mineral resources, but each tract for a different reason. In the San Rafael Swell, tracts are most favorable for uranium and vanadium. This favorability,

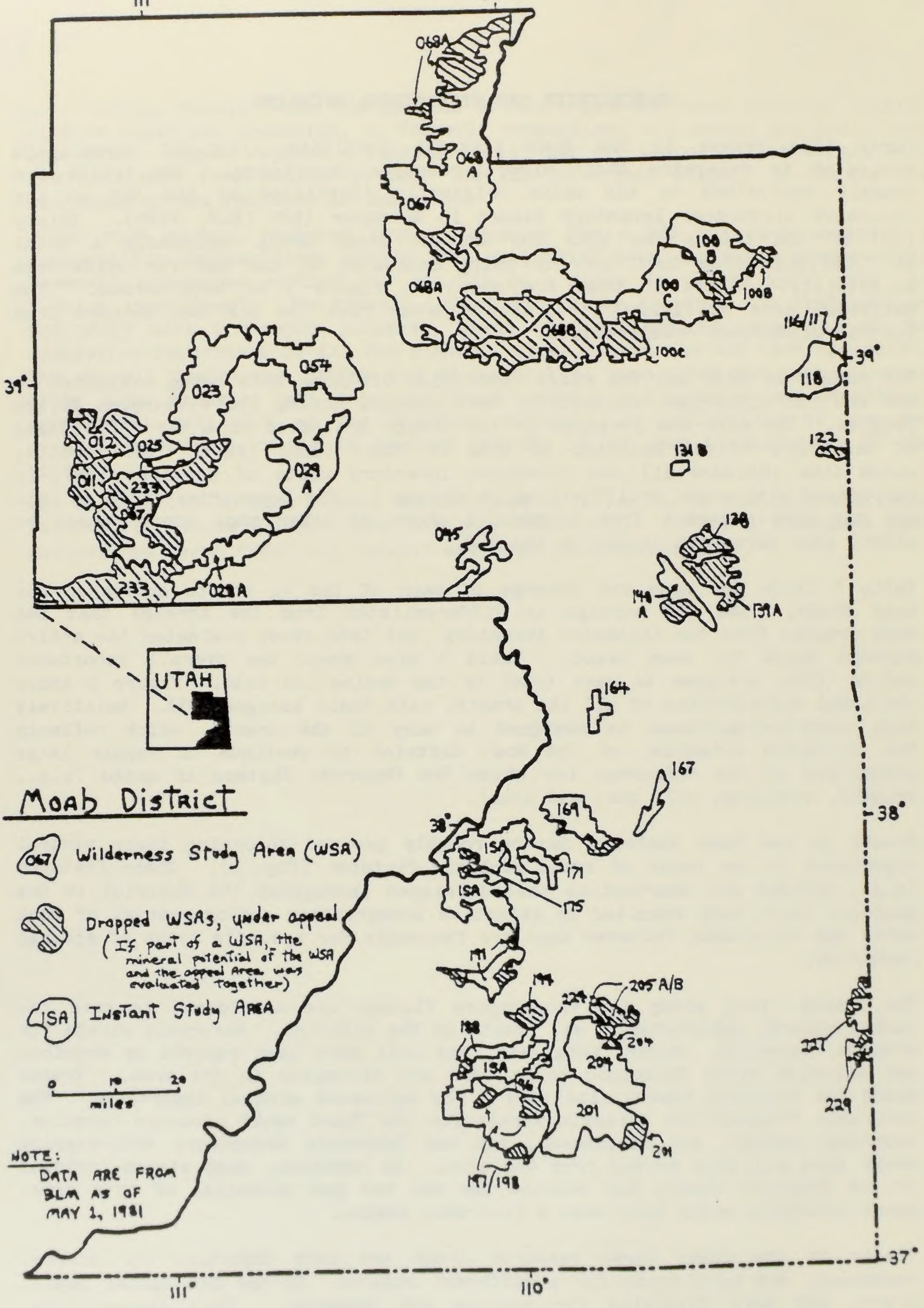


Figure 1. Tracts evaluated for this study.

TABLE 1. The Acreage Evaluated for Mineral Importance in the Moab District

Area Number	Area Name	WSA Acreage	Additional Acreage Evaluated	Overall Importance Rating
UT-060-007	Muddy Creek	31,360		3+
UT-060-011	Upper Muddy Creek		20,405	3
UT-060-012	Molen Reef		35,160	4
UT-060-023	Sids Mountain	80,530	12,470	2+
UT-060-025	Devils Canyon	9,610	14,440	3
UT-060-028A	Crack Canyon	25,315	7,385	3+
UT-060-029A	San Rafael Reef	55,540	17,730	2-
UT-060-045	Horseshoe Canyon	18,610		3
UT-060-054	Mexican Mountain	60,360		3-
UT-060-067	Turtle Canyon	33,970		3
UT-060-068A	Desolation Canyon	257,975	84,185	4
UT-060-068B	Floy Canyon		82,300	2+
UT-060-100B	Diamond Canyon	48,440	6,100	3-
UT-060-100C	Cottonwood Canyon	64,670	20,570	2+
UT-060-116/117	Wrigley Mesa/Jones Canyon	5,100		1
UT-060-118	West Water Canyon	30,800	6,840	1
UT-060-122	Granite Creek		4,800	1
UT-060-131B	South Lost Spring Canyon	3,880	4,540	2
UT-060-138	Negro Bill Canyon		9,420	3
UT-060-139A	Mill Creek		17,820	3
UT-060-140A	Behind the Rocks	12,930	6,370	3
UT-060-164	Lockhart Basin	7,300		2
UT-060-167	Bridger Jack Mesa	5,300		2-
UT-060-169	Butler Wash	22,120	5,750	2
UT-060-171	Sweet Alice Canyon		9,880	2
UT-060-175	Middle Point		5,990	1
UT-060-188	Pine Canyon	11,300	3,880	1+
UT-060-191	Cheese Box Canyon	15,410	12,110	3-
UT-060-194	Harmony Flat		10,470	1+
UT-060-196	Bullet Canyon	8,730		1+
UT-060-197/198	Slickhorn Canyon	46,800	13,910	2
UT-060-201	Road Canyon	65,000	11,170	2
UT-060-204	Fish Creek Canyon	48,530	3,520	2
UT-060-205A/205B	Arch Canyon/Mule Canyon	5,600	7,500	1+
UT-060-224	Shieks Canyon	3,070		1
UT-060-227	Squaw & Papoose Canyons	6,580	3,090	3
UT-060-229	Cross Canyon	1,000	1,112	3
UT-060-233	San Rafael Knob		119,570	4
ISA	Grand Gulch	34,928		2
ISA	Dark Canyon	49,904		2
	TOTALS	1,070,662	558,487	

GRAND TOTAL (sum of columns) 1,629,149

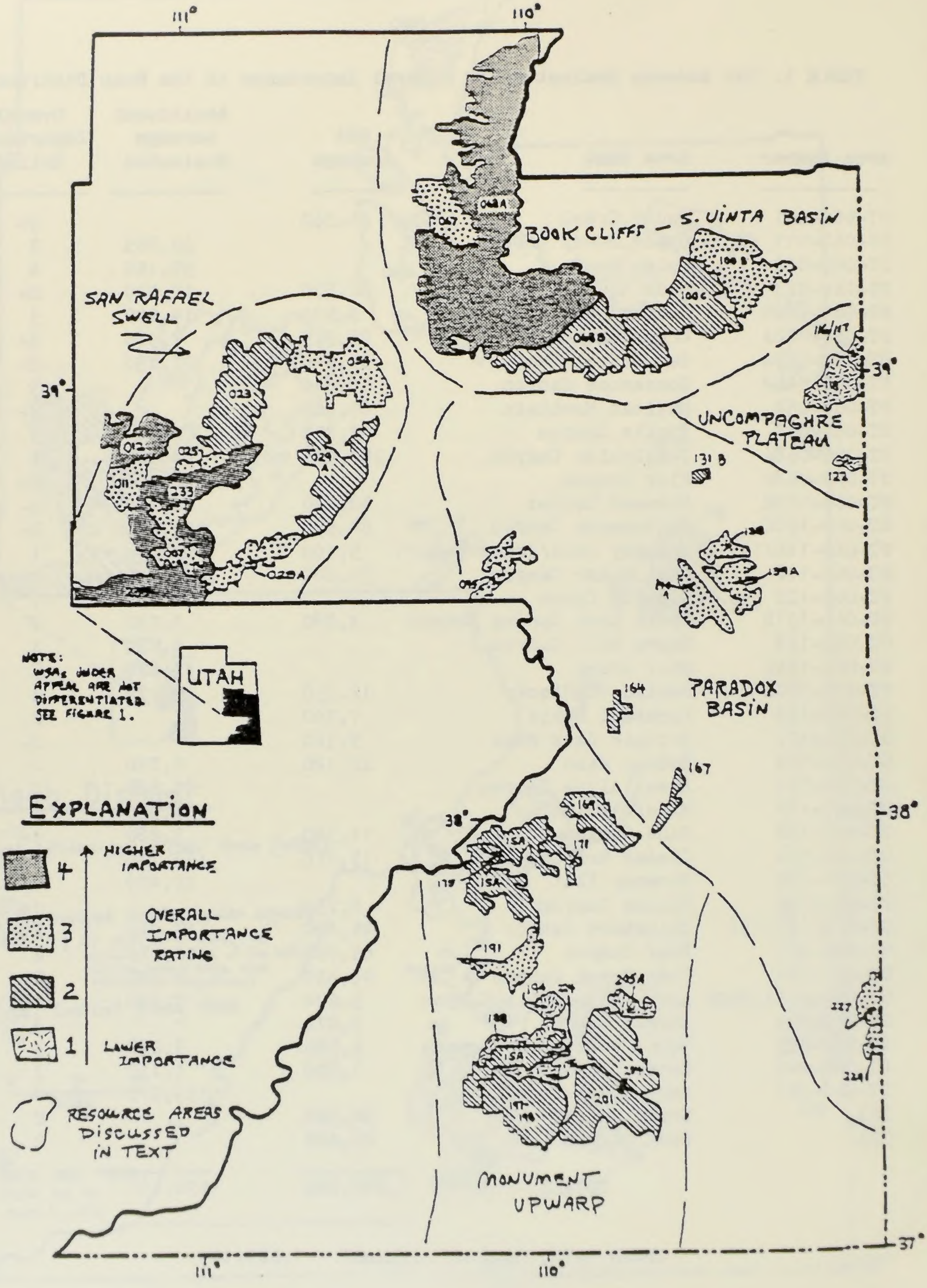


Figure 2. Overall importance rating assigned to tracts.

along with the relatively high certainty that uranium and vanadium occur in the tracts, are the chief reasons for their high overall importance. Oil-impregnated rock deposits also contributed to the OIR in some tracts along the San Rafael Swell.

In the Book Cliffs resource area, the high OIRs generally correspond to a moderate potential for oil and gas, combined with a low to moderate potential for coal and oil-impregnated rocks. The certainty that resources occur in many of these tracts is moderately high for oil and gas, and absolute in the case of coal and oil-impregnated rocks. Also, many of the tracts in the Book Cliffs are very large, and size tended to slightly increase a tract's overall mineral-importance.

Tracts in the Paradox Basin resource area are all relatively important for mineral resources, chiefly because of oil, gas, and uranium. However, the certainty that these resources exist (particularly oil and gas for those tracts in the northern Paradox Basin) is very low.

Factors that influenced the OIR for each tract are discussed in the individual tract evaluation (see Part 3). Favorability and certainty ratings were the most important, size was important for some tracts, and, in a few cases, the tract's proximity to National Parks was important (see appendix for a discussion on the derivation of a tract's OIR). If factors such as these did influence the tract's OIR, they were stated in the individual tract evaluation (see Part 3).

Figure 3 shows (1) the distribution of the four OIR categories, based on the number of tracts assigned to each (fig. 3a), and (2) the total acreage assigned to each OIR category (fig. 3b). Figure 4 shows the same types of distributions, but only for those 30 tracts that are identified as WSAs. (The total acreage of those dropped areas that are contiguous with WSAs is not represented on the histograms in figure 4.) The shape of the distributions is similar in figures 3 and 4, indicating that the dropped acreage is neither more, nor less, important than the WSA acreage. In qualitative terms, more than 50 percent of the acreage evaluated in the Moab district can be considered important for future mineral exploration (as indicated by an OIR of 3 or 4).

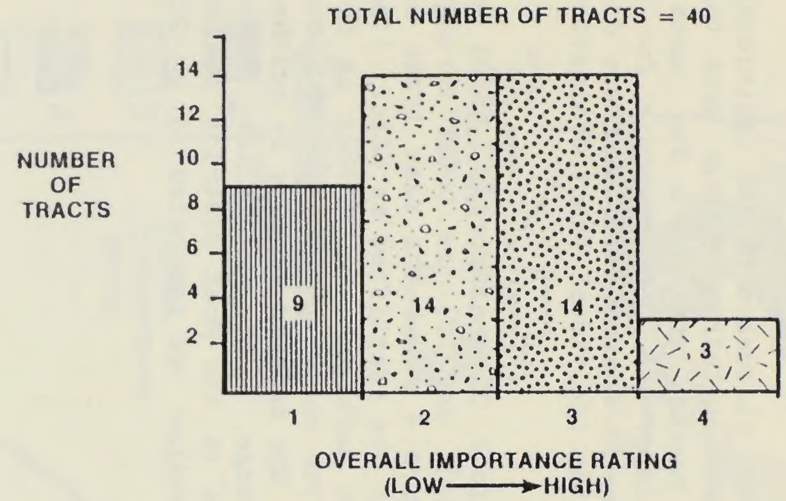


FIGURE 3a. Histogram showing the distribution of tracts in each overall importance category.

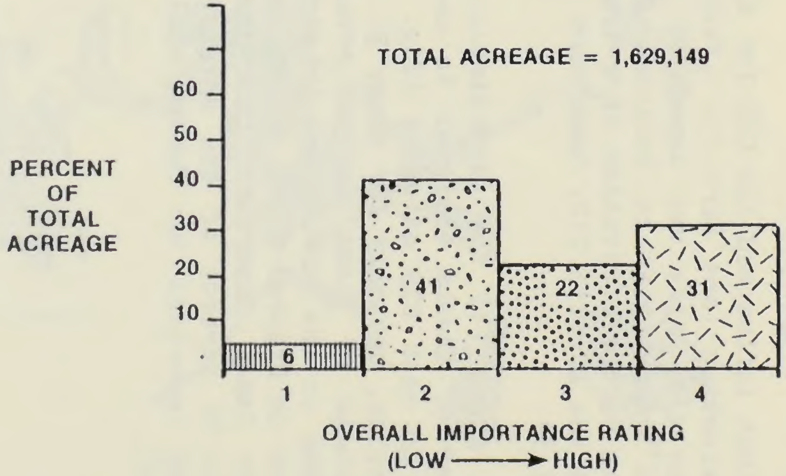


FIGURE 3b. Histogram showing the distribution of acreage in each overall importance category.

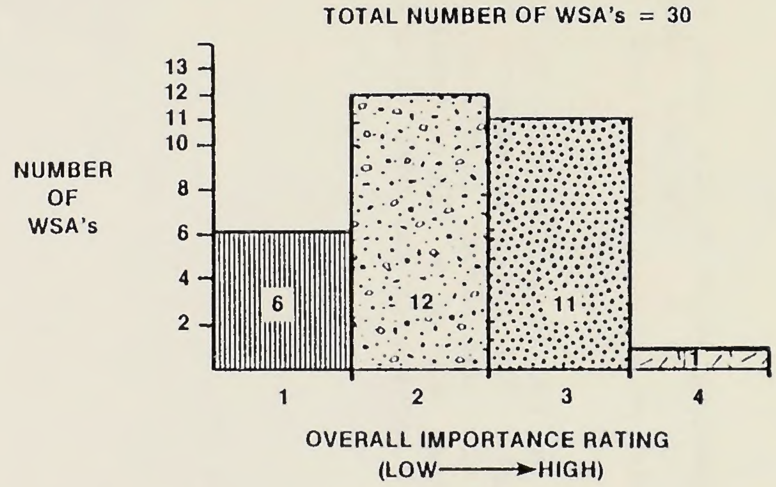


FIGURE 4a. Histogram showing the distribution of WSA's being considered for wilderness suitability in each overall importance category.

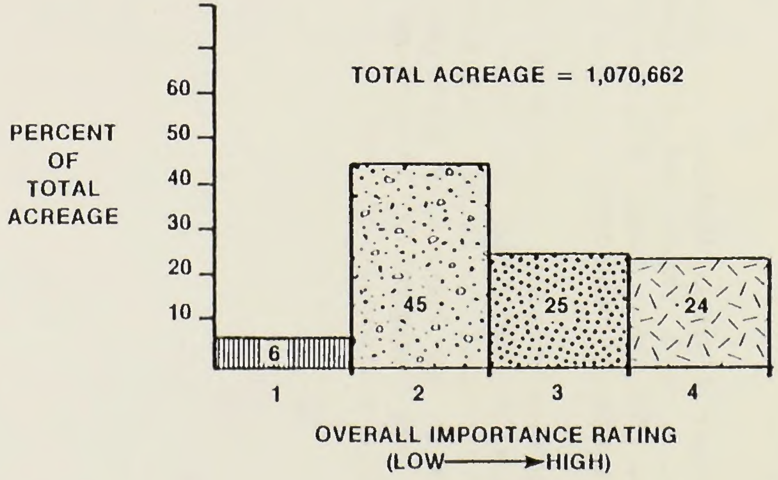


FIGURE 4b. Histogram showing the distribution of WSA acreage in each overall importance category.

COMPARISON OF RESULTS WITH RESOURCE EVALUATIONS OF OTHER BLM DISTRICTS

In April and May of 1981, two mineral evaluations structured like this study were completed for WSAs in the BLM's Cedar City district in Utah and for WSAs Coeur d'Alene district in Idaho. Although these two evaluations examined only energy resources, they can be compared with the evaluation of the Moab district because the non-fuels evaluated for tracts in the Moab district (copper, manganese, and potash) did not contribute significantly to the overall mineral importance of the tracts.

In the Cedar City district, 29 tracts totalling 785,000 acres were evaluated for their energy-resource potential. Six of the tracts were assigned an OIR of 3, and these accounted for 57 percent of the acreage evaluated. Ten tracts were assigned an OIR of 2, accounting for about 34 percent of the total acreage. The remaining 13 tracts, accounting for 9 percent of the acreage, were assigned OIRs of 1. No tract in the Cedar City district was assigned an OIR of 4.

In the Coeur d'Alene district, 5 tracts encompassing about 40,000 acres were evaluated. Each tract was assigned an OIR of 1 or 2. The WSA acreage evaluated for the Coeur d'Alene district was relatively unimportant for potential energy resources.

The estimated mineral importance of tracts in the Moab district is high compared with tracts in the Cedar City district. The total acreage in each district assigned to an OIR category of 3 or more was almost identical, but no tracts in the Cedar City district were assigned OIRs of 4. In contrast, an OIR of 4 was assigned to 24 percent of the WSA acreage in the Moab district, which was contained in one WSA.

PART 2

PART 2

MINERAL RESOURCES IN THE MOAB DISTRICT--AN OVERVIEW

Geologic Setting and History

The Moab district lies wholly within the Colorado Plateau--a physiographic province encompassing about 150,000 square miles (fig. 5). Fenneman (1928) subdivided the Plateau into six sections on the basis of geomorphic features. The Moab district, as shown on figure 5, lies almost entirely within the Canyon Lands section. Elevations throughout the district are generally between 5,000 and 7,000 feet above sea level, although the La Sal and Abajo Mountains rise to over 13,000 feet.

Rocks at the surface in the Moab district are chiefly of sedimentary origin, flat-lying, and of upper Paleozoic and Mesozoic age (fig. 6). Exceptions include the small masses of Cenozoic igneous intrusive rocks that comprise the La Sal and Abajo Mountains, early Tertiary sedimentary rocks in the northern part of the district, and Precambrian igneous and metamorphic rocks exposed on the Uncompaghre Plateau (fig. 6). Sedimentary rocks older than Pennsylvanian age are known only from well data and from exposures outside the district. Figure 7 is a stratigraphic correlation chart for southeastern Utah prepared by Molenaar (1978) that shows formation names and thicknesses, and major unconformities.

Very little is known about the Precambrian rocks underlying the Moab district. On the basis of deep well-data and geophysical investigations, Case and Joesting (1972) believe the Precambrian rocks are composed of granite, gneiss, schist, and mafic intrusive rocks. In some areas, Precambrian sedimentary rocks may also be preserved within fault blocks, similar to those exposed in the Grand Canyon. Baars and Stevenson (1981) summarize the evidence of Precambrian tectonism and speculate that two continental-scale shear zones--one trending to the northeast and the other trending to the northwest--became active about 1.7 billion years ago and intersected in southeastern Utah. According to these authors, most of the major structural features of the Colorado Plateau (and the Moab district) can be attributed to periodic rejuvenations, in Paleozoic and Mesozoic time, of structural patterns that had been established in Precambrian time.

During most of Paleozoic and Mesozoic time the Colorado Plateau was a shelf area lying east of a large marine basin--the Cordilleran Geosyncline--that covered most of the western United States. Seas that existed in the geosyncline periodically spread eastward, crossing much of what is now the Rocky Mountain region. The sediments deposited in these advancing and retreating shallow seas are represented today on the Colorado Plateau by relatively thin marine and continental strata. Only during Pennsylvanian time did large, deep marine-basins develop in the area of the present-day Colorado Plateau.

Cambrian, Devonian, and Mississippian rocks in the Moab district consist predominantly of thin sandstones, shales, and limestones. (Ordovician and Silurian rocks are not preserved in the Moab district, nor throughout much of the Rocky Mountain region; also, Paleozoic rocks are not preserved on

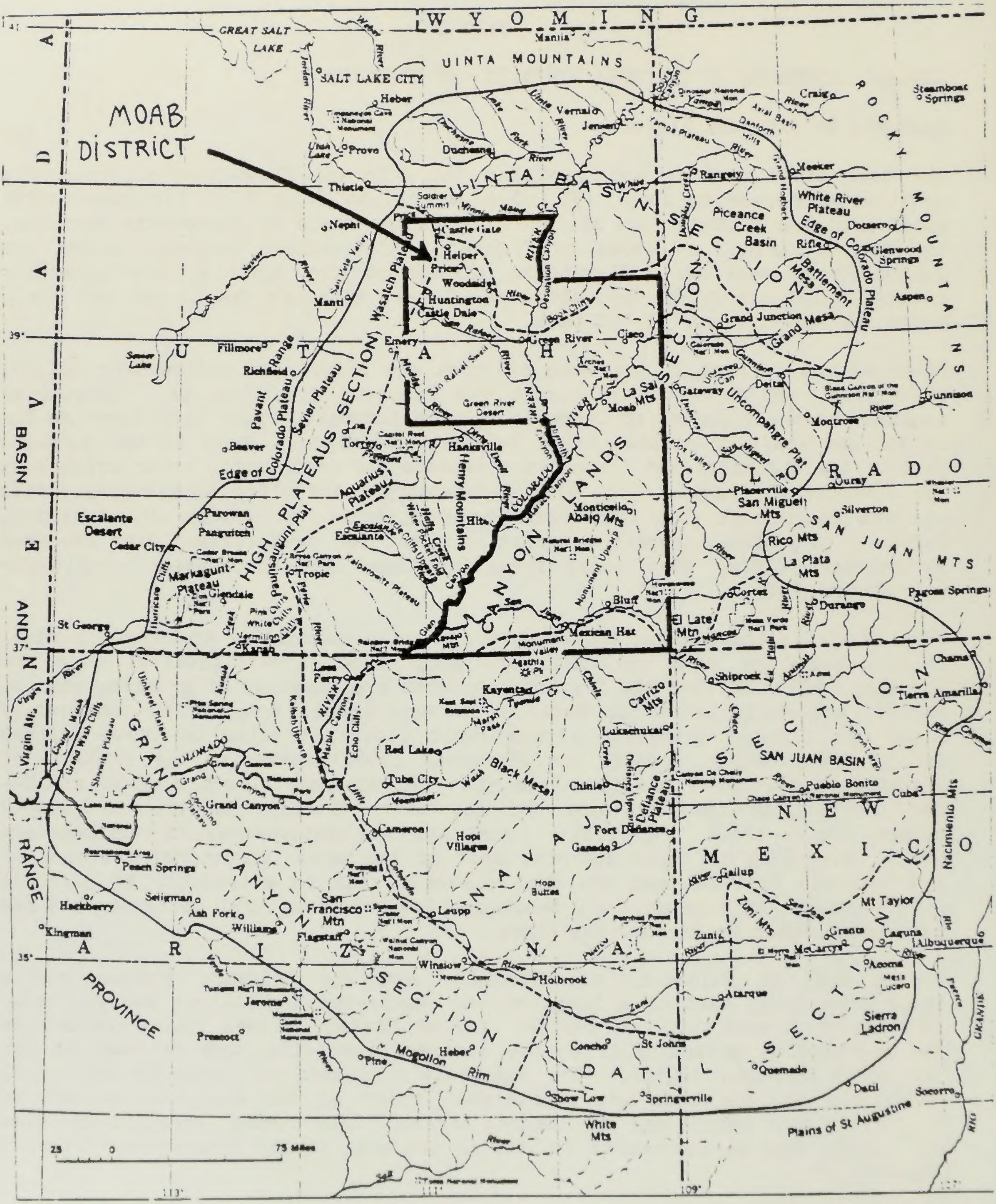
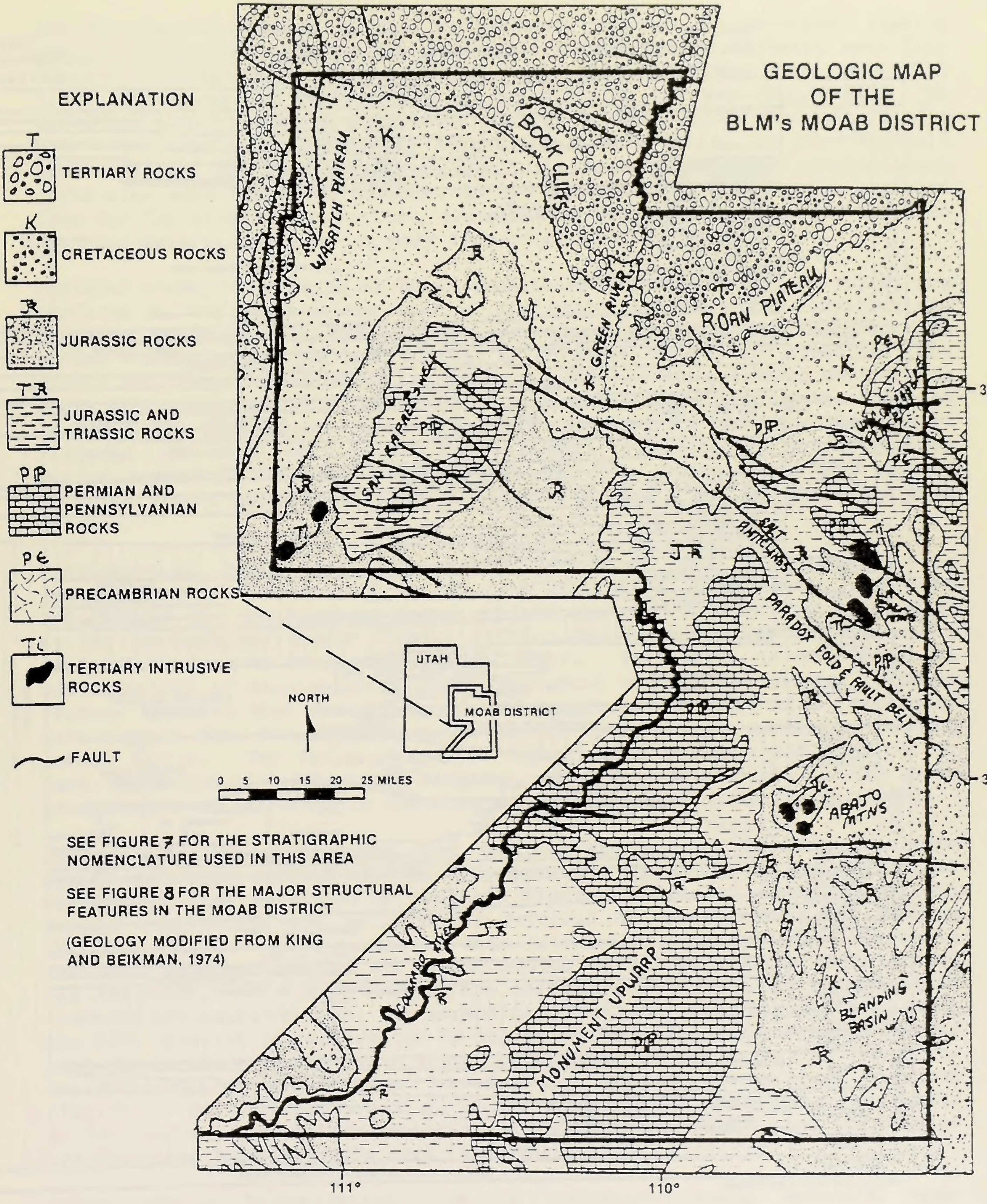


Figure 5. Index map of the Colorado Plateau showing the extent of the Moab district (from Hunt, 1956).



SEE FIGURE 7 FOR THE STRATIGRAPHIC NOMENCLATURE USED IN THIS AREA

SEE FIGURE 8 FOR THE MAJOR STRUCTURAL FEATURES IN THE MOAB DISTRICT

(GEOLOGY MODIFIED FROM KING AND BEIKMAN, 1974)

Figure 6. Geologic map of the Moab district

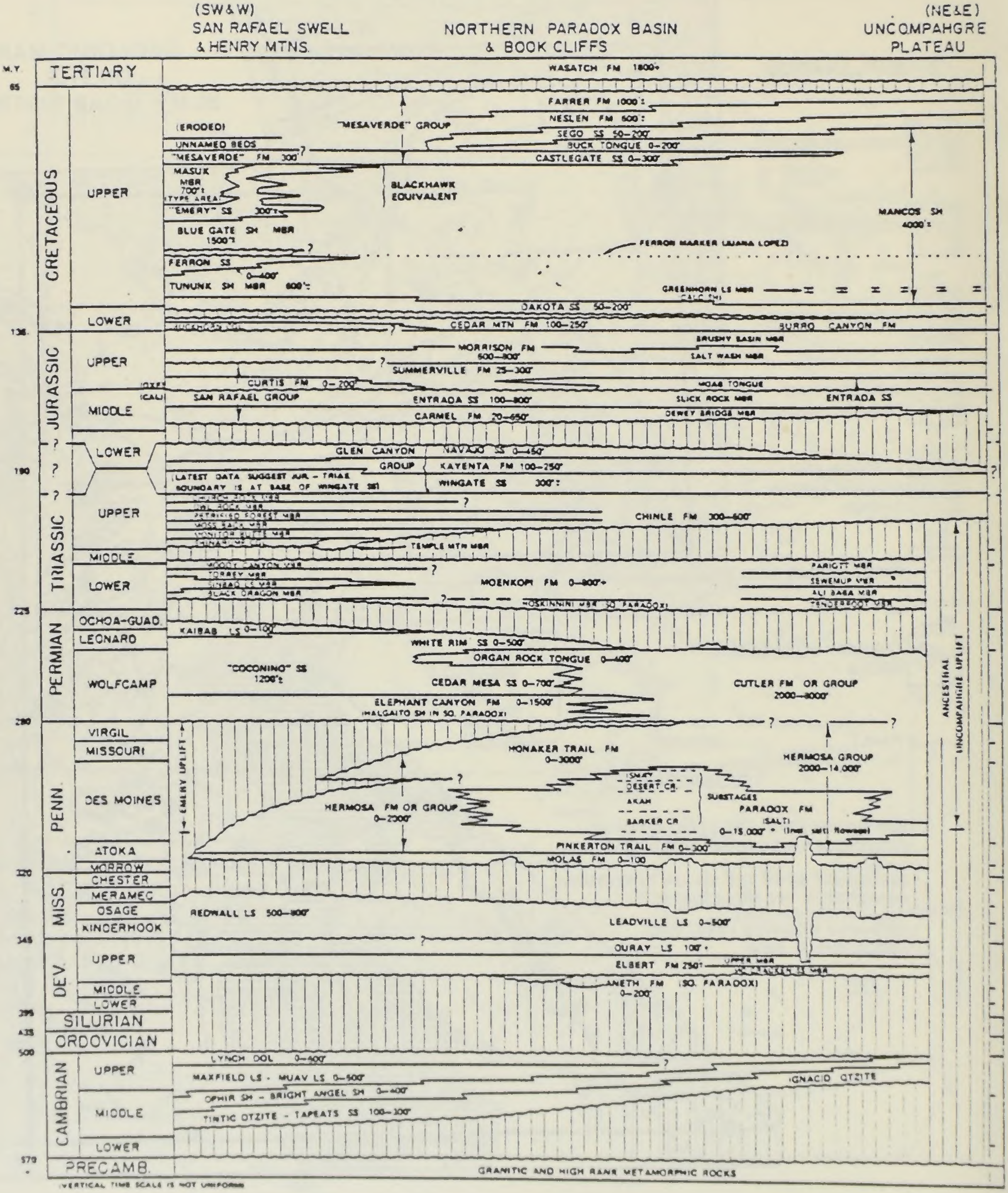


Figure 7. Stratigraphic correlation chart for the Moab district (from Molenaar, 1978)

the Uncompaghre Plateau in the northeastern part of the district; figs. 6 and 7.) Cambrian rocks in the southeastern part of the district near Four Corners are less than 200 feet thick; they thicken gradually to more than 1,500 feet along the western side of the district (Lochman-Balk, 1972). In ascending order, Cambrian formations consist of the Ignacio Quartzite/Tintic Quartzite/Tapeats Sandstone, the Bright Angel/Ophir Shale, the Mauv/Maxfield Limestone, and the Lynch Dolomite (fig. 7). The sediments that compose these formations were deposited adjacent to and within a sea that spread eastward from the Cordilleran Geosyncline, trangressing and regressing across the Moab district several times during many tens-of-millions of years.

Devonian rocks, consisting of basal sandstones a few hundred feet thick, are confined to the southeastern part of the district (the Aneth Formation and McCraken Sandstone; fig. 7). These sandstones are overlain throughout the entire district by a few hundred feet of dolomite, shale, and limestone (the Elbert and Ouray Formations, fig. 7; Baars, 1972). The thickness of Devonian rocks decreases from about 700 feet in the southeastern part of the district to about 200 feet in the northern part of the district near the Uncompaghre Plateau. Devonian rocks in the Moab district originated in broad, shallow marine depressions within a stable craton. In western Utah and Nevada, Devonian strata accumulated along a continental shelf and are therefore much thicker.

Mississippian rocks are represented throughout the district by the Redwall/Leadville Limestone (fig. 7). The unit ranges in thickness from about 200 feet at the southeastern corner of the district to more than 1,000 feet at the northwestern corner (Craig, 1972). The Redwall Limestone represents deposition along a broad continental shelf. Variations in the thickness and lithology of Mississippian rocks throughout much of the central Colorado Plateau indicate that the crust was being deformed at this time; deep well data suggest that the deformation was in the form of major northwest-trending normal faults. The faults disrupted depositional patterns and resulted in local build-ups of sandbars and bioherms, which were prime sites for the later accumulation of petroleum in Devonian and Mississippian rocks (Baars, 1966).

During Pennsylvanian time the Moab district and much of the Rocky Mountain region underwent intense crustal deformation. The mountains and structural depressions that developed in southern Wyoming, Colorado, eastern Utah, and central New Mexico are collectively referred to as the Ancestral Rockies (Mallory, 1972). As a result of this deformation, Pennsylvanian strata in the Rocky Mountain region are characterized by abrupt changes in lithology and thickness, and these changes are particularly evident in Pennsylvanian rocks in southeastern Utah. In ascending order, the Pennsylvanian section in the Moab district is represented by the Molas Formation and the Hermosa Group (fig. 7). Where the Hermosa Group is composed predominately of evaporite deposits, the formation name "Paradox" is applied to the rock sequence (fig. 7). The Paradox Formation is one of the most interesting rock units in the region, from both a geologic and economic standpoint, and its origins are described briefly in the next few paragraphs.

During middle Pennsylvanian time, a northwest-trending mountain range developed in the northern part of the Moab district and in adjacent parts of Colorado. This range, called the Uncompaghre Uplift, reached heights of a few thousand to perhaps 10,000 feet above sea level. It was generally coincident in trend and position with the present-day Uncompaghre Plateau, although the ancient Uncompaghre Uplift was more extensive. Adjacent to the Uncompaghre Uplift on the southwest, a slowly subsiding marine depression developed that is referred to by geologists as the Paradox Basin. The deepest parts of the Paradox Basin lay adjacent and parallel to the Uncompaghre Uplift. The basin gradually became shallower to the south, southwest, and west, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. Streams fed by surrounding lowlands far to the west, north, and south of the district shed large volumes of clastic and organic debris into the developing basin. This debris sustained large algal communities that flourished in the warm, shallow waters along the periphery of the basin. At the same time, hugh volumes of coarse debris--perhaps as much as 20,000 feet thick--poured into the Paradox Basin from rapid erosion of the adjacent Uncompaghre Uplift (Baars and Stevenson, 1981).

The rocks that developed in the Paradox Basin during middle Pennsylvanian time record a remarkable depositional environment. On many occasions, and over long periods of time, the basin's source of fresh marine water was cut off. During these times, water salinity in the basin rose dramatically as dissolved solids in the water became increasingly concentrated because of extreme evaporation. As a result, thick deposits of gypsum, anhydrite, and halite began to accumulate. In the deepest parts of the basin where salinity levels were extreme, thick beds of potash formed. If projected to today's land surface, the maximum extent of the evaporite deposits in the Paradox Basin would encompass most of the Moab district and would extend far into southwestern Colorado. Deep drilling has confirmed, however, that evaporite deposition expanded and contracted many times in response to changing environmental and structural conditions in the area. [Hite (1961) recognized 29 separate depositional cycles in Pennsylvanian rocks of the Paradox Basin.]

During or soon after the deposition of evaporites in the deep parts of the Paradox Basin, the bedded salt deposits began to flow in the subsurface toward the southwest. Salt flowage may have started in response to the ever-increasing weight of sediments being dumped into the basin from erosion of the Uncompaghre Uplift. The salt flowed laterally until it presumably was buttressed against the east-facing, northwest-trending fault blocks that had developed, in part, before salt deposition began (Baars, 1966). As the salt accumulated along these faults blocks, it began to move vertically toward the surface, bowing the overlying strata. Thus began the development of the salt anticlines that are so prevelant today throughout east-central Utah and southwestern Colorado [the Paradox fold of fault belt of Kelley (1955)]. Many of the anticlines contain thousands of feet of salt, and the Paradox Valley anticline contains a salt section about 14,000 feet thick (Baars and Stevenson, 1981). Vertical flow of salt was rapid in late Pennsylvanian and early Permian time, but it slowed in Triassic time and ended in Jurassic time as the bedded salt deposits were depleted.

During the first half of Permian time, the Uncompaghre Uplift continued to supply large amounts of debris to surrounding lowlands. Eventually, much of the Rocky Mountain region was covered with the outwash of the eroding Ancestral Rockies--deposits commonly referred to today as Permian "red beds."

The deposits covered most of the pre-existing uplifts and filled pre-existing depressions in the Moab district. As a result, the thickness of Permian rocks can vary widely over short distances. Permian rocks are about 5,000 feet thick along the base of the Uncompaghre Plateau and are generally between 1,000 and 2,000 feet thick throughout the remainder of the district.

The Permian rocks in the Moab district consist chiefly of sandstone that originated in floodplains and coastal lowlands. Streams heading in the Ancestral Rockies flowed westward across the low-lying area of the present-day Moab district toward a sea that still covered most of the western United States. The sediments deposited by these streams are now represented by the Cutler Formation in the northeastern part of the district and by finer-grained, laterally equivalent rocks to the west (see nomenclature in figure 7). By late Permian time the Uncompaghre Uplift had finally been worn down to near sea level, and the ocean lying to the west had advanced part way into the Moab district. The sediments deposited in this late Permian sea are represented by the Kiabab Formation (fig. 7).

Mesozoic rocks are well represented throughout the Moab district, except along the Monument Upwarp and San Rafael Swell where they have been eroded (fig. 6). Triassic rocks are generally about 2,000 feet thick and consist of a well known sequence of continental red beds and marine deposits. During Triassic time, the Moab district was part of a broad continental shelf that accumulated marine and continental deposits. Source areas for the abundant sands in Triassic rocks were the well-worn Ancestral Rockies in Colorado and New Mexico. In western Utah and Nevada, the Cordilleran Geosyncline still existed and accumulated thick layers of sediment.

Jurassic rocks in the Moab district had many source areas, including the far-western states which at this time were undergoing mountain-building. The rocks consist primarily of varicolored shales, red beds, and marine deposits, and they range in thickness from about 1,000 feet along the east side of the district to more than 2,000 feet along the west side. Formation names are shown in figure 7. In late Jurassic time, the climate in the Moab district was probably arid, and debris-laden streams flowing from western source areas deposited an extensive blanket of sandstone, shale, volcanic debris, and lacustrine limestone throughout the Rocky Mountain west. The formation comprising these sediments is referred to as the Morrison, and some of the largest uranium deposits in the United States occur in this unit.

During Cretaceous time, the Cordilleran Geosyncline, which had existed to the west of the Moab district since late Precambrian time, was in the midst of a succession of major uplifts that began shedding sediment into the Rocky Mountain region. At about the same time, the Rocky Mountain States (and broad areas of the central United States) began subsiding, and seas from the Arctic and the Gulf States encroached across the region. The large basin that developed is referred to by geologists as the Rocky Mountain Geosyncline. Cretaceous rocks in the Moab district that originated in and adjacent to the Rocky Mountain Geosyncline are represented by the Mancos Shale and laterally equivalent beds to the west and by the Mesa Verde Group (fig. 7).

The Cretaceous climate in the western states was warm and humid. Depending on sea-level changes and the rate of tectonism, the north-trending western shoreline of the Rocky Mountain Geosyncline fluctuated from east to west across Utah. Broad areas lying between the mountains in western Utah and this fluctuating shoreline were covered by enormous swamps. The debris that accumulated in these swamps is now represented by coal deposits throughout Utah, including the Sego and other coal fields in the Moab district.

During late Cretaceous and early Tertiary time, while large parts of the crust in the western states were being compressed and intruded by igneous masses, the Colorado Plateau remained a relatively distinct, little-disturbed structural unit. Some of the smaller structures that already existed on the Plateau were enlarged during this mountain-building episode (referred to by geologists as the Laramide orogeny). The high-angle faults that had been periodically active in early and middle Paleozoic time once again became the sites of fault slip. Many of the faults, however, did not extend to the surface, and overlying Mesozoic rocks were apparently only flexed ("draped") across the faults, resulting in the many monoclines that are visible today thoughout the Colorado Plateau.

During early Tertiary time the entire Colorado Plateau was uplifted and tilted to the north. Drainage was chiefly internal, and resulted in the development of large lakes in Utah and Wyoming. In middle Tertiary time the igneous masses comprising the La Sal, Abajo, and Henry Mountains were intruded into the crust, perhaps along intersecting basement fractures (Kelley, 1955). Finally, during late Tertiary time (and presumably still occurring today) the entire Colorado Plateau was once again elevated, and drainage was gradually diverted to the south through a series of stream piracies. Thus, the canyons and mesas that attract so many visitors to southeastern Utah are recent, and surely ephemeral, features.

Oil and Gas

The region encompassing the Moab district is usually referred to in petroleum literature as the "Paradox Basin" (Schneider and others, 1971). The Paradox Basin is not a present-day topographic feature, but refers to a large, northwest-trending marine depression that existed in the Moab region in Pennsylvanian time--about 300 million years ago (fig. 7). Almost 10,000 feet of salt and sediment were deposited in this basin, and most of the oil and gas produced in the Moab district comes from discoveries in rocks of Pennsylvanian age (77 percent of the oil and 63 percent of the gas; Berghorn and Reid, 1981). As of January 1, 1978 the oil and gas fields in southeastern Utah had produced a total of about 369 million barrels of oil and 653 billion cubic feet of gas (Thomaidis, 1978). Most of this production, however, came from only two fields--the Aneth field, discovered in 1956, and the Lisbon field, discovered in 1960. Despite the fact that the first oil discovered in this region was a 70-foot "gusher"(in 1908 at Mexican Hat, Utah), the Aneth and Lisbon fields have been the only major discoveries made to date.

From a national standpoint, the oil and gas potential of southeastern Utah, which includes most of the Moab district, is moderately high. A recent assessment by the U.S. Geological Survey (USGS) places the undiscovered, recoverable oil and gas resources in the Moab district (and surrounding counties in Utah and Colorado) at 0.2 to 3.2 billion barrels of oil and 0.7 to 10.6 trillion cubic feet of gas (Dolton and others, 1981; the range in estimates represents the 95% and 5% probability-of-existence levels--these are not reserves). The mean estimate for undiscovered oil resources in this region is 1.2 billion barrels, which represents 1.5 percent of the Nation's total oil resources of 82.6 billion barrels (Dolton and others, 1981). For gas, the mean estimate for the region is 3.8 trillion cubic feet, which represents 0.6 percent of the Nation's total gas resources of 593.9 trillion cubic feet (Dolton and others, 1981). These USGS estimates are for an area about twice the size of the Moab district, but they nevertheless indicate the magnitude of the district's petroleum potential.

Oil and gas fields occur widely throughout the Moab district, but most are along the east side as illustrated in figure 8 (Brown and Ritzma, 1982). The Greater Aneth field is by far the largest field in the region (fig. 8), having ultimate recoverable reserves exceeding 375 million barrels of oil (Fassett, 1978). Lisbon field, the second largest, contains estimated ultimate recoverable reserves of 45 million barrels of oil (fig. 8; Molenaar, 1972). After these fields were discovered in the 1950s and early 1960s, exploration was brisk, but results were discouraging. Recent discoveries (Bug and other fields in extreme southeastern Utah) have generated a resurgence of leasing and exploratory drilling in the Paradox Basin (Stevenson and Baars, 1981; Krivanek, 1981; McCaslin, 1980), but the fields discovered have been small; less than 10 million barrels of oil or gas equivalent (see appendix). According to Stevenson and Baars (1981), the Bug field contains estimated recoverable oil reserves of 8 to 12 million barrels.

The most important exploration targets in the district are rocks of Mississippian, Pennsylvanian, and Permian age (fig. 7). In the extreme northern part of the district, Paleozoic rocks do not occur along the Uncompaghre Plateau (as explained previously), and small, shallow oil and gas fields have been discovered in Mesozoic and Tertiary rocks. Of the 31 oil and gas fields described by Molenaar (1972, p. 283) in the Paradox Basin, the Greater Aneth field accounted for 81 percent of the oil production and 54 percent of the gas production through 1/1/70. Production from the Lisbon field for this period accounted for 10 percent of the oil and 30 percent of the gas Molenaar, 1972). These two fields, therefore, accounted for at least 91 percent of the oil and about 84 percent of the gas produced from the Moab district through 1/1/70. The paragraphs below describe, from oldest to youngest, the most favorable rocks in the district for oil and gas discoveries.

Devonian: The oldest rocks considered by most investigators to have oil and gas potential are Devonian in age (Schneider and others, 1971). The Devonian section is represented by three formations in the Moab district (fig. 7). Oil production from Devonian rocks has been minor and almost exclusively from the McCraken Sandstone at the structurally-controlled Lisbon field. The source of hydrocarbons in the McCraken Sandstone is still a matter of uncertainty. Some geologists believe the hydrocarbons were derived from younger Pennsylvanian rocks, such as at the Lisbon field where Pennsylvanian rocks are in fault contact with the McCraken Sandstone. Other geologists believe the dark shales at the base of the Devonian section in the southeastern part of the district are the likely source. It seems significant, however, that in the only area of production from Devonian rocls, these rocks are in fault contact with Pennsylvanian rocks, which are commonly considered the most favorable hydrocarbon source rocks in the district. Whatever the hydrocarbon source, the McCraken Sandstone has proven to be a suitable reservoir rock at the Lisbon field. The McCraken is more than 100 feet thick in the southeastern part of the district (Hintze, 1973), but wedges out to the west and northwest.

It seems reasonable to believe that scattered stratigraphic and structural traps containing small amounts of petroleum exist throughout the district within Devonian rocks. The largest of these accumulations will probably be in the thickest parts of the McCraken Sandstone where it is faulted against Pennsylvanian rocks. (This sandstone is well cemented in other parts of the district where it has been tested.) Based on the limited production from Devonian rocks in the district (Gustafson, 1981, table 1) and on the general lack of identifiable source beds for these rocks, the Devonian section would generally be expected to contain pools with recoverable resources of less than 10 million barrels of oil or gas-equivalent (an f2 favorability designation; see appendix). Gustafson (1981) believes that stratigraphic traps involving Devonian rocks throughout the Moab district have a good petroleum potential.

Mississippian: The volume of oil and gas produced from Mississippian rocks in the Moab district is second only to Pennsylvanian rocks. Mississippian rocks are represented by only one formation, referred to as the Redwall Limestone in the western part of the district and the Leadville Limestone in the eastern part (fig. 7). Essentially all production from Mississippian rocks is from structural, rather than stratigraphic, traps, and the Lisbon field (fig. 8) accounts for more than 90 percent of all Mississippian production in the district. According to Gustafson (1981), the Lisbon field is "one-of-a-kind" in size (details below), but other fields in Mississippian rocks in the region are similar both stratigraphically and structurally to Lisbon.

The identification of Mississippian structures in many parts of the district is difficult because (1) overlying Pennsylvanian rocks contain thick layers of salt deposits, and (2) the pre-Pennsylvanian structures do not necessarily coincide with structures now exposed at the surface. Well-log data for Lisbon field and for other parts of the salt basin indicate that faulting and salt flowage occurred widely in late Pennsylvanian and early Permian times. Put simply, this means that the surface geology in the Paradox fold and fault basin is not an accurate reflection of the subsurface geology. For example, Smith and Prather (1981) point out that the fault responsible for trapping oil at the Lisbon field is not the same fault that is mappable at the surface in Lisbon Valley. In general, the oil and gas favorability of Mississippian rocks will be highest where they are in fault contact with rich source rocks of Pennsylvanian age. This structural configuration is most likely to occur in the Paradox fold and fault belt (fig. 8). Based on the moderate amount of drilling that has occurred in this belt (PIC, 1981), it seems unlikely that a field larger than Lisbon exists in Mississippian rocks in the district. According to Clark (1978), ultimate recoverable reserves at the Lisbon field are about 43 million barrels of oil and about 250 billion cubic feet of gas. Thus, the most favorable Mississippian rocks in the district would generally be assigned a rating of f3 (see appendix). [At the time of this writing, Exxon Corporation was drilling a deep prospect (Mississippian?) in the Paradox fold and fault belt north of the La Sal Mountains (Times-Independent newspaper, Moab, Utah, August 19, 1982). The results of this test are not yet known.]

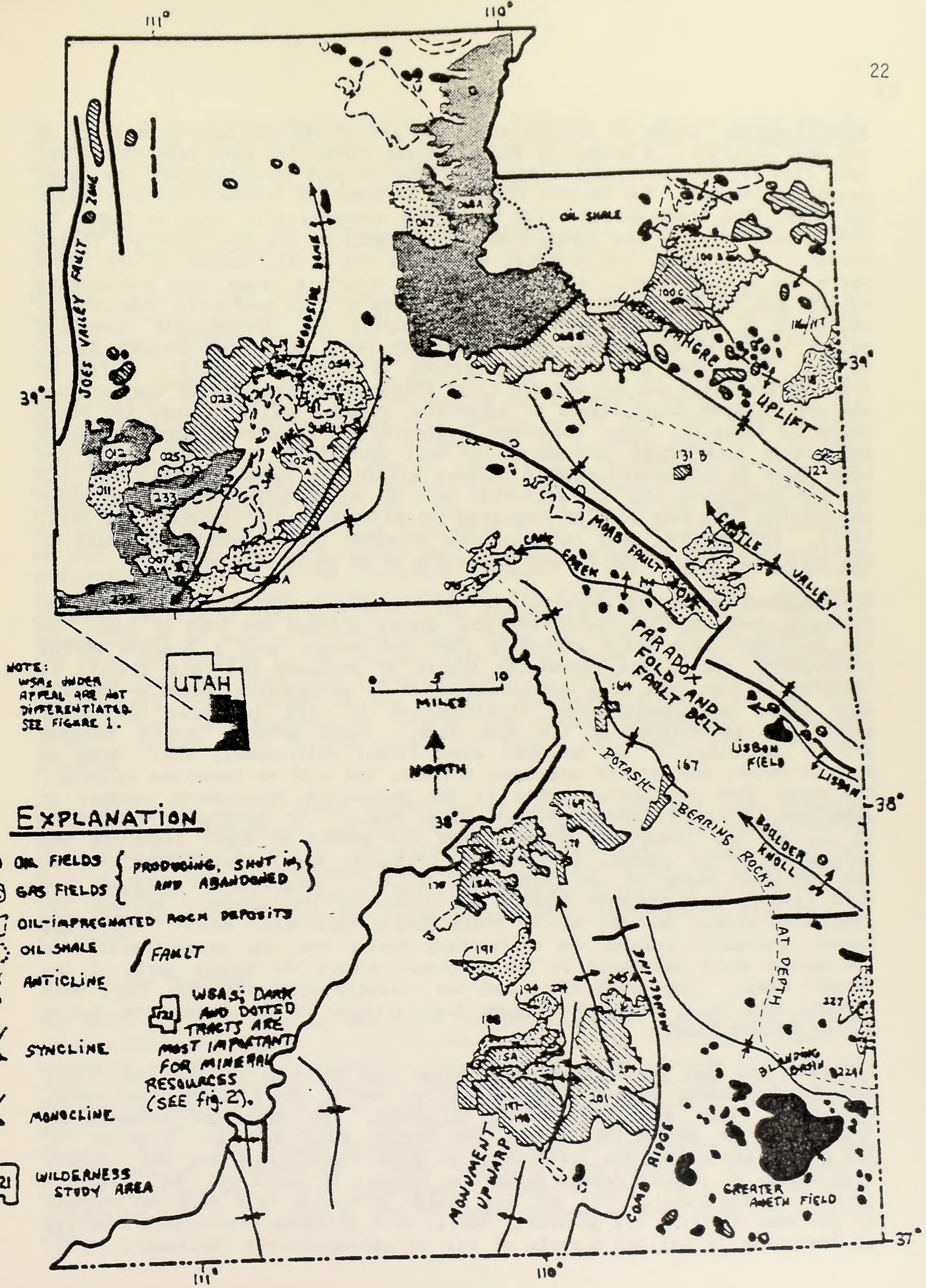


Figure 8. Map showing oil and gas fields, oil-impregnated rocks, and oil shale in the Moab district (from various publication of the Utah Survey).

Pennsylvanian: Rocks of Pennsylvanian age are by far the most productive in the Moab district. A number of Pennsylvanian formations have been identified (see fig. 7), but the various facies of the Paradox Formation are the chief petroleum targets. The Paradox Formation is commonly divided into four major substages (the times during which the strata accumulated), named in figure 7. During each substage the depositional environment in the Moab district varied widely. In general, the district was below sea level, except to the north where the sea bordered a northwest-trending mountain range (the Uncompaghre Uplift; see "Geologic History" at the beginning of this section). Immediately southwest of the Uncompaghre Uplift, a slowly but continuously subsiding marine basin was developing--what geologists refer to as the Paradox Basin. On many occasions, and over long periods of time, the basin's source of fresh marine water was cut off and rapid evaporation concentrated the seawater and precipitated thick layers of anhydrite, gypsum, halite, potash and other evaporite deposits. Also, limestone, dolomite, and widespread layers of black shale were interbedded throughout the salt deposits. The black shales are used today as time-stratigraphic markers within the Paradox Formation. Oil and gas production from the salt-rich part of the Paradox Formation is minor and derived from thin beds of fractured dolomite and shale (Berghorn and Reid, 1981). Furthermore, many investigators consider the petroleum potential of the salt-rich part of the Paradox Formation to be relatively low.

The thickest evaporite deposits in the Paradox Basin accumulated in the northwest-trending deep depression that passed through the town of Moab. To the southwest, the basin gradually rose and merged into a shallow marine environment, called the penesaline facies by Berghorn and Reid (1981). [A "facies" is that part of a continuous layer of sedimentary deposits--usually many miles in diameter--that distinguishes it from laterally equivalent parts that accumulated at the same time. These gradual lateral changes are an indication of the original depositional environment; e.g. deep vs shallow water, the type of organisms present, and arid vs temperate climate.] The rocks that eventually formed in the penesaline environment consist of limestone, dolomite, anhydrite, and black shale. Of particular importance to oil and gas resources, however, are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallower parts of the penesaline facies. According to Berghorn and Reid (1981), the thickest mounds are close to the boundary between the penesaline facies and the marine shelf facies (discussed next). The algal mounds apparently trapped the sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field each produce from algal mound structures that existed in the penesaline facies during Paradox time.

Southwest and west of the penesaline facies (but still in the Moab district), the Paradox Basin merged with a shallow marine shelf where limestones, dolomites, black and red shales, siltsones, and sandsones accumulated. Similar to the penesaline facies, the marine shelf was well situated for the growth and widespread development of algal-limestone mounds and blanket-like masses of organic debris consisting largely of shell and reef fragments (called a biostrome). Oil and gas fields producing from this environment in the Moab district are generally small, with ultimate recoverable reserves of less than 10 million barrels of oil or gas-equivalent (Molenaar, 1978).

In nearby parts of New Mexico and Colorado, however, the marine shelf facies contains a few fields with about 20 million barrels of ultimately recoverable oil or gas-equivalent [the Tocito Dome field in New Mexico (Spencer, 1978) and the Dineh-Bi-Keyah field in Arizona (Molenaar, 1972)].

In summary, rocks of the penesaline and marine shelf facies of the Paradox Formation are favorable oil and gas targets in the Moab district.

Permian: Oil and gas production from Permian rocks in the Moab district is minor. Almost all of the 4 million barrels produced from Permian rocks in the Four Corners area as of 1/1/78 came from the Coconino Sandstone at the Boundary Butte field located about 15 miles southwest of Aneth (figs. 7 and 8; Thomaidis, 1978). Throughout most of the northeastern part of the district, Permian rocks are represented by the Cutler Formation (fig. 7). This formation is composed largely of debris eroded from the then-existing Uncompaghre Uplift. The debris accumulated in a large alluvial fan that spread southwestward from the base of the Uplift. Farther southwest in the district, this fan merged with coastal dunes and marine sandstones that are assigned to a variety of formations (fig. 7). The oil and gas favorability of the Cutler Formation is generally considered to be very low; thus, the Permian section throughout the northeastern part of the district is not a significant exploration target. To the southwest, however, marine and marginal-marine time-equivalents of the Cutler Formation are favorable for oil and gas, although few fields have been discovered (Brown and Ritzma, 1982). The huge accumulations of oil in oil-impregnated rocks in Permian strata exposed at and near the surface in the western part of the Moab district demonstrates the very favorable reservoir characteristics of these rocks (Ritzma, 1979). Nevertheless, large areas in the western and southern parts of the Moab district have been stripped of Permian and younger sedimentary rocks, and in still larger areas, Permian strata lie only a few hundred feet below the surface.

Other Favorable Rocks: Small quantities of oil and gas have been produced from Jurassic, Cretaceous, and Tertiary reservoirs on the Uncompaghre Plateau in the northeastern part of the district (fig. 8). Most of the fields are shallow, and they produce from lenticular sandstone bodies in stratigraphic and structural traps (Molenaar, 1972). It seems reasonable to expect that many additional small petroleum accumulations await discovery in this part of the district.

Uranium and Vanadium

The Moab district lies in the heart of the Colorado Plateau--the leading uranium-producing region in the United States. The Colorado Plateau is estimated to contain 48 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources (DOE, 1980). The uranium-bearing deposits in this region have yielded most of the uranium, almost all of the vanadium, and about half of the radium recovered from domestic ores. The largest deposits are confined to sandstones and mudstones of Triassic and Jurassic age. These "sandstone-type deposits" occur chiefly in the Morrison and Chinle Formations. Deposits range in size from those containing only a few tons of ore to those containing more than one million tons.

The Morrison Formation of Jurassic age is the host unit in two of the largest uranium trends in the United States--the Grants mineral belt in New Mexico and the Uravan mineral belt in west-central Colorado. The Morrison Formation (in just the San Juan Basin of New Mexico) is estimated to contain nearly 80 percent of the probable and possible uranium resources estimated by DOE (1980) for the entire Colorado Plateau. In Utah, however, the Chinle Formation of Triassic age has accounted for about 80 percent of the State's uranium production--chiefly from the Moab district--whereas the Morrison Formation has accounted for only about 15 percent (Hilpert and Dasch, 1964). The remaining 5 percent of Utah's uranium production is attributed to the Dakota Sandstone of Cretaceous age, the Moenkopi Formation of Triassic age, and the Cutler Formation of Permian age (Hilpert and Dasch, 1964).

Sandstone-type uranium deposits result from a succession of geologic events. First, a source of uranium must exist. Second, sufficient water, permeable rocks, and an oxidizing environment must be present to dissolve and transport the uranium. Third, host rocks containing reducing agents are required for the precipitation of the uranium. The absence of any one of these conditions precludes the acculumation of this type of uranium deposit.

Parts of the Morrison and Chinle Formations in the Moab district contain favorable characteristics for the accumulation of uranium deposits. Both formations were deposited in fluvial-lacustrine environments and they contain lenticular, cross-bedded sandstone and interbedded lenses of claystone and mudstone. The sandstone beds are confined largely to paleo stream-channels ranging in width from tens-of-feet to many miles. Parts of the channel sandstones are very permeable, and the organic-rich mudstones and claystones along the periphery of the channels provided favorable reducing environments. The source of the uranium on the Colorado Plateau has always been a subject of debate among geologists, but the tuffaceous and volcanic interbeds within the Morrison and Chinle Formations are the most likely sources. In some areas, however, weathering of nearby granitic terranes may also liberate large amounts of uranium. The time of ore emplacement is still uncertain, although geologic evidence suggests emplacement prior to late Cretaceous time (Fischer, 1968). Available isotopic age dates for uranium ore on the Colorado Plateau vary widely and are thus unreliable.

The Chinle Formation is exposed at the surface in many places throughout the Moab district, most notably along the prominent monoclines and escarpments that flank the San Rafael Swell and the Monument Upwarp (fig. 6). In the subsurface, the Chinle Formation underlies most of the Moab district, except where it has been removed across major uplifts by erosion. Throughout most of the district, the Chinle Formation is subdivided into six members. From oldest to youngest, these members are referred to as the Shinarump, Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock (Campbell and others, 1980a,b,c; Lupe and others, 1980; Peterson and others, 1980). With few exceptions, uranium deposits in the Chinle Formation are confined to the three lower members. Lisbon Valley in east-central Utah accounts for most of the uranium produced from the Chinle Formation on the Colorado Plateau (Wood, 1968).

The Morrison Formation is also exposed widely in the Moab district, especially in the southeast and along a belt that partly surrounds the San Rafael Swell and the northern part of the Paradox fold and fault belt (fig. 6). The Morrison Formation is subdivided into two or three members, depending on location--the Tidwell Member at the base, overlain by the Salt Wash Member and the Brushy Basin Member (Campbell and others, 1980a,b,c; Lupe and others, 1980; Peterson and other, 1980). The most important uranium deposits occur in the Salt Wash Member. About two-thirds of the uranium produced from the Colorado Plateau has come from the Morrison Formation in the Grants mineral belt in New Mexico and from the Uravan mineral belt in Colorado (Kelley and others, 1968; Motica, 1968). Most of the vanadium produced from the Colorado Plateau has come from the Morrison Formation in the Uravan area (Motica, 1968; Fischer, 1968).

The Moab district contains four important uranium-producing areas: Lisbon Valley, White Canyon, Monument Valley, and the San Rafael Swell (see fig. 9). At Lisbon Valley, uranium deposits occur at the base of the Chinle Formation and along the contact between the Chinle and the underlying Cutler Formation. The mineralized area is an arcuate belt, about 15 miles long by a half-mile wide, lying along the southwest flank of the Lisbon Valley anticline. Mineralized beds have an average thickness of 6 feet, but in some areas mineralization is as much as 30 feet thick. The host rock is predominantly a fluviatile, calcareous, fine-grained to conglomeratic sandstone (Wood, 1968). By mid-1965, more than 24,000 tons of uranium oxide had been produced from the Lisbon Valley area (Wood, 1968).

Uranium deposits in the White Canyon and Monument Valley areas are also contained the Chinle Formation. At Monument Valley, however, the uranium deposits are associated with vanadium, whereas the uranium in the White Canyon area is associated with small red-bed copper deposits. Most deposits lie in an arcuate about 3 to 13 miles wide and convex to the west (Malan, 1968). The belt extends for nearly 130 miles from Monument Valley at the south end to White Canyon at the north end. By mid-1965, about 8,600 tons of uranium oxide had been produced from 174 properties. Two of mines--Monument No. 2 and Happy Jack--account for about half of this total production (Malan, 1968). Many of the uranium deposits in the Monument Valley/White Canyon area contain less than 1,000 tons of ore.

The San Rafael Swell is a broad, 100-mile-long, egg-shaped anticline in the northwestern part of the Moab district (fig. 6). The Chinle and Morrison Formations crop out in an almost-continuous belt around the structure. Uranium deposits occur in the Temple Mountain, Monitor Butte, and Moss Back Members of the Chinle Formation. According to Mickle and others (1977), the Temple Mountain district and the Delta mine, both along the southeast side of the Swell, have produced a combined total of about 1,000 tons of uranium oxide. In the Tidwell area on the east flank of the San Rafael Swell, uranium deposits occur the Salt Wash Member of the Morrison Formation. Total production from the Tidwell area exceeds 1,550 tons of uranium oxide and 2,700 tons of vanadium oxide (Trimble and Doelling, 1978).

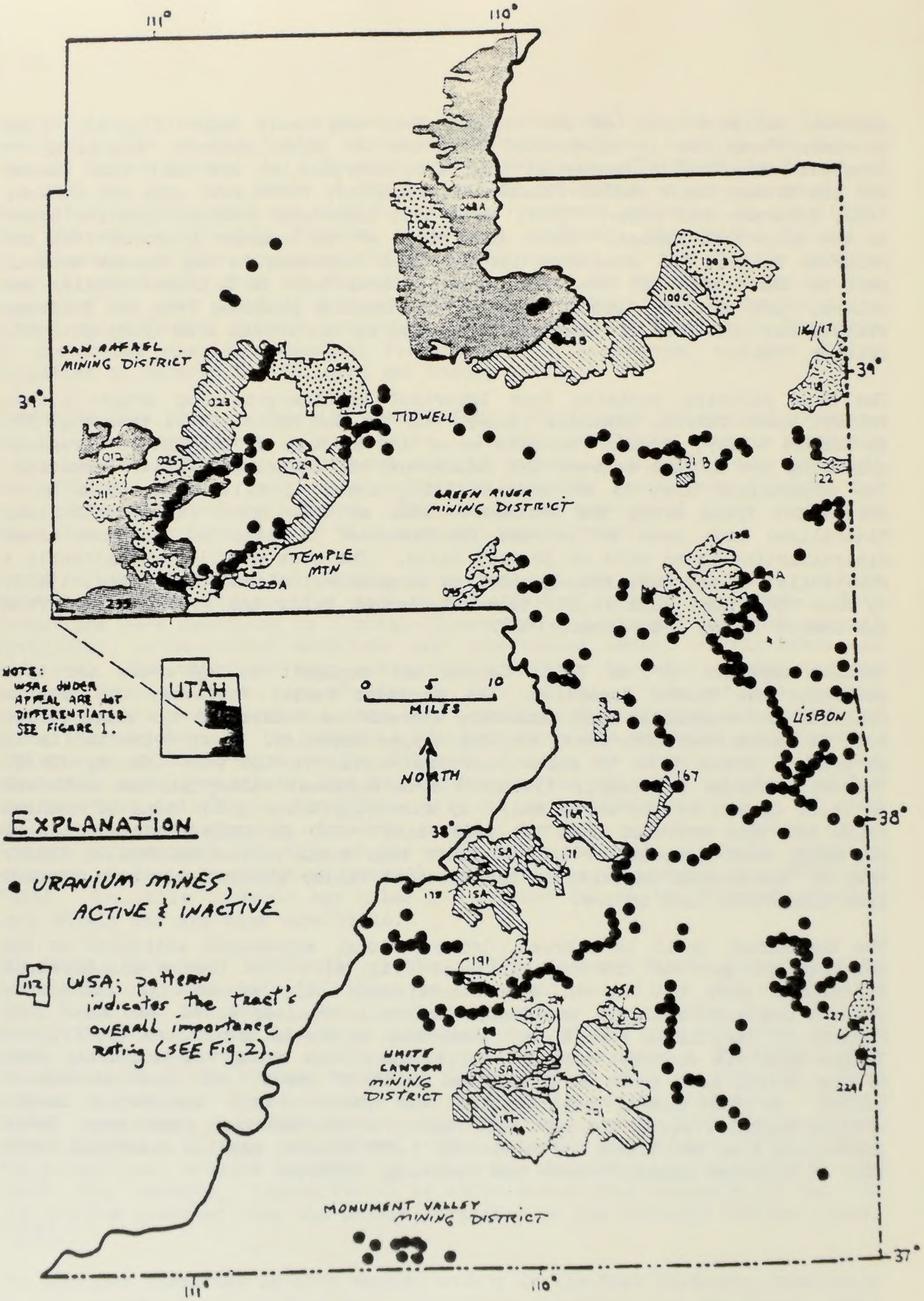


Figure 9. Map showing active and inactive uranium mines in the Moab district (from Utah Geological and Mineral Survey, 1977).

Coal

Utah contains an estimated 6.5 billion tons of coal, which is equivalent to 1 percent of the Nation's total demonstrated coal reserve base of 475 billion tons (EIA, 1981; reserve estimates based on 1979 data). Most of the coal in Utah is Cretaceous in age, subbituminous in rank, and extractable chiefly by underground methods (EIA, 1981; Averitt, 1964). A large part of Utah's demonstrated coal reserve is contained within the Moab district.

Coal-bearing Cretaceous rocks crop out in a continuous belt across the northern part of the Moab district (fig. 10). Along the eastern and southeastern sides of the district, coal-bearing rocks also occur in the La Sal and San Juan fields, but the combined resources in these fields are minor and they are omitted from further discussion in this overview [see Doelling and Graham (1972) for a discussion of the La Sal and San Juan fields].

Coal fields in the northern part of the Moab district include, from west to east, the Emery field, the Wasatch Plateau field, the Book Cliffs field, and the Sego field. Each field is described briefly in the paragraphs below from information contained in Doelling (1972) and Doelling and Graham (1972).

The Emery field, part of which extends into the adjacent Richfield district, contains an estimated 758 million tons of demonstrated coal. Coal production from the Emery field began in earnest in 1930, and about 1.6 million tons had been extracted through 1970. The most important coal beds average 4-feet thick and occur in the Mancos Shale of Cretaceous age (the Ferron Sandstone Member). The Emery field is the fifth largest coal producer in Utah and accounted for about 1 percent of the State's coal output through 1970.

The Wasatch Plateau field, like the Emery field, also extends into the Richfield district. Reserves are estimated at 6.2 billion tons, but this figure includes inferred reserves, which are not a part of the demonstrated coal-reserve base (Doelling, 1972). All the coal in the Wasatch Plateau field occurs in the Blackhawk Formation of late Cretaceous age. About 22 beds are known to contain coal in excess of 4-feet thick. Through 1970, the Wasatch Plateau field was the second largest coal producer in Utah, accounting for 31 percent of the State's total output.

The Book Cliffs field is the largest producer in the State, accounting for 65 percent of the State's total output through 1970. Coal occurs in the Blackhawk Formation of Cretaceous age. Although the field is 70 miles long, mining has been concentrated in the Sunnyside and Castlegate areas. Doelling (1972) estimates that about one billion tons of coal are recoverable from the Book Cliffs field.

The Sego field, in the northeastern part of the Moab district, has produced only about 2.6 million tons of coal, or about 0.8 percent of the State's total output through 1970. The most important coal beds are contained in the Price River Formation of Cretaceous age, and are confined to a relatively small area in the central part of the field. Coal beds in the eastern and western parts of the field are generally thin and are reportedly impure.

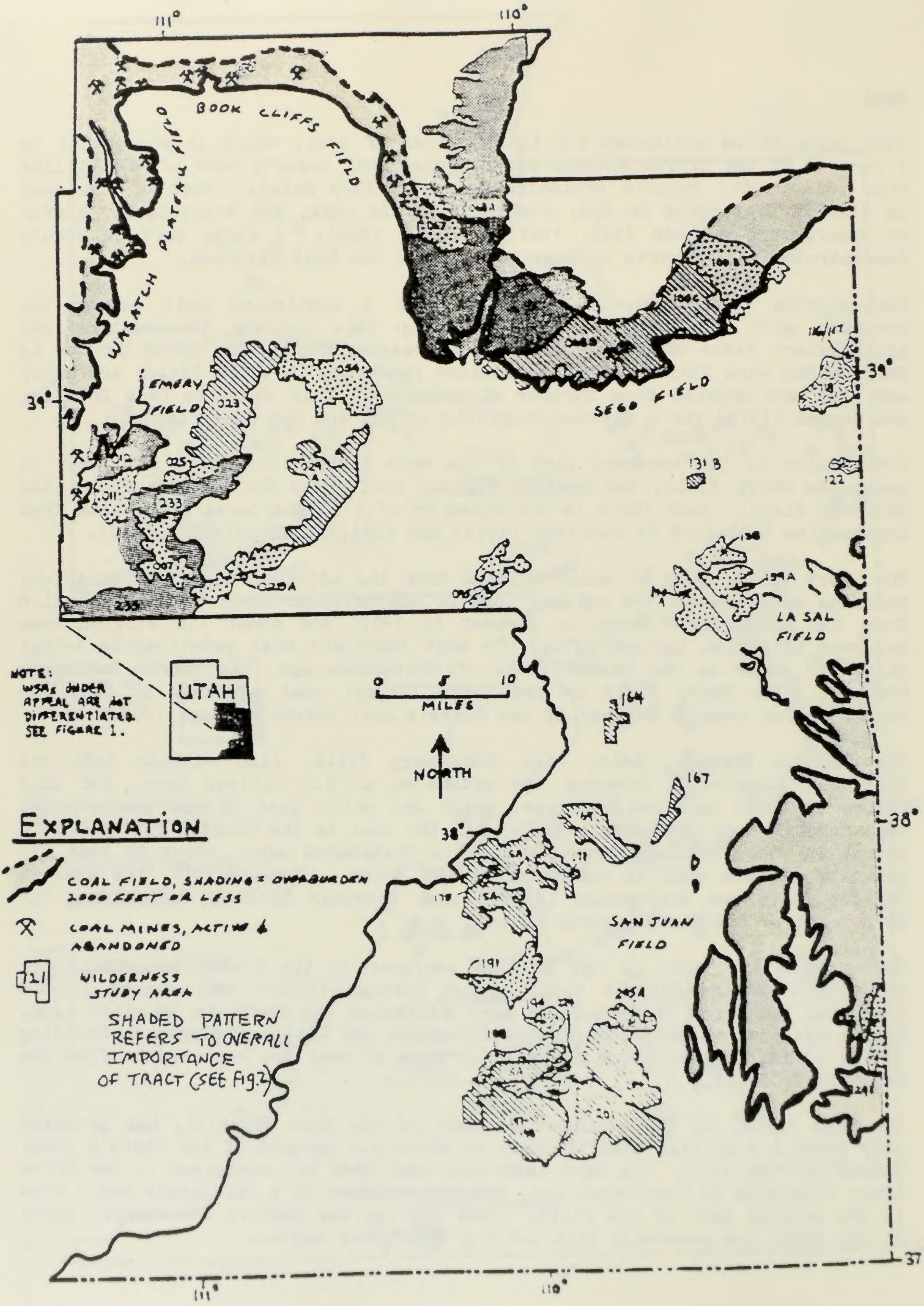


Figure 10. Coal-Bearing Rocks in the Moab District

Geothermal

A geothermal resource is loosely defined as an amount of thermal energy that can be extracted from the earth and used economically now or in the near future. If the energy is in the form of hot water, it can be used directly for space-heating. If the geothermal system is hot enough, the thermal energy may be convertible to electrical energy.

Although various types of geothermal systems occur in nature, the hydrothermal or "hot water" systems have the greatest potential for future development. Hydrothermal systems are generally divided into three temperature categories. High-temperature systems exceed 150°C, moderate-temperature systems are between 150°C and 90°C, and low-temperature systems are between 20°C and 90°C (Muffler and others, 1978). The present state of geothermal technology is such that only some of the high-temperature hydrothermal systems may be developed for electrical generation during the next 25 years.

Hydrothermal systems are most abundant and closest to the surface in areas that are characterized by crustal instability, igneous rocks generally younger than one million years old, high heat-flow, and a steep geothermal gradient. Compared with other structural provinces in the west, the Colorado Plateau is unique because these favorable geothermal characteristics are essentially absent. In fact, only one thermal spring (near Lake Powell) and two thermal wells are known from the entire Moab district, and they range in temperature from only 20°C to 28°C (NOAA, 1980).

The U.S. Geological Survey estimates that the entire Colorado Plateau contains about 0.0003 percent of the total identified, recoverable geothermal resources of the western United States (Muffler and others, 1978). Although low-temperature resources probably exist at great depth throughout the district (as they probably do throughout most of the country), the overall geothermal potential of the Moab district is very low.

Hydropower

The total installed hydroelectric capacity of Utah is 190 megawatts from 40 existing facilities (U.S. Army Corps of Engineers, 1979). Almost 75 percent of the State's output, however, is attributed to Flaming Gorge on the Green River and to one facility operated by Utah Power and Light along the Bear River (U.S. Army Corps of Engineers, 1979). Utah is ranked 32nd among the states in installed hydroelectric capacity, contributing far less than 1 percent to the Nation's total installed hydroelectric capacity of 63,702 megawatts (U.S. Army Corps of Engineers, 1979).

The hydroelectric potential of Utah at 48 undeveloped sites identified by the U.S. Corps of Engineers (1979) is 9,259 megawatts. About one-third of this potential is attributed to 13 sites within the Moab district, distributed as follows: 4 sites along the Green River totalling 337 megawatts, 3 sites along the Colorado River totalling 1,148 megawatts, 2 sites along the San Juan River totalling 403 megawatts, and 4 sites along Cottonwood, Willow, and Mill Creeks totalling 12 megawatts (U.S. Army Corps of Engineers, 1979). Because of the arid climate, most other stream beds in the Moab district are dry. Therefore, aside from the large hydropower potential that exists along major rivers, most lands in the Moab district have little or no hydropower potential.

Copper

Almost all copper production in Utah has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964).

Copper is transported to the earth's crust by igneous intrusions and mineralized solutions. Ore accumulations resulting directly from these processes include porphyry and vein-type deposits. Copper can also be remobilized by chemical and mechanical weathering and reconcentrated as strata-bound accumulations in favorable sedimentary rocks. According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

On the Colorado Plateau in eastern Utah, small amounts of copper have been produced as a by-product of uranium and vanadium mining. Copper production from the Moab district has come largely from four areas (see fig. 9): (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons. According to Tooker (1980), the part of the Colorado Plateau coinciding with the Moab district has only a low potential for copper resources.

Manganese

The Colorado Plateau is not known for its resources of manganese, but the Moab district has a relatively long history of manganese production. Despite widespread occurrences of manganese, the Moab district is estimated to contain only minor amounts of recoverable manganese (Baker and others, 1952; Pardee, 1921), and the resource potential of the district is considered to be low (Tooker and Cannon, 1980).

Most of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein fillings and as impregnations of the country rock along faults and joints. Detrital deposits, those deposits eroded chiefly from the blanket-type deposits that litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district (near Green River, Utah) in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Intermittent manganese mining in the Moab district during the first half of this century produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952). Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. When World War I began and the prices for most raw materials increased, manganese mining in the Little Grand district was resumed, but soon after the war the district once again became idle. With the outbreak of World War II and the increasing need for manganese, small-scale development work was conducted on many of the deposits in the BLM's Moab district, but largely to determine the quality and quantity of manganese available. In their evaluation of the manganese deposits in this part of Utah, Baker and others (1952) concluded that "...the richer parts of the known ore bodies have been removed [by previous mining]..." and that only "...as much as 15,000 tons of ore containing more than 30 percent manganese could be obtained by hand sorting of material from open-cut workings along the outcrops of widely scattered small deposits. The reserves of lower-grade oxide ore in scattered deposits of various types are estimated to aggregate nearly 500,000 tons, of which about 350,000 tons contains less than 10 percent manganese." Thus, the Moab district is not considered a future potential source of large tonnages of manganese ore.

Potash

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (see fig. 8; Hite, 1961). If projected to the surface in Utah only, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The potash deposits occur in the Paradox Formation of Pennsylvanian age (fig. 7), at depths ranging from 1,700 to 14,000 feet below the surface (Hite, 1961). The Paradox Formation originated in a slowly-subsiding, northwest-trending marine basin that existed in the Moab region about 300 million years ago. On occasions, the basin was cut off from a fresh source of sea water. As salinity levels in the basin rose because of extreme evaporation, deposits of anhydrite and halite began to accumulate. In the deepest parts of the basin where salinity levels were very high, potash deposits began to accumulate. The cumulative thickness of the evaporitic rocks may have been about 7,000 feet, but lateral and vertical flowage of the salt after it was deposited has resulted in thicknesses as much as 14,000 feet in some of the so-called "salt anticlines" in the region (Hite, 1961).

According to Hite (1961; 1964), 29 cycles of deposition are recognized in the Paradox Formation on the basis of well data from petroleum exploration. Each complete cycle of deposition contains black, organic-rich shale, limestone, dolomite, anhydrite, halite, and potash. Because of changing geochemical and structural conditions, however, not each cycle went to completion. Of the 29 cycles, 18 are known to contain potash in the Moab district and 11 are potentially exploitable (Hite, 1964).

Only two potash minerals are abundant in the Paradox Formation--sylvite (KCl) and carnallite ($KCl:MgCl_2:6H_2O$). Although the potash content of carnallite in the Paradox Formation is low (generally <17 percent), some deposits can be traced continuously through a subsurface area of about 3,000 square miles, and locally may reach a thickness of more than 400 feet (for example, salt bed #19; Hite, 1964). Nevertheless, sylvite is the only potash-bearing mineral with current economic importance in the Moab district.

The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone about 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite, 1964; Hite and Cater, 1972]. As stated above, the minimum depth to the potash deposits in the Moab district is about 1,700 below the surface; the minimum depth to potentially economic potash deposits is about 1,800 feet (Hite, 1961). Because potash minerals are more susceptible to flowage under stress than are other rocks, it is not uncommon for the potash to be thicker and of higher grade in the apex of large anticlines.

At Cane Creek near the town of Moab, Texasgulf, Inc. , opened a conventional underground potash mine in 1954. Because of the structural complexity of the potash deposits in this area, Texasgulf flooded the mine in 1970, and it now operates as a solution mine (Searls, 1980)

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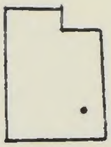
PART 3

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 164 **TRACT NAME:** Lockhart Basin **STATE/COUNTY:** UT/San Juan

BLM DISTRICT: Moab **WSA ACREAGE:** 7,300 **UNIT ACREAGE:** 7,300

DATE PREPARED: April 1982 **UPDATE:** August 1982



LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 164 lies along the north-plunging nose of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Rocks exposed in the tract include flat-lying beds of the Cutler Formation of Permian age (Williams, 1964; the arkosic, coarse-grained facies of the Cutler Formation interfingers with the fine-grained Cedar Mesa Sandstone Member of the Cutler Formation in this area). The underlying Rico Formation of Pennsylvanian age is exposed along Indian Creek which flows across the tract and into the Colorado River about 1-mile to the northwest. Structural features in the area include Gibson Dome to the southeast, Rustler dome to the north, and Meander anticline to the west. The Needles fault zone, a complex of horsts and grabens, lies about 4-miles to the southwest.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (<25% __, 25-50% __, 50-75% __, 75-100% ✓).

RATING SUMMARY: (See last page for brief explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f3/c2	**COPPER:**	f2/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f3/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 164 lies within the "Paradox Basin." As used by most authors, the Paradox Basin refers to a large structural depression that existed in this region about 300 million years ago during late Paleozoic time. The Paradox Basin encompassed much of the surface area of the present-day Moab district southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the Four Corners region (includes the Moab district) has come from rocks of Pennsylvanian age that originated in the Paradox Basin (defined below). If production from older rocks that are associated with development of the Paradox Basin are included (such as production from Mississippian rocks at Lisbon field, for which the oil source is believed to be Pennsylvanian rocks), the Paradox Basin has probably accounted for about 90 percent of the oil and 85 percent of the gas produced in the vicinity of the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway--referred to by geologists as the Paradox Basin. The axis of the basin (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending plateau (the Uncompaghre Uplift) stood several thousand feet above sea level. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, surrounding highlands to the west, north, and south shed large volumes of debris into the Paradox Basin.

The stratigraphy and structural setting of the Paradox Basin in the vicinity of Tract 164 are very different compared with the edge of the basin to the south and west, and different also from the very deep, hypersaline environment that existed in the central part of the basin to the east of Tract 164. On the one hand, the algal mounds that grew in the shallow warm waters along the basin's periphery--that are now sites of large oil accumulations in extreme southeastern Utah--did not exist in the relatively deep-water environment in and near Tract 164. On the other hand, structural adjustments before and during salt deposition in the form of normal, northwest-trending faults--along which large quantities of oil and gas are produced at Lisbon field--apparently affected the deeper parts of the Paradox Basin more than the shallower parts in the vicinity of Tract 164. [The deepest parts of the Paradox Basin accumulated the greatest thickness of evaporite deposits. These deposits then began to flow southwestward, presumably in response to the weight of overlying sediments being shed into the Paradox Basin from the Uncompahgre Uplift. The salt was presumably diverted upward at the fault buttresses of Mississippian rock (Cater, 1972). These fault buttresses will be described in more detail below as they relate to Tract 164.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline (very saline), penesaline (less saline), and marine-shelf (normal salinity) environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), Tract 164 was within the hypersaline environment during all substages of the Paradox Formation, except the Ismay, at which time the hypersaline environment retreated to the north and deposition continued in the penesaline environment.

Oil and gas production from the hypersaline facies of the Pennsylvanian Paradox Formation has come from Long Canyon, Shafer Canyon, Cane Creek, and Bartlett Flat (all about 12 to 20 miles east of Tract 164), and from Wilson Canyon (about 20 miles southeast of Tract 164). Production is derived from fractured beds of limestone, shale, and shaly dolomite that are interbedded with the salt [the Cane Creek zone; Smith (1978a, 1978b); Mickel (1978); Brown and Ritzma (1982)]. Many of the fields are shut-in, abandoned, or produce only small amounts of petroleum [for example, 6 barrels of oil per day at Wilson Canyon field; Mickel (1978)]. The favorability of the hypersaline environment of the Paradox Formation in the vicinity of Tract 164 is considered to be relatively low by many investigators (a low f2 in our classification) because the reservoir rocks are very thin (the clastic interbeds), lack continuity, and generally have low permeabilities. The strata that accumulated in the penesaline environment in the vicinity f Tract 164, however, are favorable for petroleum as described below.

A broad penesaline environment existed in southwestern during Ismay time (Berghorn and Reid, 1981). Of particular importance to oil and gas resources in the vicinity of Tract 164 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that may have accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environment of part of the Paradox Formation in Tract 164 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 164, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 164 the Paradox Formation is probably less a few 100 feet below the surface and it is exposed along the Colorado River a mile west of the tract (Williams, 1964). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and certainly Permian rocks in and near Tract 164 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the Colorado River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 164 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 164 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 164, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 164 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississppian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults similar to Lisbon exist in this part of the Monument Upwarp.

Tract 164 lies outside the Paradox fold and fault belt defined by Kelley (1955), but salt flowage has nevertheless occurred in nearby areas such as Gibson dome, and more recently at the Neddles fault zone (and probably Upheaval dome to the northwest). Vertical salt flowage in all these areas (except the Needles fault zone) may have been induced by the buttressing affect of pre-salt fault structures in the area. On this basis, Mississippian rocks in Tract 164 are considered favorable for oil and gas.

Many wells have been drilled along the dominant structures in this area (Gibson dome, Rustler dome, etc.) and some oil and gas shows have been reported (PIC, 1980; Heylmun and others, 1965). Most of the wells penetrated Mississippian and/or Devonian rocks, but the section is certainly not thoroughly tested as very few wells have been drilled west of the tract (PIC, 1980).

The most favorable oil and gas prospect in the vicinity of Tract 164 is a structural trap affecting Mississippian rocks, as well as the possibility for small accumulations in Pennsylvanian stratigraphic traps. Although the results of nearby drilling have been discouraging, we have nevertheless assigned the tract an oil and gas favorability rating of f2, and a certainty of resource occurrence of c2 (on the basis of oil and gas shows in nearby wells).

URANIUM/VANADIUM f3/c2

The Colorado Plateau contains some of the largest and most important uranium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of

Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from depsoits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation [vanadiferous phosphate and shale deposits are not known to occur in southeastern Utah and they are not discussed further (see Fischer and Vine, 1964)].

Scattered uranium occurrences are reported from the Cutler and Rico Formations in and near the northeastern corner of Tract 164 (Williams, 1964; Campbell and others, 1980). The closest area with significant production is the Inter River mining area within the greater Green River mining district (Utah Geological and Mineral Survey, 1977). Some uranium deposits in the Inter River area are moderately large (between 100 and 1,000 tons of uranium oxide), and all occur in the Moss Back Member of the Chinle Formation (Johnson, 1959).

The Morrison and Chinle Formations have been removed by erosion from Tract 164. The Cutler Formation, which has produced about 1,200 tons of uranium oxide at Lisbon Valley, and the Rico Formation, comprise all surface rocks in the tract. The depositional environment of the Cutler and Rico Formations in this area consisted of fluvial arkosic sandstones and shales that interfinger to the west and southwest with massive sandstones, shales, limestones, and eolian sandstones. The most favorable areas for uranium in these formations are apparently where the fluvial-distributary facies interfinger with the marine facies. According to Williams (1964) and Campbell and others (1980), Tract 164 lies in a zone where the arkosic beds of the Cutler Formation interfinger with the marine/eolian Cedar Mesa Sandstone Member of the Cutler Formation. Campbell and others (1980) illustrate this area as lying at the extreme southwestern end of favorable ground for Cutler rocks.

On the basis of the discussion above, we have assigned Tract 164 a uranium favorability of f3. The certainty that uranium resources occur in this area is relatively low and has been assigned a value of c2.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery County to the west of the San Rafael Swell and from Carbon County (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor coal deposits in rocks of early Tertiary age.

Bedrock at the surface of Tract 164 consists of sedimentary rocks chiefly of Permian age underlain by a thick section of older Paleozoic rocks (Williams, 1964). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 164 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal does not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are abundant in Utah--such as hot springs, young igneous rocks (less than one million years old), high heat-flow, seismic activity, and crustal instability--but these features exist mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineral Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). Therefore, the overall geothermal potential of the Colorado Plateau, including all of the Moab district, is considered to be low.

The only geothermal potential associated with Tract 164 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. On the basis of the geologic characteristics of this part of the Colorado Plateau, we have therfore assigned Tract 164 a geothermal favorabilty rating of f1 and a certainty of c3 that the resource does not exist in this area.

HYDROELECTRIC f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah and in 1979 it accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 164. On the basis of this information we have assigned Tract 164 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern

Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau (and in the vicinity of Tract 164) are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Nevertheless, copper occurs widely throughout the Plateau and is clearly associated with uranium deposits which do occur in this area. We have therefore assigned Tract 164 a copper favorability of f2 and a certainty of resource occurrence of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. With the advent of World War I and increasing prices for most raw materials, mining of manganese in the Little Grand district was resumed. Shortly after the war, however, the district once again became idle. With the outbreak of World War II, and the increasing need for manganese, small-scale development work was conducted on many of the deposits in southeastern Utah, but largely to determine the quality and quantity of the manganese available (Baker and others, 1952). Intermittent mining throughout the first half of this century, largely during the periods 1901 to 1906 and 1915 to 1918, produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952).

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Baker and others (1952) estimate that about 15,000 tons of 30 percent manganese ore could be obtained by hand sorting of widely scattered small deposits in the Summerville Formation. Reserves of lower-grade oxide ore, between 10 and 30 percent manganese, are estimated to aggregate about 150,000 tons, whereas ores containing 10 percent or less manganese total about 350,000 tons in southeastern Utah (Baker and others, 1952). With the information available, Baker and others (1952) concluded that southeastern Utah (which includes all of the Moab district) could not be considered as a source area for large tonnages of manganese ore.

Tract 164 lies south of the Little Grand manganese district, and southwest of the widely scattered deposits that occur throughout this part of east-central Utah (Baker and others, 1952; USGS, 1982; Tooker and Cannon, 1980). The chief host rocks for manganese in this region--the Chinle, Morrison, and Summerville Formations--have all been eroded from the tract. On this basis we have assigned Tract 164 a manganese favorability of f1, but with a certainty of only "c1" that manganese resources do "not" occur in the tract.

POTASH <u>f3/c3</u>

Potassium is an essential plant nutrient and the fertilizer is commonly referred to as the oxide "potash," or K_2O. The chief source of potash is from bedded deposits of marine origin, commomly within the minerals sylvite, carnallite, and other related potassium minerals. Less important, though still commercial, sources include concentrated brines from wells, relict Pleistocene lakes, and lacustrine sediments in arid regions.

Bedded potash deposits exist in the subsurface over a broad area of east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago. The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 164 lies a few miles southwest of the thickest potash-bearing zones in the Paradox Formation, although the tract does lie within the potash-bearing facies as illustrted by Hite and Cater (1972).

On the basis of the discussion above, we have assigned Tract 164 a potash favorability of f3, and a relatively high certainty (c3) that potash resources exist in this area.

OVERALL-IMPORTANCE RATING 2

Tract 164 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Of all the resources evaluated, the tract is most favorable for uranium (f3). Potash was also assigned a favorability of f3, but the likelihood that this area would ever become a target for exploration and possible development is very remote considering that thicker, richer, and shallower potash deposits occur elsewhere in the Moab district. All other resource evaluated for Tract 164 were assigned favorabilities not exceeding f2.

We assigned Tract 164 and OIR to 2, rather than 3, because the tract is relatively small, and because it is contiguous with Canyonlands National Park.

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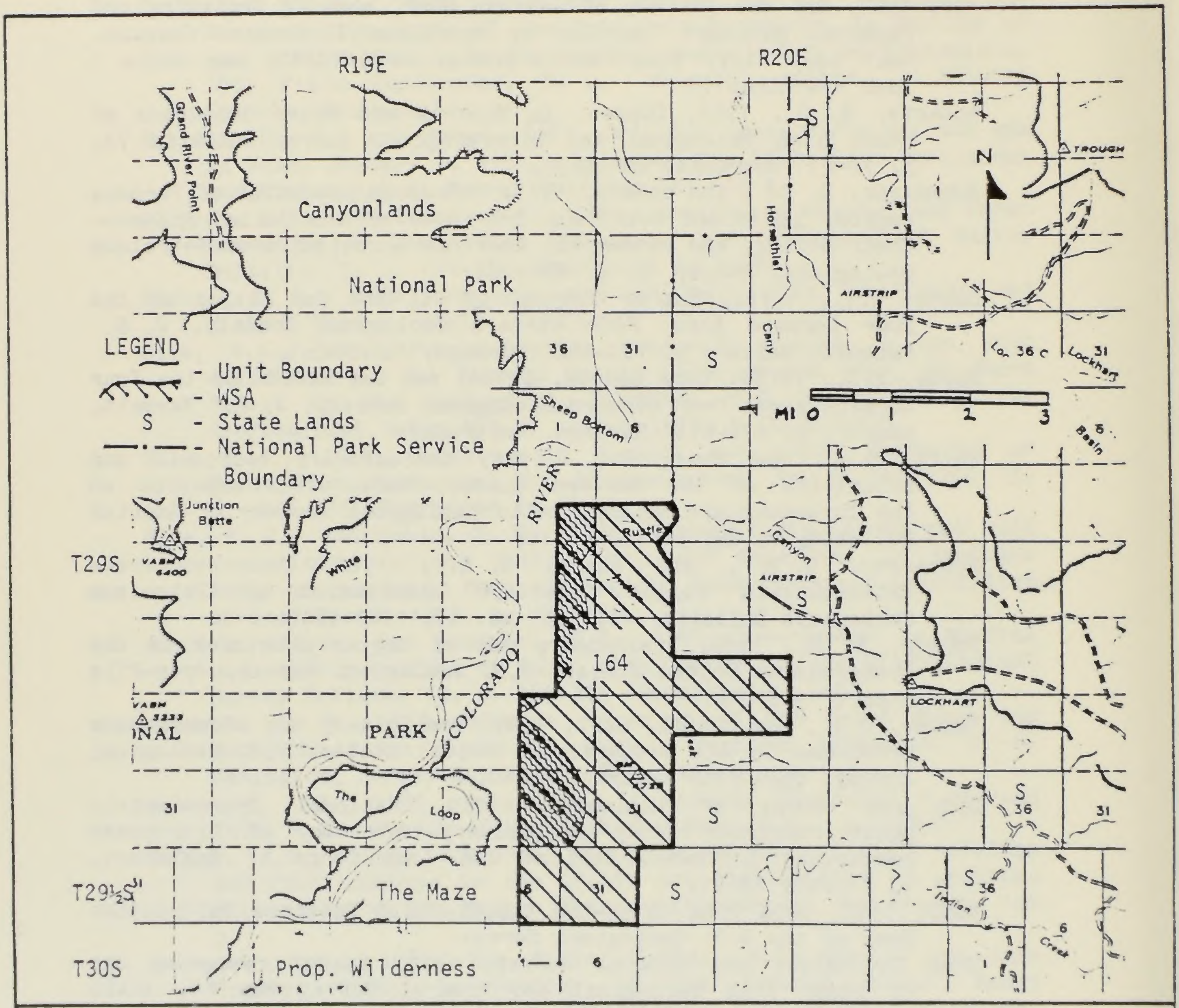
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 164 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



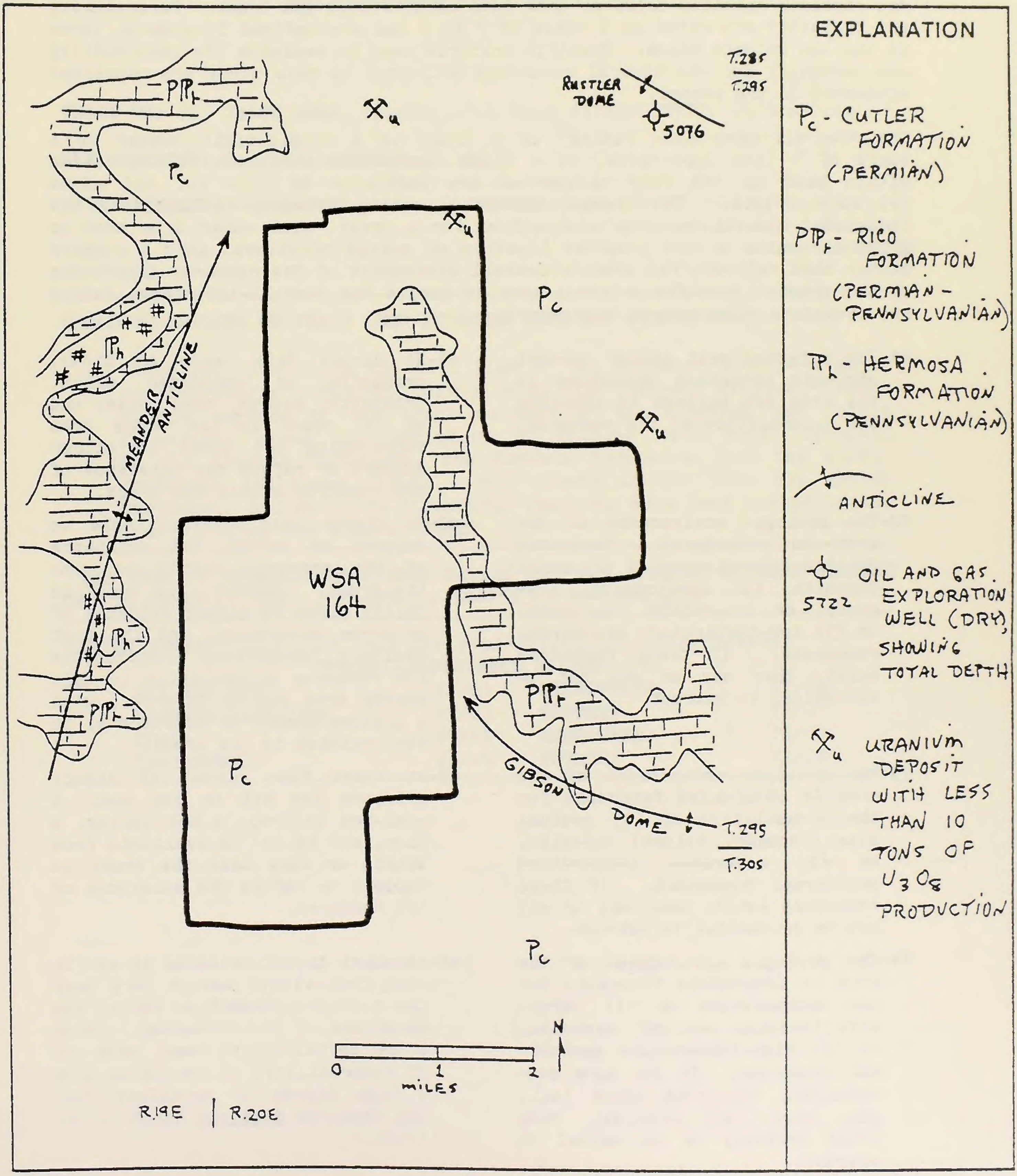
EXPLANATION

ALL MINERAL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN 53

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 164, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 167 **TRACT NAME:** Bridger Jack Mesa **STATE/COUNTY:** UT/San Juan

BLM DISTRICT: Moab **WSA ACREAGE:** 5,300

DATE PREPARED: March 1982 **UPDATE:** August 1982

LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 167 lies along the east limb of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Rocks at the surface of the tract consist of the Moenkopi and Chinle Formations along the periphery of Bridger Jack Mesa, overlain by the Wingate Sandstone, the Kayenta Formation, and the Navajo Sandstone (Williams, 1964). All strata in the area dip gently northeast, and no large structural features have been mapped in the tract (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2-" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2-

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f2/c3	**COPPER:**	f2/c1
COAL:	f1/c4	**MANGANESE:**	f2/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f2/c2

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 167 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), the Paradox Formation in Tract 167 represents deposition along the edge of the hypersaline environment during all but Ismay time. In Ismay time, deposition occurred in the central parts of the penesaline facies.

Of particular importance to oil and gas resources in the vicinity of Tract 167 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 167 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 167, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Furthermore, about 300 feet of the Paradox Formation, as well as about 800 feet of the upper part of the Hermosa Group, are exposed 20 miles west of the tract along the

Colorado River and in Gypsum Canyon . It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 167 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the deep canyons west of the tract may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 167 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 167 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 167, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 167 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Missisppian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do suggest that significant pre-salt faults do not exist in this part of the Monument Upwarp.

As of October 1981, only a few exploratory wells had been drilled in the vicinity of Tract 167 and all were reportedly dry (PIC, 1981). Oil staining, however, has been reported in Mississippian and Permian rocks in the area (Heylmun and others, 1965; Weitz and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 167, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger anticlines, and many of the smaller anticlines in this area have already been tested. In addition, hydrocarbon accumulations are possible along the east-trending, normal-fault system that passes south of the tract from north of the Abajo Mountains.

In summary, the oil and gas favorability of Tract 167 is considered to be low because of deep erosion that probably resulted in the loss of hydrocarbons and the loss of reservoir pressure. Small fields may nevertheless exist in stratigraphic and structural traps in Pennsylvanian rocks, and perhaps in Mississippian rocks. On this basis, we have assigned Tract 167 a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low because of the sparsity of wells, and has been assigned a rating of c1.

URANIUM <u>f2/c3</u>

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Tract 167 lies along the east side of the Monument Upwarp. The White Canyon uranium mining district lies about 30 miles to the southwest (Malan, 1968). By mid-1965, a few thousand tons of uranium oxide had been extracted from the Chinle Formation in this district, although the Happy Jack mine accounts for most of this production (Malan, 1968). Many of the uranium deposits in the White Canyon district contain less than 1,000 tons of ore.

Numerous uranium prospects and small deposits occur in the Moss Back Member of the Chinle Formation a short distance east, northeast, northwest, and south of the tract; those to the northeast are the largest and have produced in excess of 20 tons of uranium oxide (Williams, 1964).

According to Campbell and others (1980a/b), the Chinle is most favorable for uranium in the lower part of the formation, and this is where the largest deposits have been found in the vicinity of Tract 167. Some of these deposits have produced as much as 50 tons of uranium oxide in the Elk Ridge mining district about 50 miles southwest of the tract in the Abajo Mountains (Campbell and others, 1980a/b). The character of the Chinle Formation in the vicinity of the tract is closely related to a paleo-stream corridor in which deposition of sands was abundant. The uranium ore bodies are generally tabular and contained in sandstones, conglomerates, and siltstones that are interbedded with mudstone. The mineralized rock contains abundant carbonaceous debris, and some asphaltite. Unlike uranium deposits in the Chinle Formation elsewhere, deposits in this area are not always confined to permeable channel sandstones (Campbell and others, 1980a/b). In general, the Chinle Formation in this area is favorable for moderately-small uranium deposits.

The underlying Cutler Formation is not considered favorable for uranium in the immediate vicinity of Tract 167 (Campbell and others, 1980a/b). The basis for this belief is the eastward extension across Tract 167 of the Cedar Mesa Sandstone Member of the Cutler Formation. The Cedar Mesa is considered unfavorable for uranium because it is primarily of marine and eolian origin, and thus lacks the fluvial sandstones that are so abundant to the northeast and that are apparently so important for uranium mineralization (Campbell and others, 1980a/b).

On the basis of the discussion above, we have assigned Tract 167 a uranium and vanadium favorability rating of f2. Because numerous uranium deposits occur nearby, the certainty that uranium and vanadium occur somewhere in the tract is relatively high and has been assigned a rating of c3.

COAL <u>f1/c4</u>

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery County to the west of the San Rafael Swell and from Carbon County (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor coal deposits in rocks of early Tertiary age.

Bedrock at the surface of Tract 167 consists of sedimentary rocks of Jurassic and Triassic age underlain by a thick section of Paleozoic rocks (Williams, 1964; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 167 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal does not exist in this WSA.

GEOTHERMAL <u>f1/c3</u>

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 167 is deep-seated, low-temperature thermal waters (between $20^{\circ}C$ and $90^{\circ}C$). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling drilling costs. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 167 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 167. On the basis of this information we have assigned Tract 167 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and

fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau (and in the vicinity of Tract 167) are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Nevertheless, copper occurs widely throughout the Plateau and is clearly associated with uranium deposits which are abundant in this area. We have therefore assigned Tract 167 a copper favorability of f2 and a certainty of resource occurrence of c1.

MANGANESE f2/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. With the advent of World War I and increasing prices for most raw materials, mining of manganese in the Little Grand district was resumed. Shortly after the war, however, the district once again became idle. With the outbreak of World War II, and the increasing need for manganese, small-scale development work was conducted on many of the deposits in southeastern Utah, but largely to determine the quality and quantity of the manganese available (Baker and others, 1952). Intermittent mining throughout the first half of this century, largely during the periods 1901 to 1906 and 1915 to 1918, produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952).

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds

of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Baker and others (1952) estimate that about 15,000 tons of 30 percent manganese ore could be obtained by hand sorting of widely scattered small deposits in the Summerville Formation. Reserves of lower-grade oxide ore, between 10 and 30 percent manganese, are estimated to aggregate about 150,000 tons, whereas ores containing 10 percent or less manganese total about 350,000 tons in southeastern Utah (Baker and others, 1952). With the information available, Baker and others (1952) concluded that southeastern Utah (which includes all of the Moab district) could not be considered as a source area for large tonnages of manganese ore.

Tract 167 lies south of the Little Grand manganese district, and southwest of the widely scattered deposits that occur throughout this part of east-central Utah (Baker and others, 1952; USGS, 1982; Tooker and Cannon, 1980). The chief host rocks for manganese in this region--the Morrison and Summerville Formations--have been eroded from the tract. The less favorable Chinle Formation occurs at shallow depths throughout most of the tract, and on this basis we have assigned Tract 167 a manganese favorability of f2. The certainty that manganese resources occur in the tract is low and has been assigned a value of c1.

POTASH <u>f2/c2</u>

Potassium is an essential plant nutrient and the fertilizer is commonly referred to as the oxide "potash," or K_2O. The chief source of potash is from bedded deposits of marine origin, commonly within the minerals sylvite, carnallite, and other related potassium minerals. Less important, though still commercial, sources include concentrated brines from wells, relict Pleistocene lakes, and lacustrine sediments in arid regions.

Bedded potash deposits exist in the subsurface over a broad area of east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago. The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 167 lies along the border of the thick potash-bearing zones in the Paradox Formation, as illustrated by Hite and Cater (1972).

On the basis of the discussion above, we have assigned Tract 167 a potash favorability of f2, with a relatively low certainty (c2) that potash resources exist in this area.

OVERALL-IMPORTANCE RATING 2-

Tract 167 has been assigned an overall importance rating (OIR) of 2- (on a 1 to 4 scale where 4 is equated with high mineral importance). All resource evaluated for Tract 167 were assigned favorabilities not exceeding f2.

We assigned Tract 167 and OIR to 2-, rather than 2, because of its small size.

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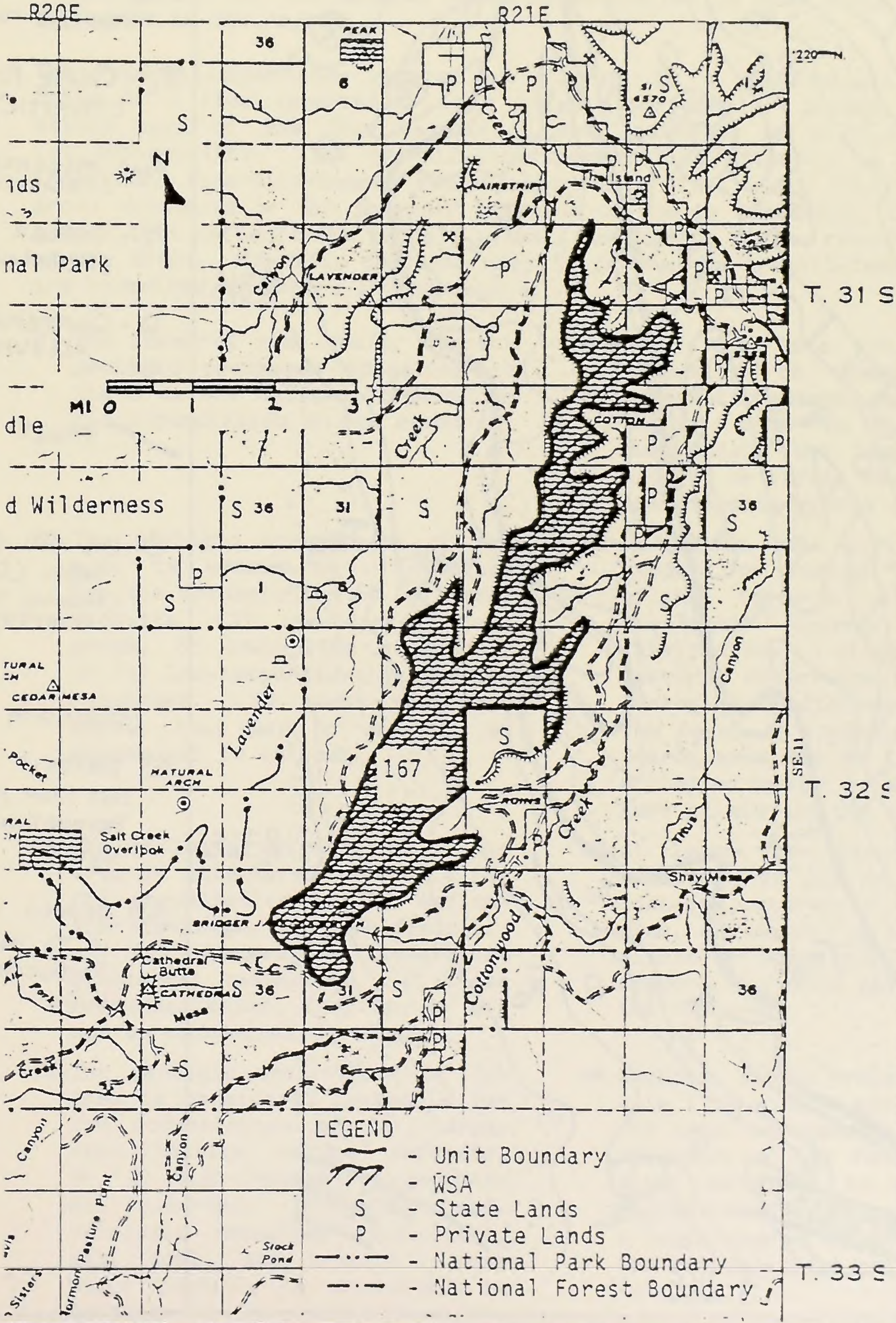
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 167 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



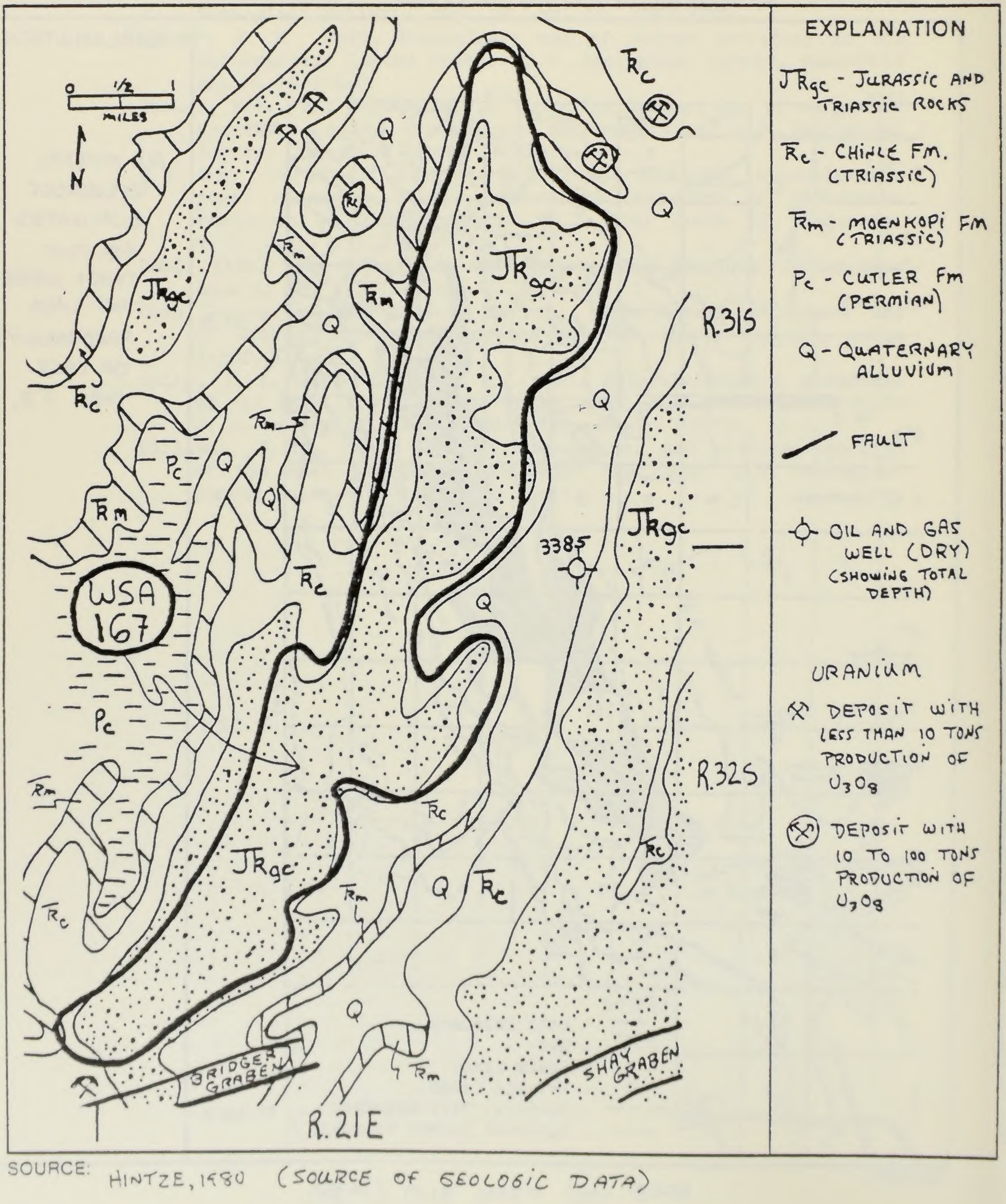
EXPLANATION

ALL MINERAL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED FAVORABILITIES OF LESS THAN f3.

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 167 , UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



SOURCE: HINTZE, 1980 (SOURCE OF GEOLOGIC DATA)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

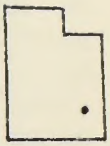
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 169* **TRACT NAME:** Butler Wash **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 22,120 **UNIT ACREAGE:** 27,870

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

*[The resource evaluation of this tract includes contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract, which includes the intensive inventory unit acreage, is shown on the attached Geologic Sketch Map. The tract boundary was determined from a "Wilderness Status Report" prepared on May 1, 1981 by the BLM's district office in Moab, Utah.]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 169 lies near the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists largely of flat-lying beds of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Williams, 1964). The underlying Rico Formation of Permian and Pennsylvanian age is exposed along Butler Wash, and the Moenkopi and Chinle Formations of Triassic are exposed in buttes and ridges in the southern part of the tract. Structural feature include the Salt Creek--Bridger Jack grabens to the south and the Needles fault zone to the north. Numerous small folds occur a few miles southwest of the tract (for example, the Beef Basin anticline and the South Plains syncline)

THE OVERALL-IMPORTANCE RATING ("2") APPLIES TO (<25%___, 25-50%___, 50-75%__, 75-100%✓) OF THE TRACT'S AREA.

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f2/c4	**COPPER:**	f2/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f2/c2

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 169 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), the Paradox Formation in Tract 169 represents deposition near the interface between the penesaline and hypersaline environments during all but Ismay time. In Ismay time, deposition occurred chiefly in the penesaline facies.

Of particular importance to oil and gas resources in the vicinity of Tract 169 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 169 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 169, broad uplifts beginning in Late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Furthermore, about 300 feet of the Paradox Member of the Hermosa Formation, as well as about 800 feet of the upper part of the Hermosa, are exposed to the west in Gypsum

Canyon. It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Tract 169, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 169 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into Dark Canyon to the south and Gypsum to the west may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 169 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 169 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of the oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 169, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 169 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do suggest that significant pre-salt faults do not exist in this part of the Monument Upwarp.

As of October 1981, a few exploratory wells had been drilled along the Beef Basin anticline near the southwest side of the tact, but all the wells were dry (PIC, 1981). Two wells drilled in the tract were also reportedly dry (PIC, 1981). All the wells drilled in this general area are now abandoned, but oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981). In addition, wells in the southern part of the Monument Upwarp reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 169, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger anticlines, and many of the smaller anticlines in this area have already been tested. Hydrocarbon accumulations in Pennsylvanian rocks in the northwestern part of the tract seem very unlikely because of continuing deformation in the Needles fault zone (McGill and Stromquist, 1979). Hydrocarbon accumulations are possible, however, along the northeast-trending Salt Creek-Bridger Jack graben system in the southern part of the tract [referred to by Weitz and Light (1981) as the Dark Canyon-Trail Canyon fault system, and referred to by Kitcho (1981) as the "Abajo Grabens"]. Displacement along these faults is minor as indicated by offset of surface rocks, but it is not known if these are growth faults that penetrate Precambrian rocks. If these are old structures, hydrocarbons migrating up-dip along the axis of the Monument Upwarp might be trapped along faults on the north side of the grabens (Weitz and Light, 1981).

In summary, the oil and gas favorability of Tract 169 is considered to be low because of deep erosion that probably resulted in the loss of hydrocarbons and the loss of reservoir pressure. Small fields may nevertheless exist in stratigraphic and structural traps in Pennsylvanian rocks, and perhaps in Mississippian rocks. On this basis, we have assigned Tract 169 a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low because of the sparcity of wells, and has been assigned a rating of c1.

URANIUM/VANADIUM: f2/c4

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Tract 169 lies near the axis of the Monument Upwarp. The White Canyon uranium mining district lies about 25 miles to the southwest (Malan, 1968). By mid-1965, a few thousand tons of uranium oxide had been extracted from the Chinle Formation in this district, although the Happy Jack mine accounts for most of this production (Malan, 1968). Many of the uranium deposits in the White Canyon district contain less than 1,000 tons of ore. Small and scattered uranium deposits occur in the Chinle Formation in the southern part of Tract 169, but all are reported to have produced less than 10 tons of uranium oxide (Haynes and others, 1972).

Besides the small outcrops of the Chinle Formation, the Cutler Formation is the only unit in the tract that has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980a), some parts of the Cutler Formation are favorable for uranium to the north and east of Tract 169 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 169, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980a/b).

On this basis of the small uranium deposits in the Chinle Formation in the southern part of the tract, we have assigned Tract 169 a uranium favorability rating of f2, and a certainty uranium occurrence of c4.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery County to the west of the San Rafael Swell and from Carbon County (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor coal deposits in rocks of early Tertiary age.

Bedrock at the surface of Tract 169 consists of sedimentary rocks of Jurassic and Triassic age underlain by a thick section of Paleozoic rocks (Williams, 1964; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 169 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal does not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 169 is deep-seated, low-temperature thermal waters (between $20^{\circ}C$ and $90^{\circ}C$). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 169 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 169. On the basis of this information we have assigned Tract 169 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and

fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau (and in the vicinity of Tract 169) are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Nevertheless, copper occurs widely throughout the Plateau and is clearly associated with uranium deposits, many of which occur in and near the tract. We have therefore assigned Tract 169 a copper favorability of f2, but a certainty of only c1 that copper resources occur in the tract.

MANGANESE f2/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. With the advent of World War I and increasing prices for most raw materials, mining of manganese in the Little Grand district was resumed. Shortly after the war, however, the district once again became idle. With the outbreak of World War II, and the increasing need for manganese, small-scale development work was conducted on many of the deposits in southeastern Utah, but largely to determine the quality and quantity of the manganese available (Baker and others, 1952). Intermittent mining throughout the first half of this century, largely during the periods 1901 to 1906 and 1915 to 1918, produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952).

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds

of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Baker and others (1952) estimate that about 15,000 tons of 30 percent manganese ore could be obtained by hand sorting of widely scattered small deposits in the Summerville Formation. Reserves of lower-grade oxide ore, between 10 and 30 percent manganese, are estimated to aggregate about 150,000 tons, whereas ores containing 10 percent or less manganese total about 350,000 tons in southeastern Utah (Baker and others, 1952). With the information available, Baker and others (1952) concluded that southeastern Utah (which includes all of the Moab district) could not be considered as a source area for large tonnages of manganese ore.

Tract 169 lies many miles south of the Little Grand manganese district, and southwest of the widely scattered deposits that occur throughout this part of east-central Utah (Baker and others, 1952; USGS, 1982; Tooker and Cannon, 1980). The chief host rocks for manganese in this region--the Morrison and Summerville Formations--have been eroded from the tract. The less favorable Chinle Formation occurs only in a small area at the southern end of the tract and is not considered favorable for manganese. On this basis we have assigned Tract 169 a manganese favorability of f1, but a certainty of only c1 that manganese resources do no occur in the tract.

POTASH <u>f2/c2</u>

Potassium is an essential plant nutrient and the fertilizer is commonly referred to as the oxide "potash," or K_2O. The chief source of potash is from bedded deposits of marine origin, commonly within the minerals sylvite, carnallite, and other related potassium minerals. Less important, though still commercial, sources include concentrated brines from wells, relict Pleistocene lakes, and lacustrine sediments in arid regions.

Bedded potash deposits exist in the subsurface over a broad area of east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago. The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 169 lies near the border of the thick potash-bearing zones in the Paradox Formation, as illustrated by Hite and Cater (1972).

On the basis of the discussion above, we have assigned Tract 169 a potash favorability of f2, with a relatively low certainty (c2) that potash resources exist in this area.

OVERALL-IMPORTANCE RATING 2

Tract 169 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). All resource evaluated for Tract 169 were assigned favorabilities of less than f3.

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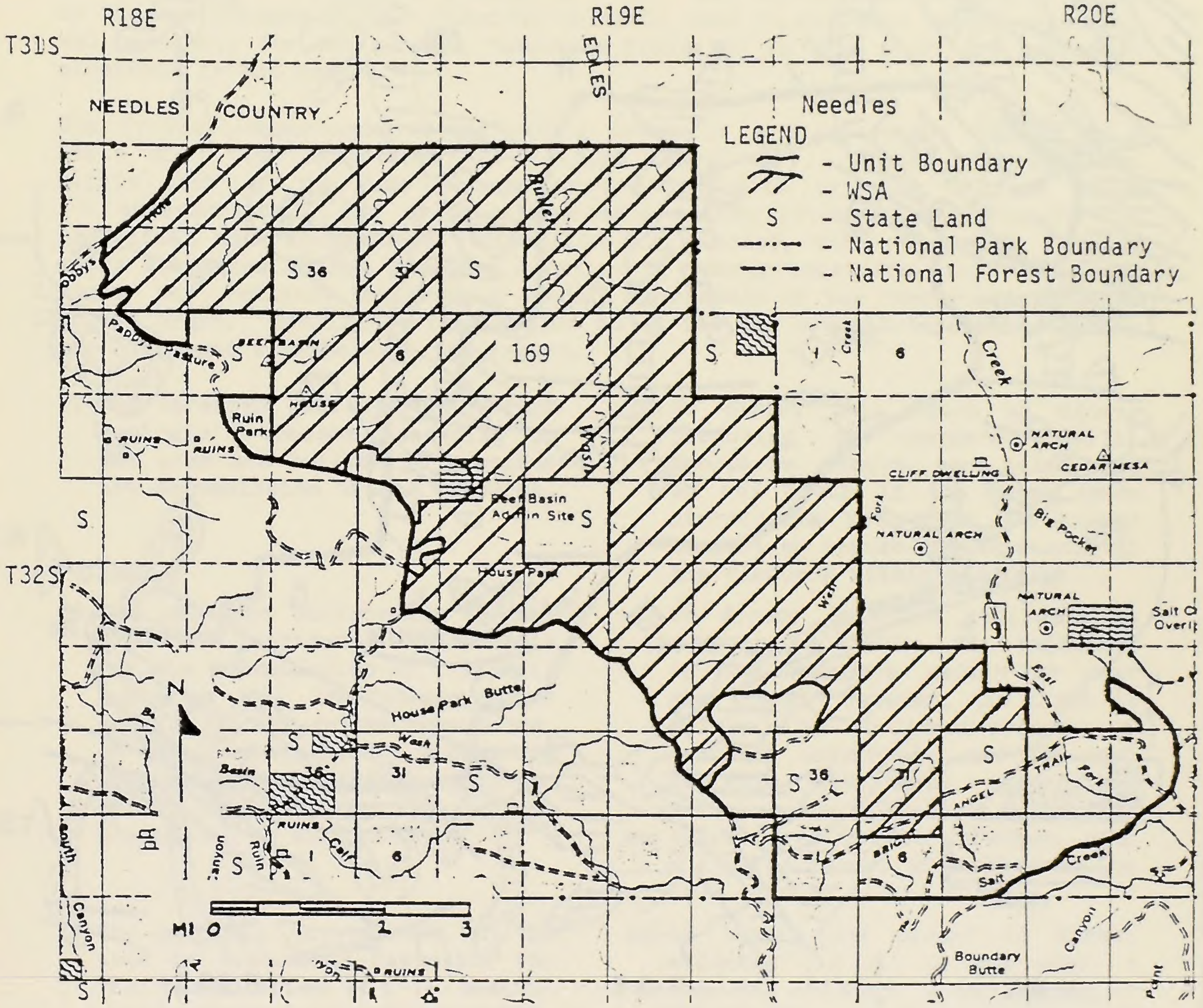
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 169 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



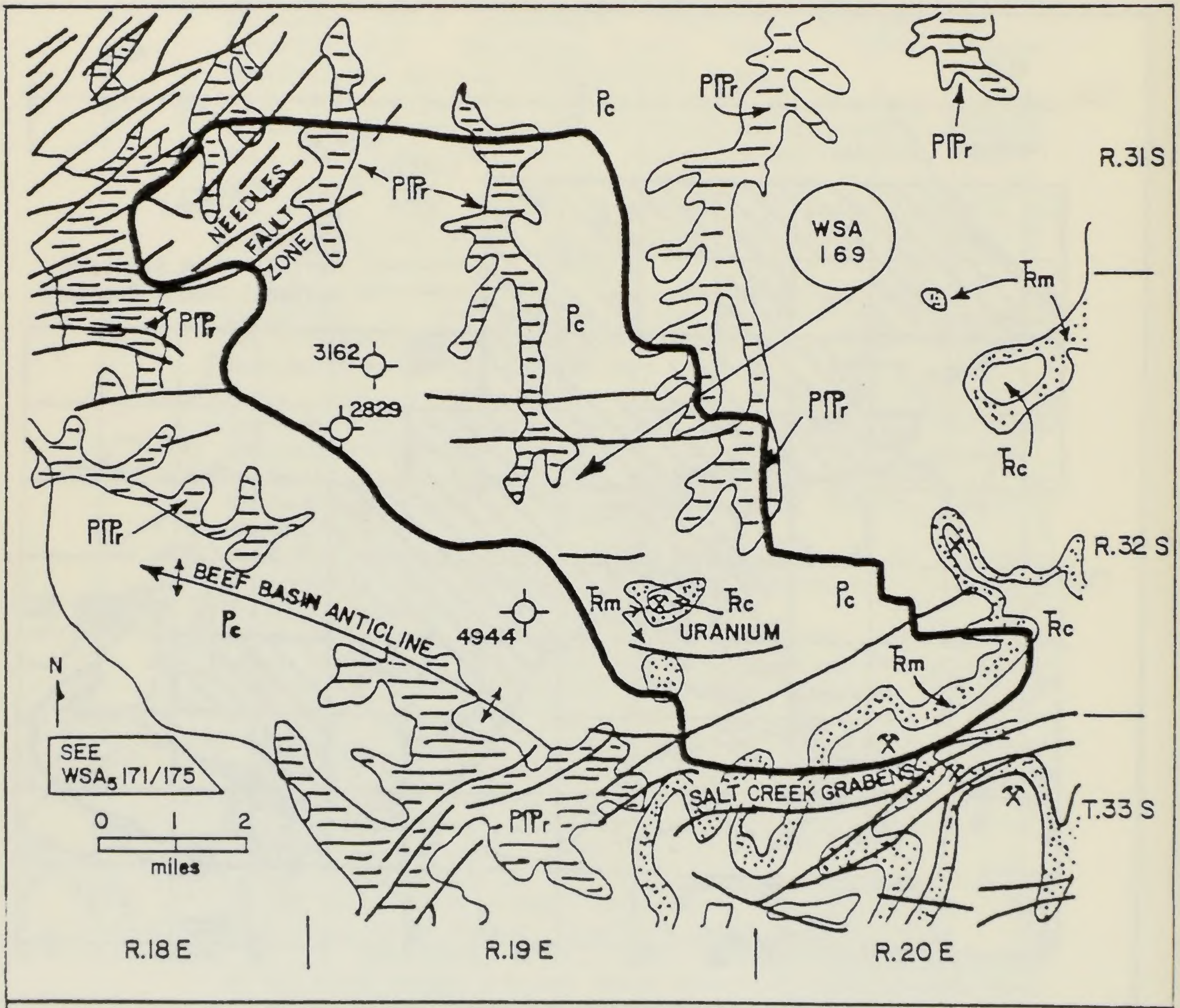
EXPLANATION

ALL MINERAL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN ≤3.

SOURCE: BLM, 1980

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 169, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

₸ - CHINLE FORMATION (TRIASSIC)

₸m - MOENKOPI FORMATION (TRIASSIC)

Pc - CUTLER FORMATION (PERMIAN)

PℙPr - RICO FORMATION (PERM-PENN)

FAULT

ANTICLINE

4944 OIL WELL (DRY), SHOW TOTAL DEPTH

⚒ URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: HINTZE (1980), SOURCE OF GEOLOGY

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3**/c2). The first rating, **"f3"**, estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, **"c2"**, is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 171* **TRACT NAME:** Sweet Alice Canyon **STATE/COUNTY:** UT/Emery

DISTRICT: Moab **UNIT ACREAGE:** 9,880

DATE PREPARED: March 1982 **UPDATE:** August 1982

LOCATION

*[This tract has been dropped from the BLM's Wilderness Review, but it is now under appeal. The boundary of the tract was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 171 lies along the axis of the Monument Upwarp--a broad northwest-trending structural division of the Colorado Plateau. The tract consists chiefly of flat-lying rocks of the Cutler Group of Pennsylvanian age. At the southern end of the tract, Triassic sedimentary rocks of the Moenkopi and Chinle Formations are preserved on some mesas. High-angle faults with minor displacement can be traced at the surface in the southern part of the tract. These faults are part of a general system of faults that trend easterly in this part of Utah (the Salt Creek graben system).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100% ✓).

RATING SUMMARY: (See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 171 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine "penesaline" environment (Berghorn

and Reid, 1981). The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), the Paradox Formation in Tract 171 represents deposition in the deeper parts of the penesaline environment during all but Ismay time. During Ismay time, deposition occurred in the shallow parts of the penesaline facies, close to the marine shelf.

Of particular importance to oil and gas resources in the vicinity of Tract 171 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 171 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 171, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Furthermore, about 300 feet of the Paradox Formation, and about 800 feet of the upper part of the Hermosa Group, are exposed in Dark, Gypsum, and Cataract Canyons a few miles to the west and south. It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Tract 171, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 171 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into Dark, Gypsum, and Cataract Canyons may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 171 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 171 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 171, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 171 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do not suggest that significant pre-salt faults exist in this part of the Monument Upwarp.

As of October 1981, only a few exploratory wells had been drilled in the vicinity of Tract 171; one well was drilled in or near the tract's southern border (PIC, 1981; see attached Geologic Sketch Map). Most of the wells were drilled in the late-1950s and early-1960s after the large discoveries at Aneth and Lisbon Valley. Although all wells that have been drilled in this general area are now abandoned, oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981). The oil seeps reported in the Honaker Trail Formation in nearby Dark Canyon by Wengerd and Matheny (1958) were considered by Weitz and Light (1981, p.

12) to be "...only irridescence caused by decaying vegetation in localized spring-fed areas...".

If oil and gas accumulations exist in the immediate area of Tract 171, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger anticlines, and many of the smaller anticlines in this area have already been tested. In addition, hydrocarbon accumulations are possible along the east-trending, normal-fault system that extends into the southern part of the tract from north of the Abajo Mountains [referred to by Weitz and Light (1981) as the Dark Canyon-Trail Canyon fault system, and referred to by Kitcho (1981) as the Abajo Grabens]. Displacement along these faults at the surface is minor, as indicated by offset of surface rocks, but it is not known if these are growth faults that penetrate Precambrian rocks.

In summary, the oil and gas favorability of Tract 171 is considered to be low because of nearby deep erosion that probably resulted in the loss of hydrocarbons and the loss of reservoir pressure. Small fields may nevertheless exist in stratigraphic and structural traps in Pennsylvanian rocks, and perhaps in Mississippian rocks. On this basis, we have assigned Tract 171 a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is low, because of the sparsity of wells, and has been assigned a rating of c1.

URANIUM/VANADIUM: f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the

Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Tract 171 lies along the west side of the Monument Upwarp. The White Canyon uranium mining district lies about 20 miles to the south (Malan, 1968). By mid-1965, a few thousand tons of uranium oxide had been extracted from the Chinle Formation in this district, although the Happy Jack mine accounts for most of this production (Malan, 1968). Many of the uranium deposits in the White Canyon district contain less than 1,000 tons of ore. Numerous uranium prospects and small deposits occur in the Chinle Formation a few miles south and west of Tract 171 (Hackman and Wyant, 1973; Haynes and others, 1972). Most of these deposits are contained in the Moss Back and Monitor Butte Members of the Chinle Formation.

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 171 (Hackman and Wyant, 1973; Haynes and others, 1972; the small patch of Triassic rocks preserved at the southern end of the tract belong to the Moenkopi Formation). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), some parts of the Cutler Formation are favorable for uranium to the north and east of Tract 171 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 171, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 171 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Certaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 171 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of middle and lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks (Hackman and Wyant, 1973; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 171 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal resources do not exist in this tract.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 171 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). A warm spring (26°C) located in Red Canyon about 15 miles southwest of Tract 171 is the only visible and naturally-occurring manifestation of geothermal energy in the entire Moab district (NOAA, 1980). Water extracted at these temperatures can be used for direct heating. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has probably resulted in extreme depths over much of the Colorado Plateau to even the low-temperature geothermal resources. On the basis of the geologic characteristics of the Colorado Plateau, we have therfore assigned Tract 171 a geothermal favorabilty rating of f1 and a moderately-high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 171 (the Cataract Canyon hydropower site lies miles to the north of the tract; designation of Tract 171 as a wilderness area would have no impact on the potential development of the Cataract Canyon site). On the basis of this information we have assigned Tract 171 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Weitz and Light (1981) report that samples of the Shinarump Member of the Chinle Formation collected from the Woodenshoe mine about 8 miles southeast of the tract contain as much as 3.10 percent copper. The Chinle and other favorable rocks for copper (and uranium) deposits have been removed by erosion from Tract 171. We therefore have assigned the tract a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout the province, the estimated manganese potential of southeastern Utah is very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 171 (Hackman and Wyant, 1973; Haynes and others, 1972). The nearest known manganese deposits are more than 30 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 171 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 171, however, lies many miles west of the thick potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks did exist in the Paradox Formation in this area, they would probably be very thin and discontinuous, and would not constitute a resource.

On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 2

Tract 171 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). The tract was judged to be favorable for small accumulation of oil and/or gas (f2). The geologic environment of the tract was considered unfavorable for all of the other resources evaluated.

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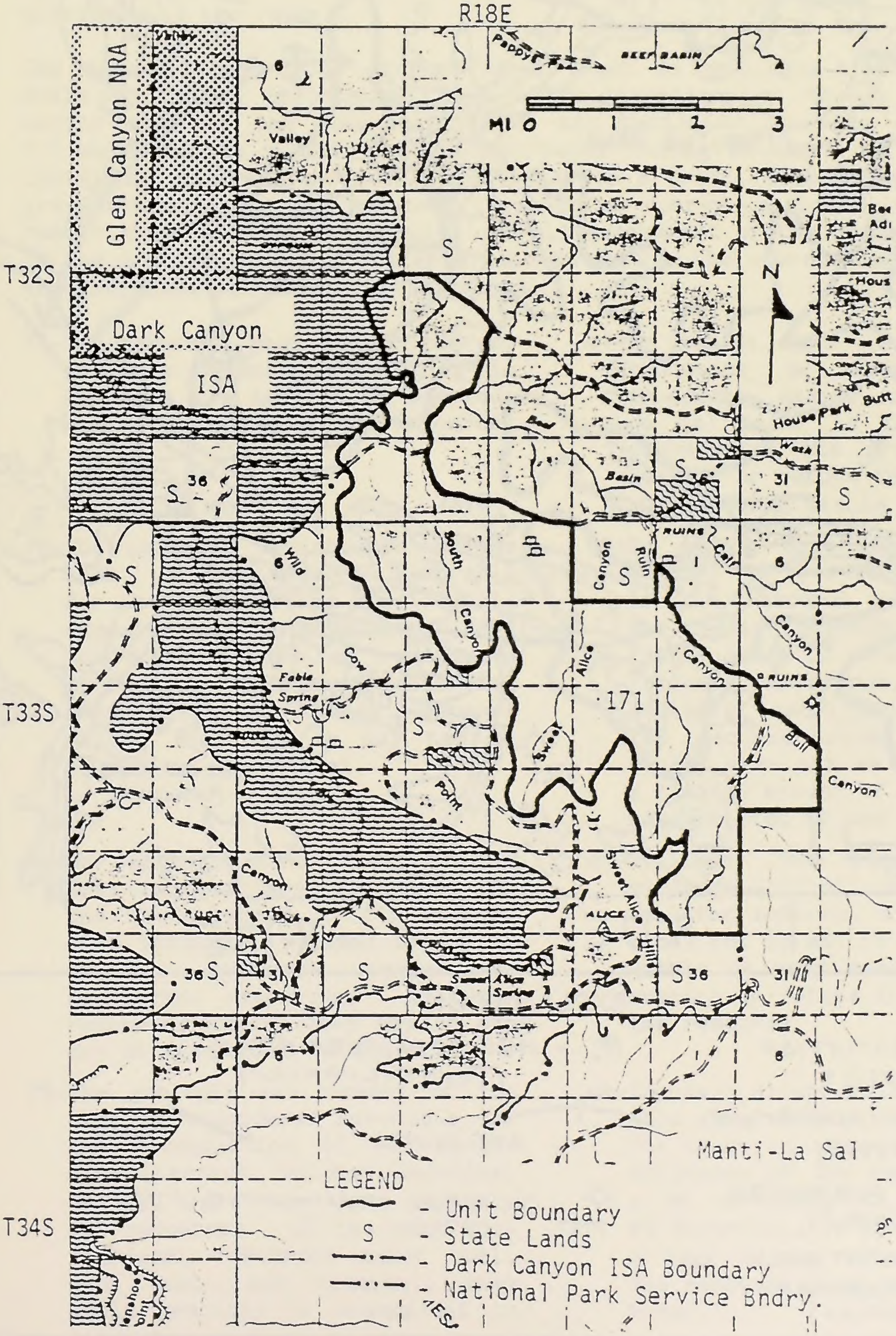
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 171, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



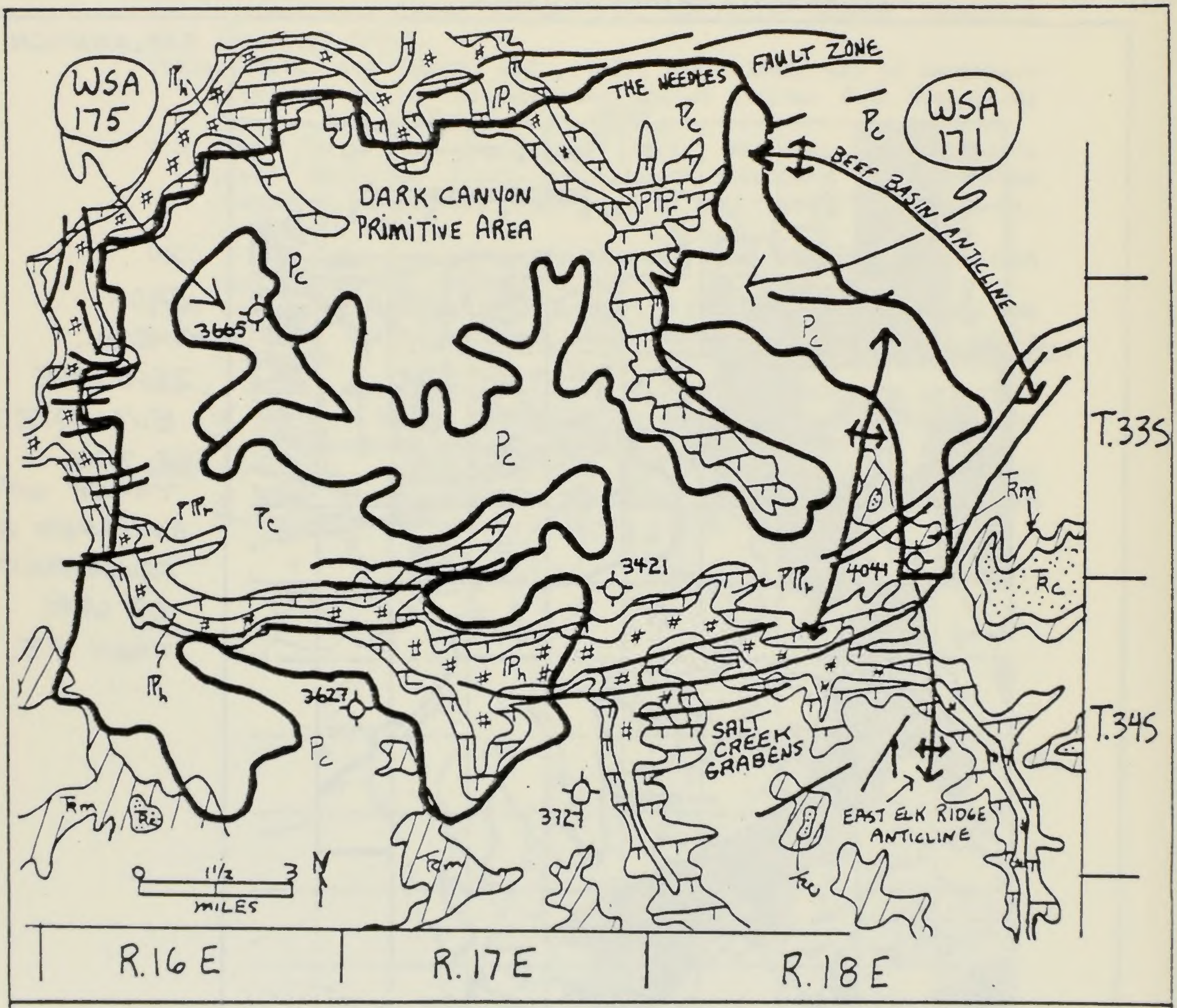
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN f3.

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 175, 171, AND DARK CANYON

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TRc - CHINLE FORMATION (TRIASSIC)

TRm - MOENKOPI FORMATION (TRIASSIC)

Pc - CUTLER FORMATION (PERMIAN)

PIPr - RICO FORMATION (PENNSYLVANIAN - PERMIAN)

IPh - HERMOSA FORMATION (PENNSYLVANIAN)

ANTICLINE

FAULT

3727 OIL WELL, SHOWING TOTAL DEPTH (DRY)

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, **"f3"**, estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, **"c2"**, is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

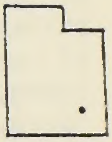
f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.	**c1**-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.
f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.	**c2**-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.
f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.	**c3**-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.
f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.	**c4**-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 175 **TRACT NAME:** Middle Point **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **UNIT ACREAGE:** 5,990

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 175 is surrounded by Dark Canyon Instant Study Area and the geology and mineral favorability of both areas are essentially identical. The track is currently under appeal. It lies slightly west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists entirely of sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). No obvious structural features extend into the tract.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "1" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 175 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine "penesaline" environment (Berghorn

and Reid, 1981). The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), the Paradox Formation in Tract 175 represents deposition in the deeper parts of the penesaline environment during all but Ismay time. During Ismay time, deposition occurred in the shallow parts of the penesaline facies, close to the marine shelf.

Of particular importance to oil and gas resources in the vicinity of Tract 175 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 175 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 175, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Furthermore, about 300 feet of the Paradox Formation, and about 800 feet of the upper part of the Hermosa Group, are exposed in Dark, Gypsum, and Cataract Canyons a few miles away. It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Tract 175, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 175 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into Dark, Gypsum, and Cataract Canyons may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 175 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 175 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 175, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 175 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do not suggest that significant pre-salt faults exist in this part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Tract 175 and one well had been drilled along the tract's east border (PIC, 1981; see attached Geologic Sketch Map). Most of the wells were drilled in the late-1950s and early-1960s after the large discoveries at Aneth and Lisbon Valley. Although all wells that have been drilled in this general area are now abandoned, oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981). The oil seeps reported in the Honaker Trail Formation in nearby Dark Canyon by Wengerd and Matheny (1958) were considered by Weitz and Light (1981, p.

12) to be "...only irridescence caused by decaying vegetation in localized spring-fed areas...".

If oil and gas accumulations exist in the immediate area of Tract 175, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger anticlines, and many of the smaller anticlines in this area have already been tested. In addition, hydrocarbon accumulations are possible along the east-trending, normal-fault system that extends into the southern part of the tract from north of the Abajo Mountains [referred to by Weitz and Light (1981) as the Dark Canyon-Trail Canyon fault system, and referred to by Kitcho (1981) as the Abajo Grabens]. Displacement along these faults at the surface is minor, as indicated by offset of surface rocks, but it is not known if these are growth faults that penetrate Precambrian rocks.

In summary, the oil and gas favorability of Tract 175 is considered to be low because of nearby deep erosion that probably resulted in the loss of hydrocarbons and the loss of reservoir pressure. Small fields may nevertheless exist in stratigraphic and structural traps in Pennsylvanian rocks, and perhaps in Mississippian rocks. On this basis, we have assigned Tract 175 a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is low, because of the sparsity of wells, and has been assigned a rating of c1.

URANIUM/VANADIUM: f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the

Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Tract 175 lies along the west side of the Monument Upwarp. The White Canyon uranium mining district lies about 15 miles to the south (Malan, 1968). By mid-1965, a few thousand tons of uranium oxide had been extracted from the Chinle Formation in this district, although the Happy Jack mine accounts for most of this production (Malan, 1968). Many of the uranium deposits in the White Canyon district contain less than 1,000 tons of ore. Numerous uranium prospects and small deposits occur in the Chinle Formation a few miles south and west of Tract 175 (Hackman and Wyant, 1973; Haynes and others, 1972). Most of these deposits are contained within the Moss Back and Monitor Butte Members of the Chinle Formation.

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 175 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), some parts of the Cutler Formation are favorable for uranium to the north and east of Tract 175 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 175, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 175 is low, and has been assigned a rating of c1.

[Note: Weitz and Light (1981) considered the area of Dark Canyon to have some uranium potential in the Shinarump Member of the Chinle Formation in a small area that extends south of N37°45'. This area was not included on the maps provided by the BLM for Tract 175 (and Dark Canyon instant study area), and was therefore not included in this evaluation.]

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Certaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 175 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of middle and lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks (Hackman and Wyant, 1973; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 175 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal resources do not exist in this tract.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 175 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). A warm spring (26°C) located in Red Canyon about 15 miles southwest of Tract 175 is the only visible and naturally-occurring manifestation of geothermal energy in the entire Moab district (NOAA, 1980). Water extracted at these temperatures can be used for direct heating. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has probably resulted in extreme depths over much of the Colorado Plateau to even the low-temperature geothermal resources. On the basis of the geologic characteristics of the Colorado Plateau, we have therfore assigned Tract 175 a geothermal favorabilty rating of f1 and a moderately-high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 175 (the Cataract Canyon hydropower site lies miles to the north of the tract; designation of Tract 175 as a wilderness area would have no impact on the potential development of the Cataract Canyon site). On the basis of this information we have assigned Tract 175 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Weitz and Light (1981) report that samples of the Shinarump Member of the Chinle Formation collected from the Woodenshoe mine about 8 miles southeast of the tract contain as much as 3.10 percent copper (the area evaluted by Weitz and Light (1981) is considerably larger than the area evaluated in this study). The Chinle and other favorable rocks for copper (and uranium) deposits have been removed by erosion from Tract 175. We therefore have assigned the tract a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout the province, the estimated manganese potential of southeastern Utah is very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 175 (Hackman and Wyant, 1973; Haynes and others, 1972). The nearest known manganese deposits are more than 30 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 175 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 175, however, lies many miles west of the thick potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks did exist in the Paradox Formation in this area, they would probably be very thin and discontinuous, and would not constitute a resource.

On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 1

Tract 175 has been assigned an overall importance rating (OIR) of 1 (on a 1 to 4 scale where 4 is equated with high mineral importance). The tract was judged to be favorable for small accumulation of oil and/or gas (f2). The geologic environment of the tract was considered unfavorable for all of the other resources evaluated.

The tract was assigned an OIR of 1 rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with other Wilderness Study Areas in this part of the Monument Upwarp.

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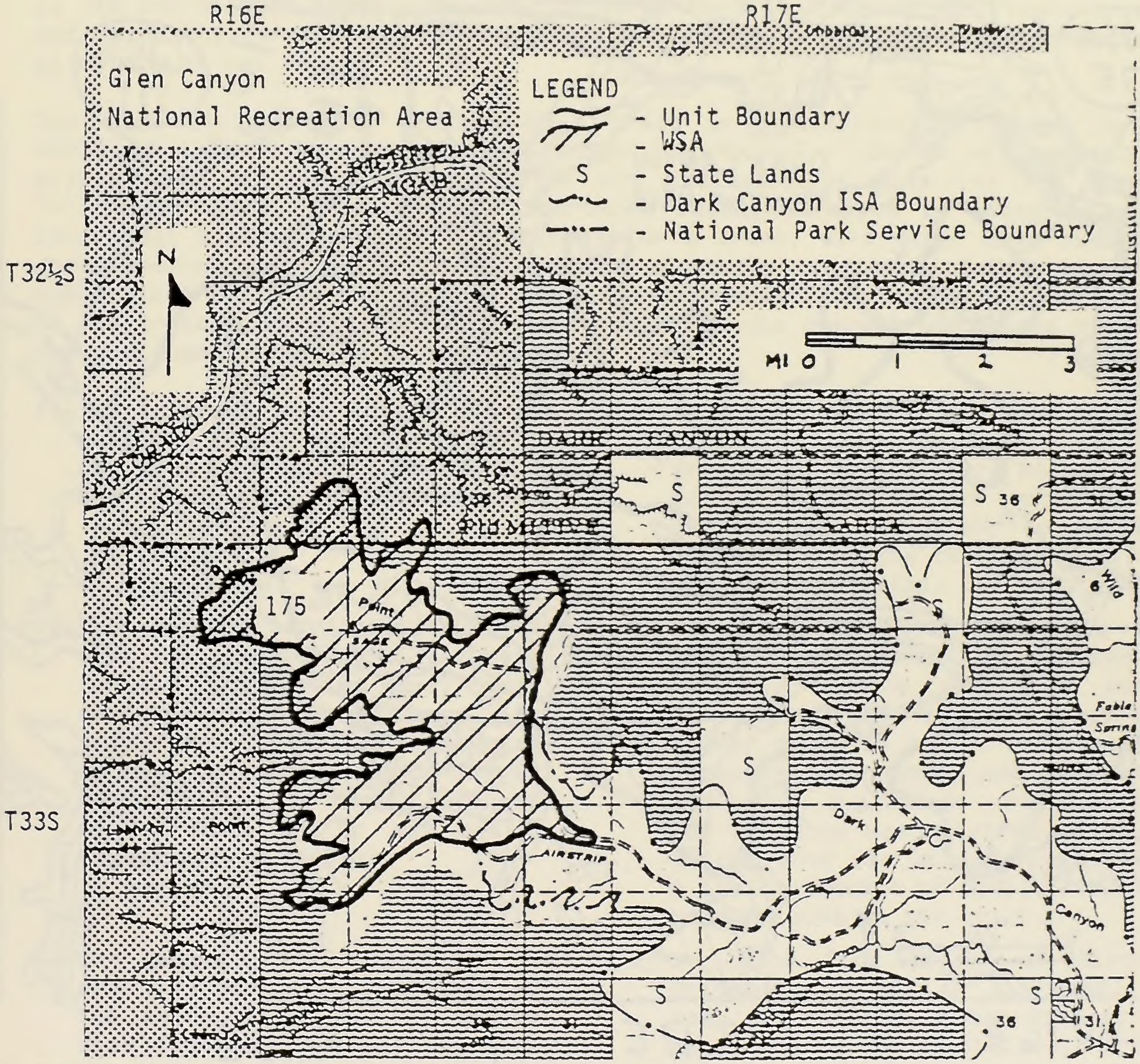
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 175 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



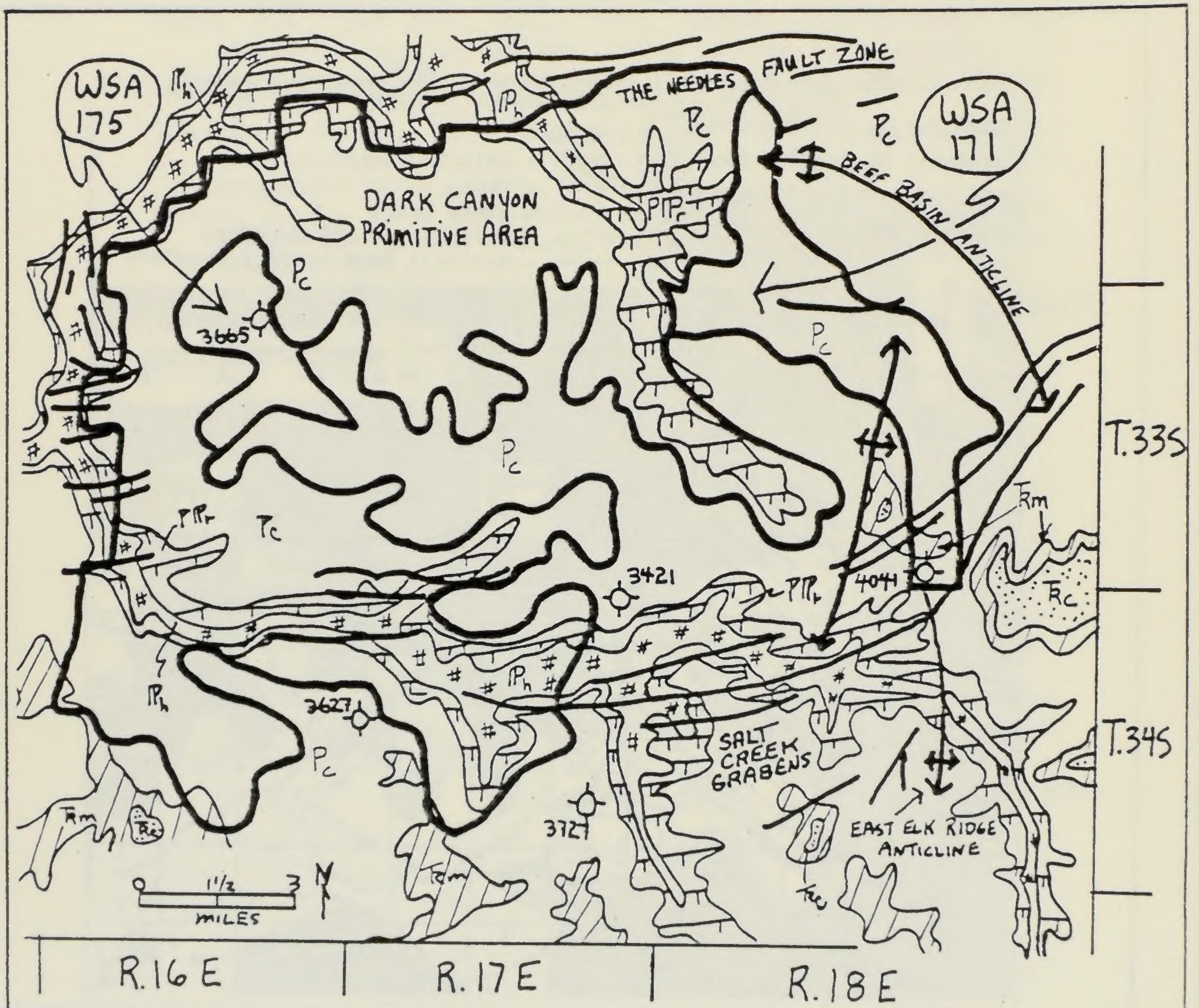
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN 5 3.

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 175, 171, AND DARK CANYON

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TRc - CHINLE FORMATION (TRIASSIC)

TRm - MOENKOPI FORMATION (TRIASSIC)

Pc - CUTLER FORMATION (PERMIAN)

PIPr - RICO FORMATION (PENNSYLVANIAN - PERMIAN)

IPh - HERMOSA FORMATION (PENNSYLVANIAN)

ANTICLINE

FAULT

3727 OIL WELL, SHOWING TOTAL DEPTH (DRY)

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, **"f3"**, estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, **"c2"**, is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

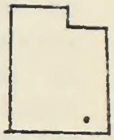
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 188* **TRACT NAME:** Pine Canyon **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 11,300 **UNIT ACREAGE:** 15,180

DATE PREPARED: May 1982 **UPDATE:** August 1982


LOCATION

*[The resource evaluation of this tract includes contiguous areas to the southwest and northeast that have been dropped from the BLM's Wilderness Review. The boundary of the tract, including the intensive inventory unit acreage, was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab, Utah].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 188 lies west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists almost entirely of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). Triassic rocks crop out a short distance to the north. Structural features in the tract include several small east- and west-trending anticlines and synclines (Hackman and Wyant, 1973)

THE TRACT'S OVERALL-IMPORTANCE RATING OF "1+" APPLIES TO WHAT PERCENT OF ITS AREA? (25%___, 25-50%___, 50-75%___, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1+

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 188 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 188 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 188 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 188 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 188, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has

stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 188 the Paradox Formation is probably less than 1,000 feet below the surface. About 20 miles south of Tract 188, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 188 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 188 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 188 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 188, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 188 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Tract 188 (one well was drilled in the tract, see attached Geologic Sketch Map; PIC, 1981). Although the wells in the area have all been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 188, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 188 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 188 lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 25 miles to the northwest and the Monument Valley uranium mining district lies about 30 miles to the south (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 188 are about 3 miles to the north in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 188 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 188 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 188, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 188 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 188 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 188 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 188 is deep-seated, low-temperature thermal waters (between 20°C and 90°C).

Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 188 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 188. The closest identified, undeveloped site is along the San Juan River near the mouth of Slickhorn Canyon a mile south of the tract [estimated capacity of 62,000 kilowatts; FERC (1981)]. Development of this site would probably not encroach upon the southern boundary of Tract 188. We have therefore assigned Tract 188 a hydropower favorability rating of f1. The certainty that a hydropower resource does not exist within the tract is high, and has been assigned a rating of c4.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 188 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE <u>f1/c1</u>

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds

of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 188. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 188 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 188 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 1+

Tract 188 has been assigned an overall importance rating (OIR) of 1+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only. The tract was assigned an OIR of 1+ rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with other Wilderness Study Areas in this part of the Monument Upwarp.

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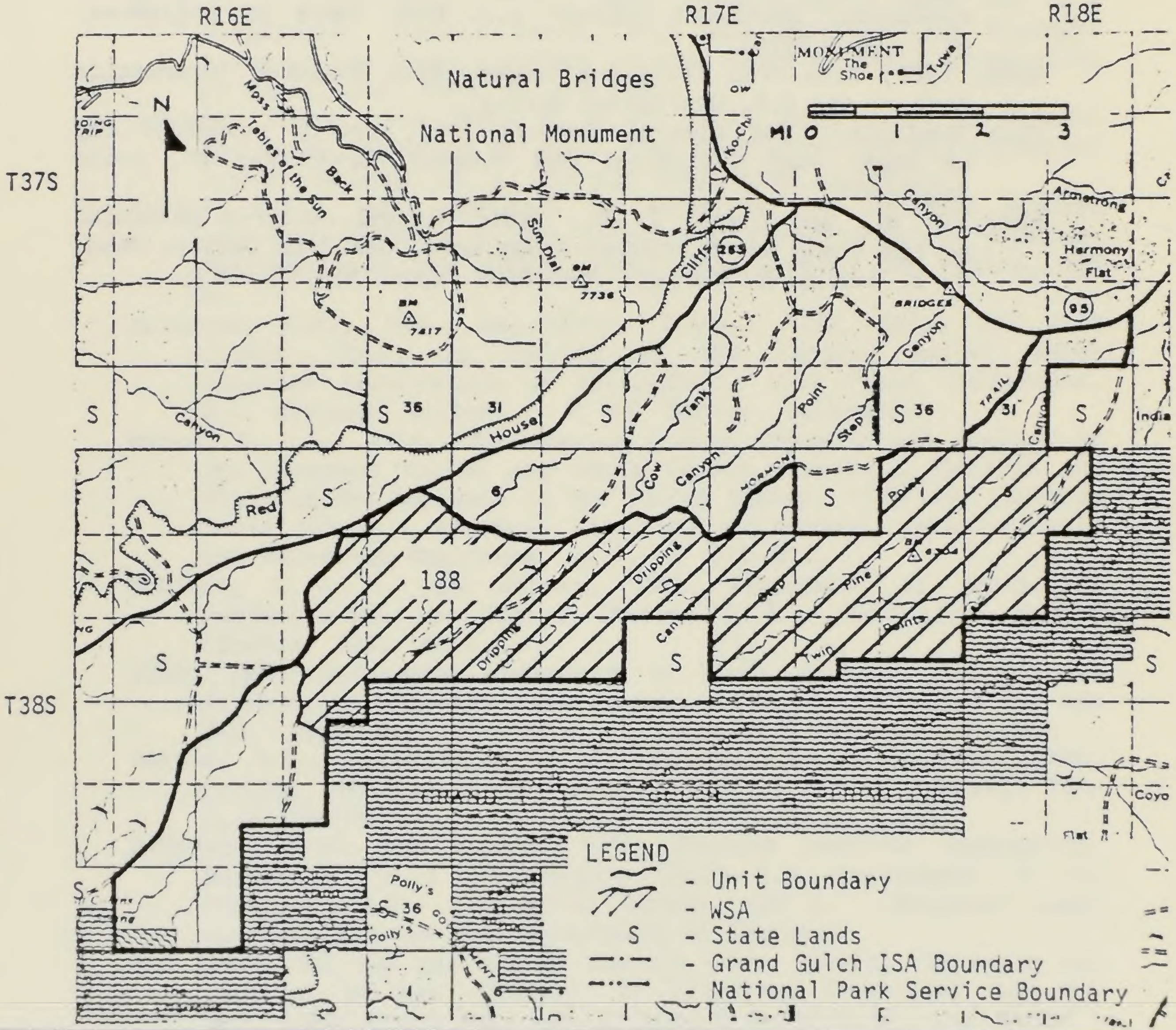
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 188, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



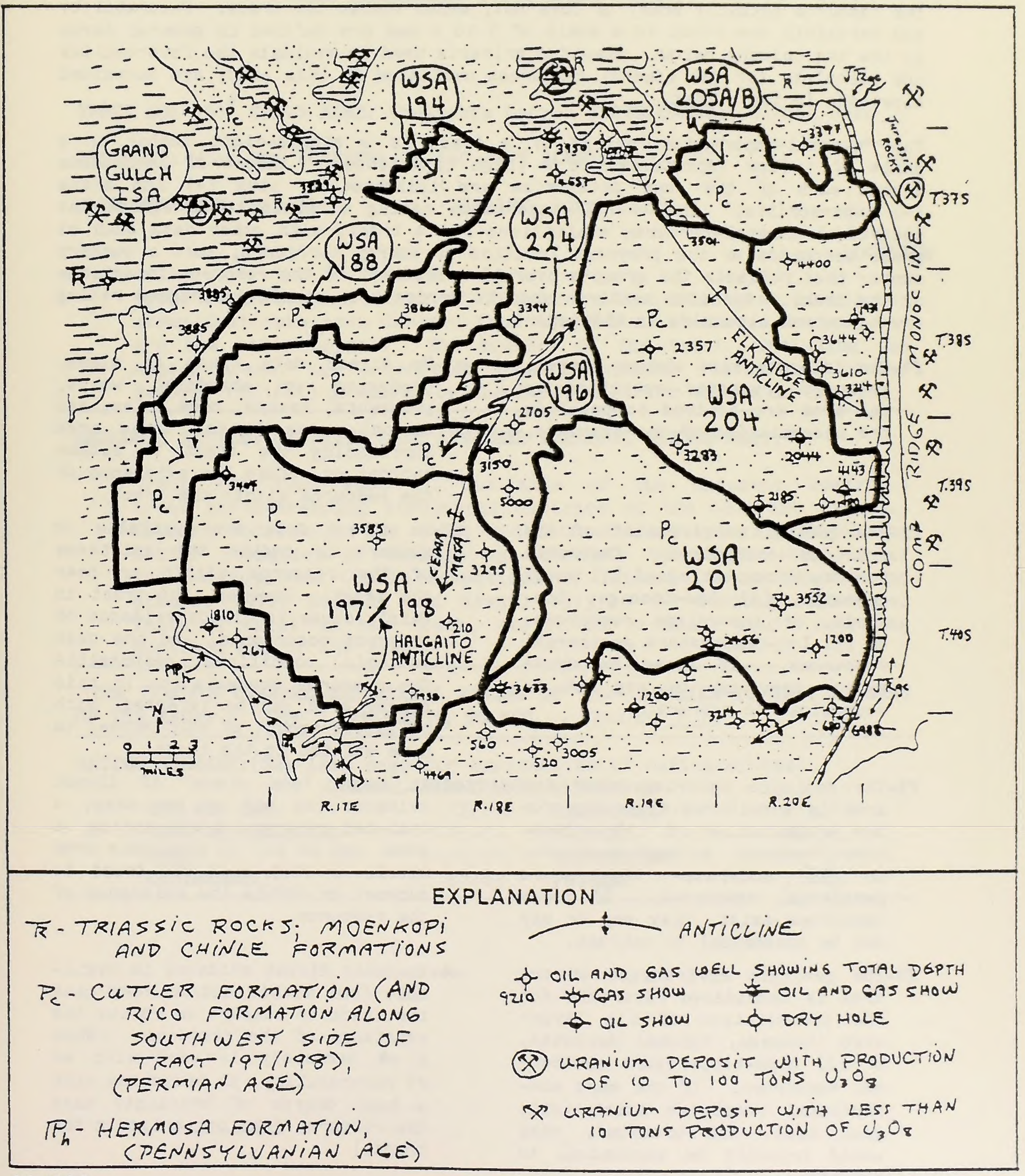
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN 3.

SOURCE: MAP SOURCE, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 191* **TRACT NAME:** Cheesebox Canyon **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 15,410 **UNIT ACREAGE:** 27,520

DATE PREPARED: May 1982 **UPDATE:** August 1982

LOCATION

*[The resource evaluation of this tract includes three contiguous areas that have been dropped from the BLM's Wilderness Review, but are now under appeal. The boundry of the tract, including the appeal areas, was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 191 lies west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock in the tract consists of flat-lying rocks of the Cutler Formation of Permian age overlain by ridges composed of the Moenkopi and Chinle Formations of Triassic rocks (Haynes and others, 1972; Hackman and Wyant, 1973). No obvious structural features exist in the tract, except for a minor fault near the northern end of the tract.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "3-" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%_✓_, 50-75%__, 75-100%___).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 3-

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f3/c4	**COPPER:**	f2/c3
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 191 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the southwest, the penesaline environment merged with a shallow marine shelf containing marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into four major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" reached its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 191 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 191 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 191 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 191, broad uplifts beginning in Late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp (remnants of these Mesozoic rocks are preserved in Tract 191). Furthermore, much of the Pennsylvanian section is exposed to the north in Cataract Canyon and to the south along the San Juan River. It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Tract 191, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 191 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 191 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 191 is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of the oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 191, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 191 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississppian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do not suggest that significant pre-salt faults exist in this part of the Monument Upwarp.

As of October 1981, only a few exploratory wells had been drilled in the vicinity of Tract 191 (PIC, 1981; two of the wells are near the tract's souther border). Most of the wells were drilled in the late-1950s and early-1960s after the large discoveries at Aneth and Lisbon Valley. Although all wells that have been drilled in this general area are now abandoned, oil staining has been reported from Mississippian and Pennsylvanian rocks north of the tract, and oil shows Devonian, Mississippian, and Pennsylvanian rocks have been reported from well south of the tract (Hansen and Scoville, 1955;

Heymun and others, 1965; Weitz and Light, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 191, they are likely to be associated with stratigraphic traps and small-scale folding. On this basis, and because of nearby deep erosion, we consider the oil and gas potential of Tract 191 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is low, and has been assigned a rating of c1.

URANIUM/VANADIUM: f3/c4

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from depsoits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Tract 191 lies within the White Canyon uranium mining district as outlined by Thaden and others (1964). The uranium deposits are concentrated in the Shinarump Member of the Chinle Formation and they generally contain copper as a byproduct. According to Thaden and others (1964, p. 1) "...Most of the uranium and copper is localized in medium- to coarse-grained and conglomeratic sandstone interbedded with mudstone that fills channels cut into the Moenkopi formation....Channels range in width from 30 to 1,000 feet and are as much as 50 feet deep...." White Canyon is one of the most productive districts that produce uranium from the Chinle Foramtion.

By mid-1965, a few thousand tons of uranium ozide had been extracted from the Shinarump Member, although the Happy Jack mine probably accounted for the bulk of this production (Malan, 1968). In plan view, the White Canyon mining district is a small part of an arcuate mineralized zone, convex to the west, that extends from northern Arizona to Elk Ridge at the north end of the Monument Upwarp. According to Malan (1968), this mineralized belt coincides with channel sandstones that were deposited along the margin of an upland that existed during early Chinle time.

Deposits range in size from a few tons of ore to more than 800,000 tons, at a grade of about 0.25 percent U_3O_8 (Campbell and others, 1980; Malan, 1968; Thaden and others, 1964). More than 95 percent of the deposits, however, contain less than 50,000 tons of ore (Malan, 1968).

Numerous uranium deposits occur within and very near to Tract 191 (see Geologic Sketch Map). Most are small and have produced less than 20 tons of uranium oxide, although production from a property along the east side of the tract has been in excess of 200 tons uranium oxide (Hackman and Wyant, 1973; many additional deposits and prospects are shown in this area by Peterson and others, 1980, plate 2).

According to Hackman and Wyant (1973), the northern-most depositional limit of the Shinarump passes through the approximate center of Tract 191. Potential uranium deposits in the tract north of this boundary will likely be small (much less than 100 tons uranium oxide). Uranium occurrences and deposits are known from the southeast side of the tract, and it seems very reasonable to assume that deposits containing between 150 and 1,500 tons of uranium oxide may be contained in this area (an f3 favorability). We have therefore assigned Tract 191 an f3 uranium favorability and a c4 certainty that uranium resources exist in the tract.

[Note: The final boundary of the WSA as it appears of maps prepared by the BLM in Novemeber 1980 does not include the favorable Chinle

Formation along the southeast side of the tract. This area, however, was included in this evaluation.]

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Certaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 191 consists of sedimentary rocks of Late Paleozoic age that are underlain by a normal sequence of middle and lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks (Hackman and Wyant, 1973; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 191 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 191 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael and Colorado River Systems has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 191 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDRPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 191. On the basis of this information we have assigned Tract 191 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c3

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and

fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

Gregory (1938, p. 107) states that copper prospecting in the White Canyon area may have begun about 1880. After much activity in 1906 and 1907 because of high copper prices, a copper processing plant was planned for Fry Canyon just south of the tract. The plant was never built and the area again became idle. The first shipment of copper ore was sent to the mill in 1916 for testing. The ore was extracted from the Happy Jack mine, but the results were not encouraging and the district remained idle until the mid-1940s (Gregory, 1938; Butler and others, 1920; Thayden and others, 1964; Malan, 1968). In 1946, two truckloads of copper ore were sent to the smelter in Garfield, Utah but the ore was unacceptable because of its uranium content. Then in 1948, after recognition of the uranium potential of the area, a truckload of uranium ore was sent to the uranium mill in Monticello, Utah. Ironically, the ore was unacceptable because of its copper content (Thayden and other, 1964). Large uranium deposits were later found and mined in the late-1940s and early-1950s, with copper as the chief byproduct. Copper content of the uranium deposits is generally between 0.12 and 1.3 percent (Malan, 1968).

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium deposits in this part of the Colorado Plateau are so closely associated (and are related in a historical sense) we have assigned Tract 191 a copper favorability of f2. The certainty that copper resources occur in the tract is high, based on known occurrences nearby, and is assigned a value of c3.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout the province, the estimated manganese potential of southeastern Utah is nevertheless very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 191, except for part of the Chinle Formation preserved along ridge tops (Hackman and Wyant, 1973; Haynes and others, 1972). The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because this area was extensively explored during the uranium boom of the 1950s (and manganese was not reported from the Chinle), and because manganese is not known to be associated with the Paleozoic sequence on the Colorado Plateau, we have assigned Tract 191 a manganese favorability of f1, but with a certainty of non-occurrence of only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin -- that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 191 lies many miles southwest of the thick potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks did exist in the Paradox Formation in this area, they would probably be thin and discontinuous, and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 3-

Tract 191 has been assigned an overall importance rating (OIR) of 3- (on a 1 to 4 scale where 4 is equated with high mineral importance). The chief reason for this rating is the uranium favorability (f3) and the relatively high certainty that uranium resources exist in the tract. If the southeastern segment of the tract had not been included in this evaluation [it is included included on the map accompanying BLM (1980)], the tract would have been assigned an OIR of 2. The tract was assigned an OIR of 3- rather than 3 because the favorable Chinle Formation is preserved in only a relatively small part of the tract.

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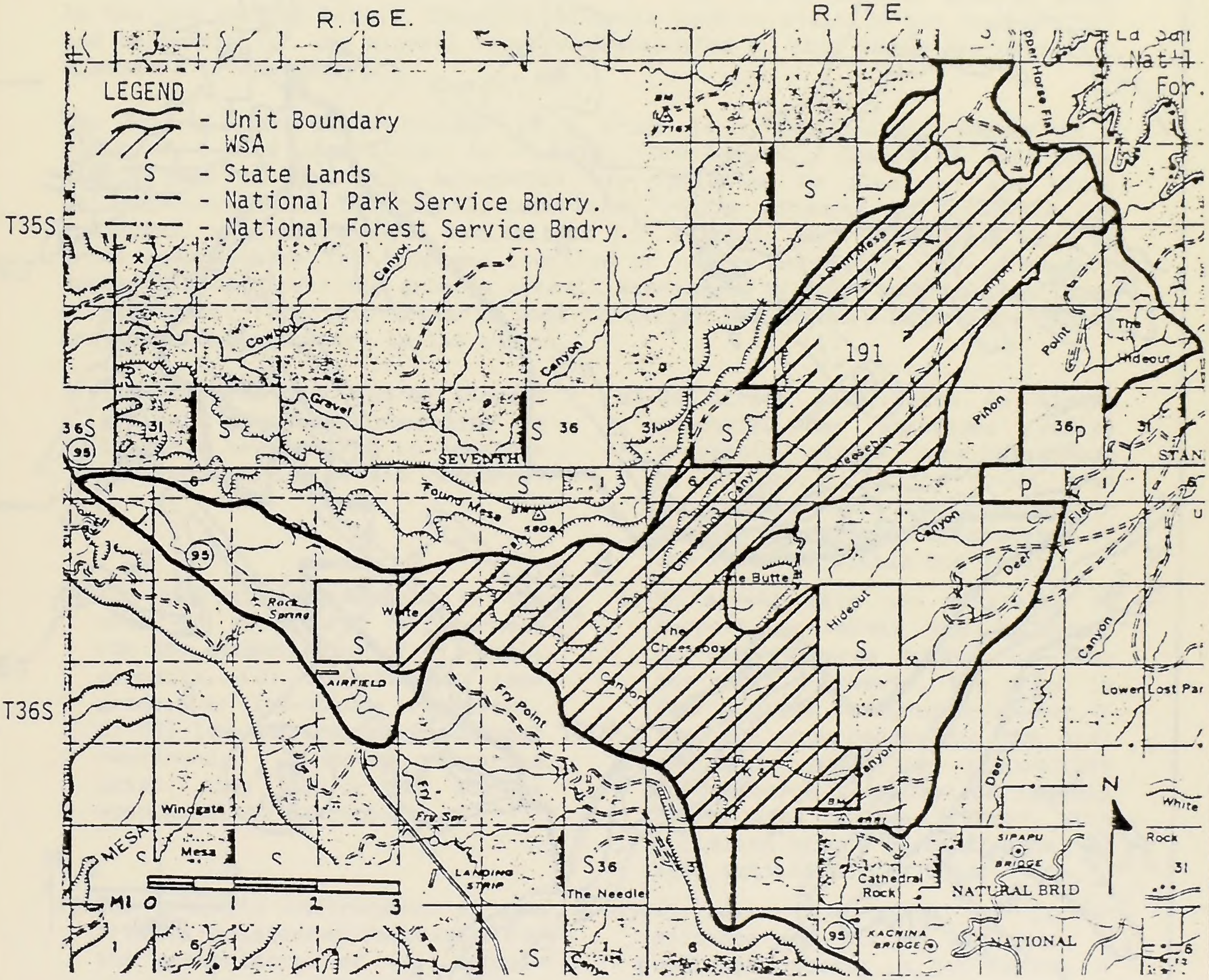
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 191, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



EXPLANATION

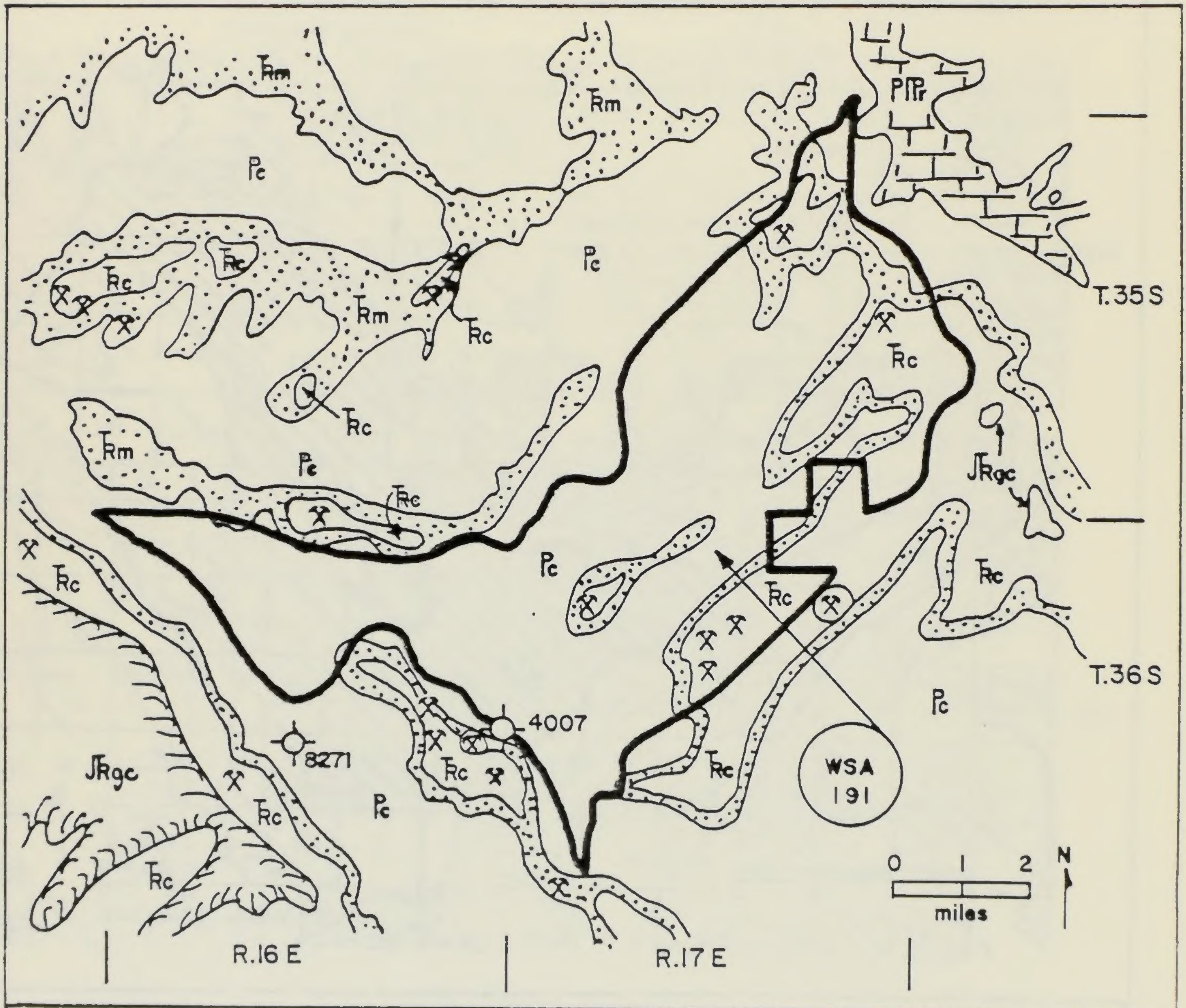
URANIUM WAS ASSIGNED A FAVORABILITY OF f3. THIS RATING APPLIES TO ONLY A SMALL PART OF TRACT 191 (SEE DIS USSION IN TEXT).

ALL OTHER RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED FAVORABILITIES OF LESS THAN f3.

SOURCE: BASE FROM BLM (1982)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 191, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

JTRgc - GLEN CANYON GROUP (TRIASSIC & JURASSIC)

TRc - CHINLE FORMATION (TRIASSIC)

TRm - MOENKOPI FORMATION (TRIASSIC)

Pc - CUTLER FORMATION (PERMIAN)

PIPr - RICO FORMATION (PENNSYLVANIAN/PERMIAN)

-ϕ-4007 OIL AND GAS EXPLORATORY WELL (DRY)

⊗ URANIUM DEPOSIT WITH 10 TO 100 TONS PRODUCTION OF U_3O_8

⚒ URANIUM, < 10 TONS PRODUCTION U_3O_8

SOURCE: GEOLOGIC DATA, HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

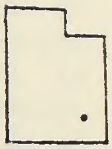
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 194* **TRACT NAME:** Harmony Flat **STATE/CUNTY:** UT/Emery

DISTRICT: Moab **UNIT ACREAGE:** 10,470

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

*[This tract has been dropped from the BLM's Wilderness Review. The boundary of the tract was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab, Utah.]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 194 lies a short distance west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists almost entirely of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). Triassic rocks crop out a few miles to the north, east, and west. No obvious structural features occur in the tract.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "1+" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1+

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 194 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 194 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 194 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 194 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 194, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has

stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 194 the Paradox Formation is probably less than 1,000 feet below the surface. About 25 miles south of Tract 194, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River, and Pennsylvanian rocks exposed about 25 miles to the north in Dark Canyon (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 194 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 194 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 194 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 194, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 194 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississppian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Tract 194 (PIC, 1981). Although the wells in the area have all been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heymun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 194, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 194 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratoy wells within the tract.

URANIUM/VANADIUM <u>f1/c1</u>

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 194 lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 25 miles to the northwest and the Monument Valley uranium mining district lies about 30 miles to the south (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 194 are about 2 miles to the west in the Fry and Red Canyon areas and a few miles to the north in the Deer flat area (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 194 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 194 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 194, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 194 is low, and has been assigned a rating of c1.

COAL <u>f1/c4</u>

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 194 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 194 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL <u>f1/c3</u>

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 194 is deep-seated, low-temperature thermal waters (between 20°C and 90°C).

Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 194 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 194. The closest identified, undeveloped site is along the San Juan River near the mouth of Slickhorn Canyon a mile south of the tract [estimated capacity of 62,000 kilowatts; FERC (1981)]. Development of this site would probably not encroach upon the southern boundary of Tract 194. We have therefore assigned Tract 194 a hydropower favorability rating of f1. The certainty that a hydropower resource does not exist within the tract is high, and has been assigned a rating of c4.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 194 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds

of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 194. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 194 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH <u>f1/c3</u>

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 194 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 1+

Tract 194 has been assigned an overall importance rating (OIR) of 1+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only. The tract was assigned an OIR of 1+ rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with designated Wilderness Study Areas in this part of the Monument Upwarp.

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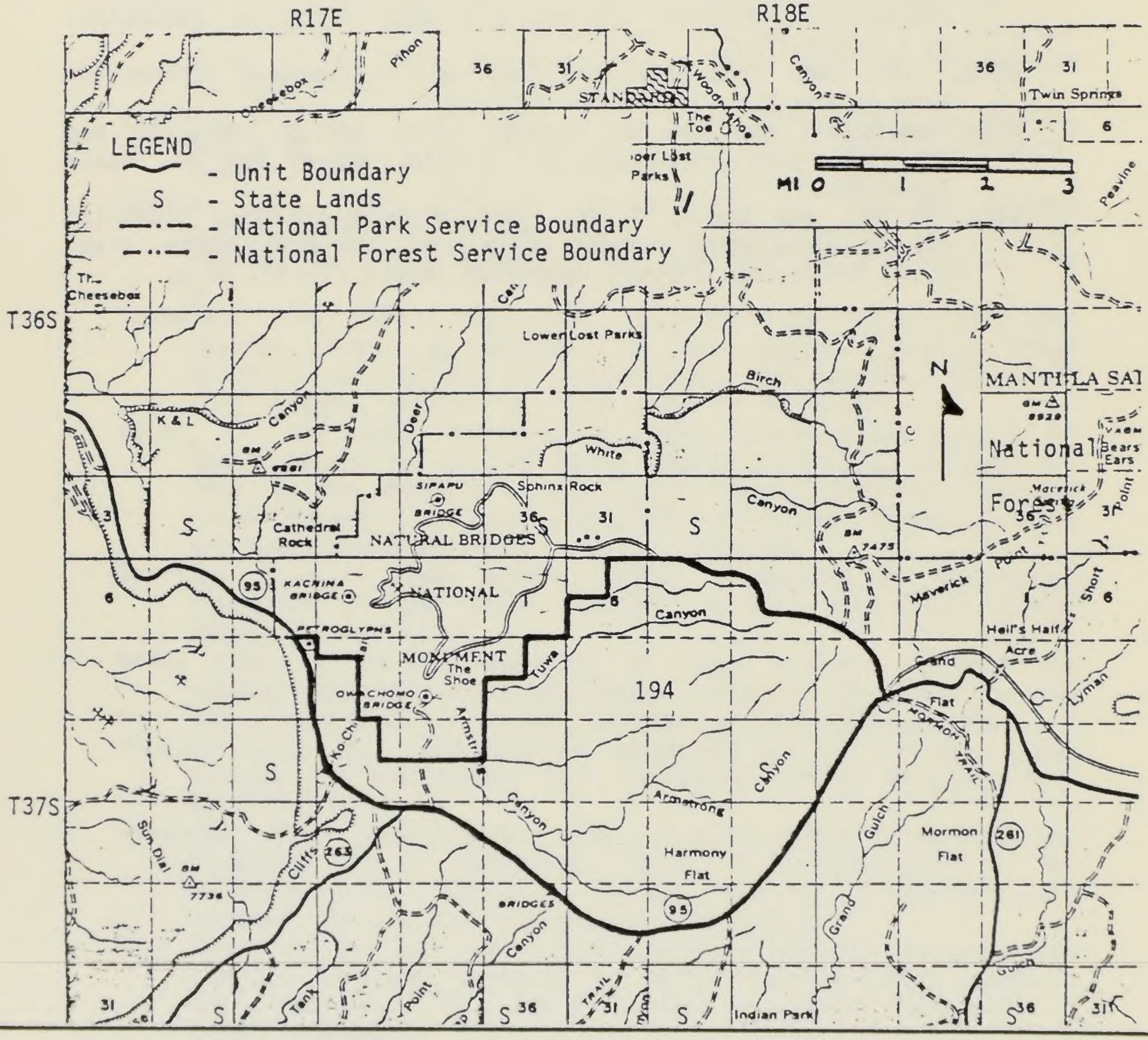
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 194 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



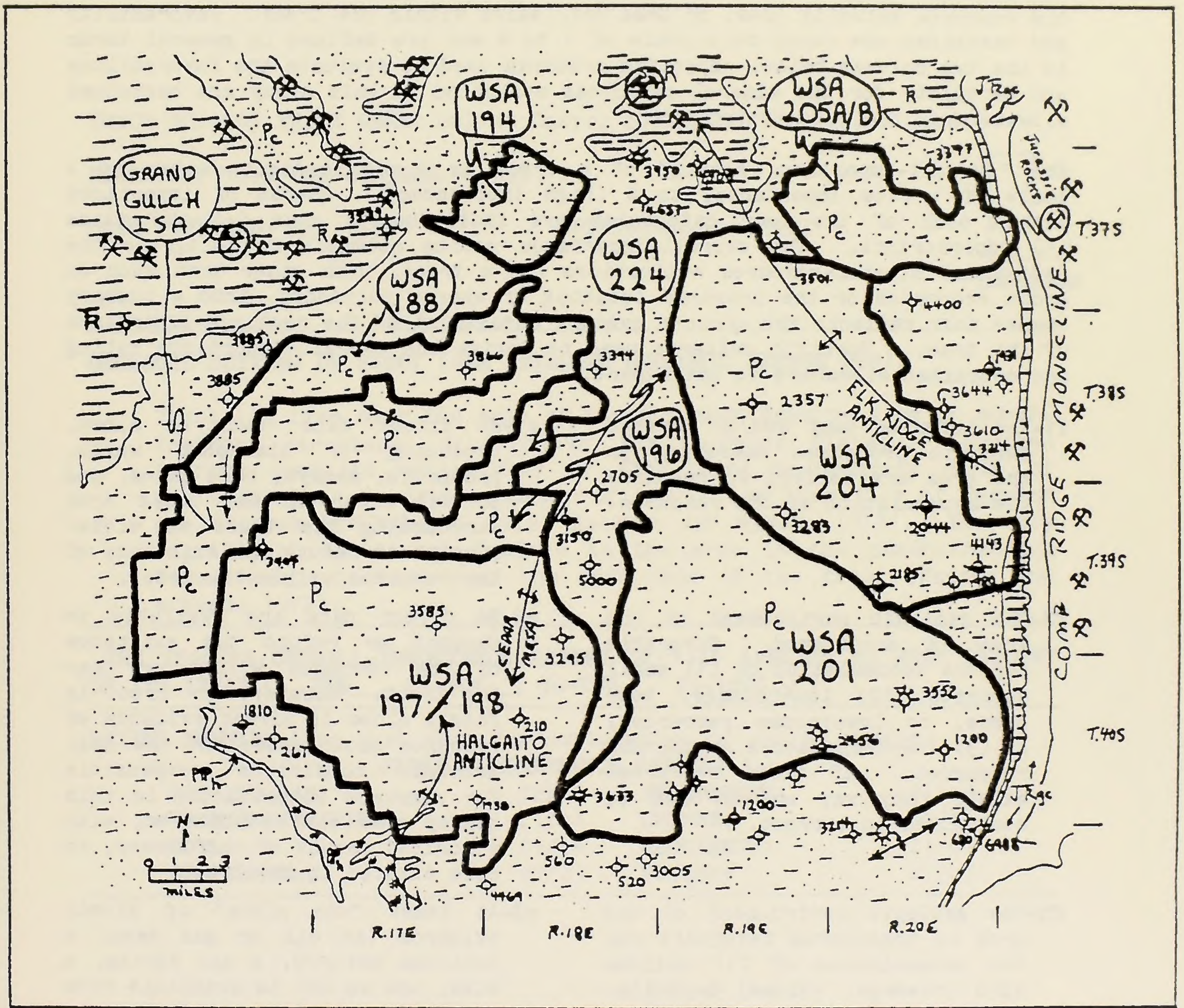
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN 53.

SOURCE: MAP SOURCE, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

T̄R - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

Pc - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

IPh - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

OIL AND GAS WELL SHOWING TOTAL DEPTH 9210

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

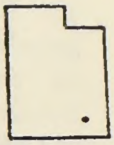
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 196 **TRACT NAME:** Bullet Canyon **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 8,730

DATE PREPARED: May 1982 **UPDATE:** August 1982


LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 196 lies near the axis of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Exposed bedrock consists exclusively of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). The only significant structural feature in the area is the north-trending Cedar Mesa anticline near the east side of the tract (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "1+" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1+

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 196 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 196 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 196 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 196 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 196, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 196 the Paradox Formation is probably less than 1,000 feet below the surface. About 15 miles south of Tract 196, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 196. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 196 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 196 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 196 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 196, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 196 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Tract 196 (PIC, 1981). Although all wells in the area have been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (see attached Geologic Sketch Map; Heylmun and others, 1965). For example, British American Oil drilled a 3,150-foot well along the Cedar Mesa anticline less than a mile from the east side of the tract and reported oil shows in the Paradox/Hermosa and in the underlying Molas Formation (Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 196, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 196 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 196 lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 25 miles to the northwest and the Monument Valley uranium mining district lies about 30 miles to the south (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 196 are about 10 miles to the north in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 196 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 196 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 196, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 196 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 196 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 196 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 196 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 196 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 196. On the basis of this information we have assigned Tract 196 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type

of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 196 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 196. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 196 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH <u>f1/c3</u>

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 196 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972).

Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 1+

Tract 196 has been assigned an overall importance rating (OIR) of 1+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only. The tract was assigned an OIR of 1+ rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with other Wilderness Study Areas in this part of the Monument Upwarp.

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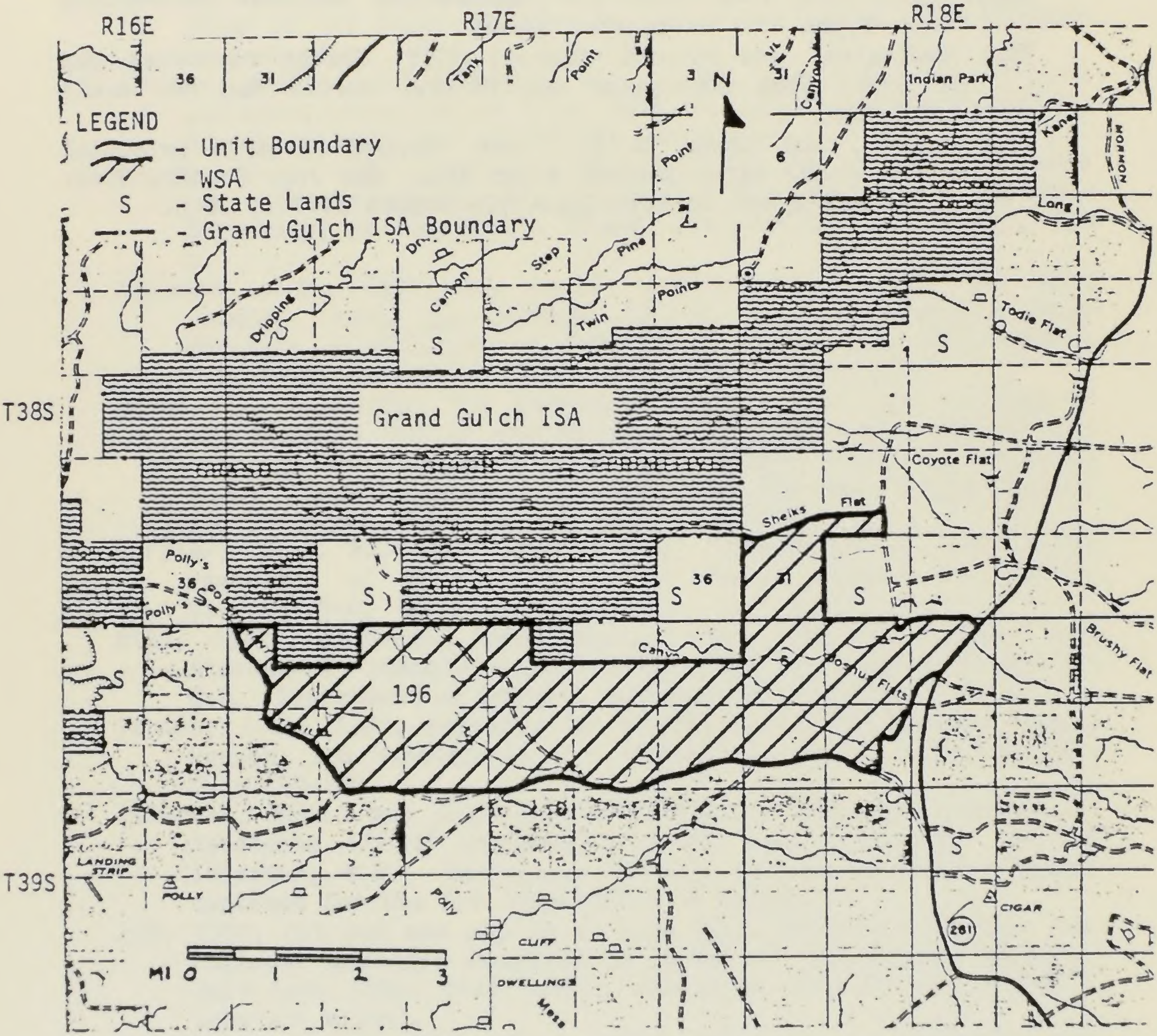
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 196 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



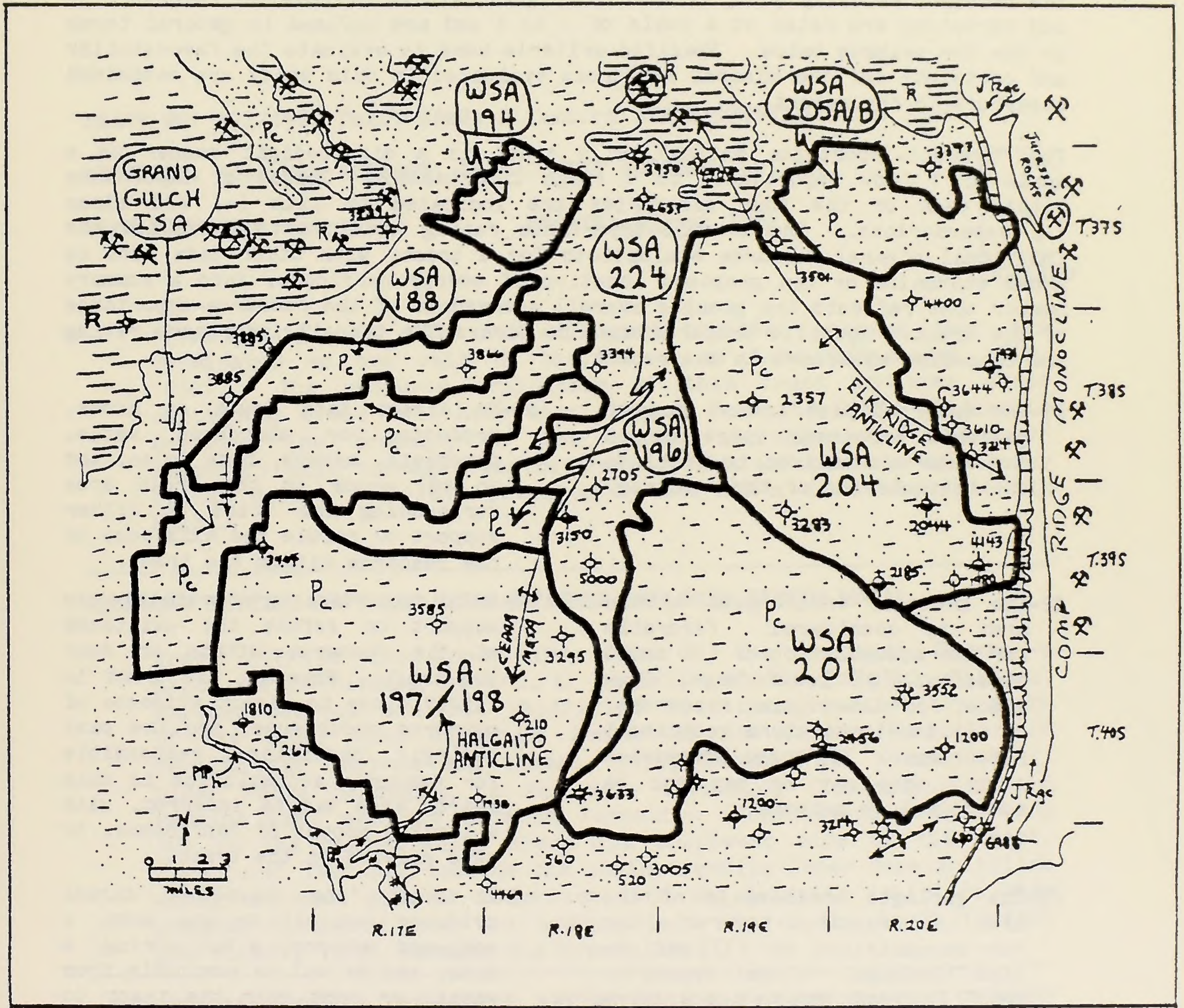
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~5~~ 3.

SOURCE: MAP SOURCE, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224, 196

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TR - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

Pc - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

IPh - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

OIL AND GAS WELL SHOWING TOTAL DEPTH 9210

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

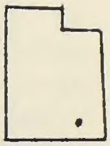
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 197/198* **TRACT NAME:** Slickhorn **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 46,800 **UNIT ACREAGE:** 60,710

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

*[Tracts 197 and 198 are evaluated together because they are considered as one unit by the Bureau of Land Management (BLM, 1980). The resource evaluation of this tract includes three contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract, including the intensive inventory unit acreage, was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 197/198 lies near the axis of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Exposed bedrock consists chiefly of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). Older rocks belonging to the Rico Formation (Pennsylvanian and Permian age) and the Hermosa Formation (Pennsylvanian age) crop out in the canyon walls along the southwest side of the tract. Structural features include the north-trending Cedar Mesa anticline along the east side of the tract, and the Halgaito anticline that extends northward into the southwest corner of the tract (Haynes and others, 1972; Hackman and Wyant, 1973).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY: (See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS <u>f2/c2</u>

Tract 197/198 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 197/198 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 197/198 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 197/198 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 197/198, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox

Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 197/198 the Paradox Formation is probably less than 1,000 feet below the surface. A short distance south of Tract 197/198, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 197/198. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away. In partial support of this hypothesis are the oil seeps in the Mexican Hat area that originally led to the discovery of the Mexican Hat field near the San Juan River in 1908 (Lauth, 1978).

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 197/198 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 197/198 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 197/198 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 197/198, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 197/198 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a dozen exploratory wells had been drilled in the vicinity of Tract 197/198 (PIC, 1981). Five of the wells were drilled within the tract; a 3,404-foot well in the northwest corner drilled by Sinclair Oil reportedly had oil shows in the Paradox Formation (Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 197/198, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 197/198 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 197/198 lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 35 miles to the northwest and the Monument Valley uranium mining district lies about 25 miles to the south (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest significant uranium deposits to Tract 197/198 are about 10 miles to the north in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 197/198 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 197/198 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 197/198, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 197/198 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 197/198 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 197/198 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 197/198 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 197/198 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 197/198. The closest identified, undeveloped site is along the San Juan River near the mouth of Slickhorn Canyon a few miles from the southwest corner of the tract [estimated capacity of 62,000 kilowatts; FERC (1981)]. Development of this site might inundate the lower part of some canyons within Tract 197/198. Nevertheless, the bulk of the tract would not be affected by development of this hydropower site, and we have assigned Tract 197/198 a hydropower favorability rating of f1. The certainty that a hydropower resource does not exist within the tract is high, and has been assigned a rating of c4.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 197/198 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 197/198. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 197/198 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 197/198 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 2

Tract 197/198 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only.

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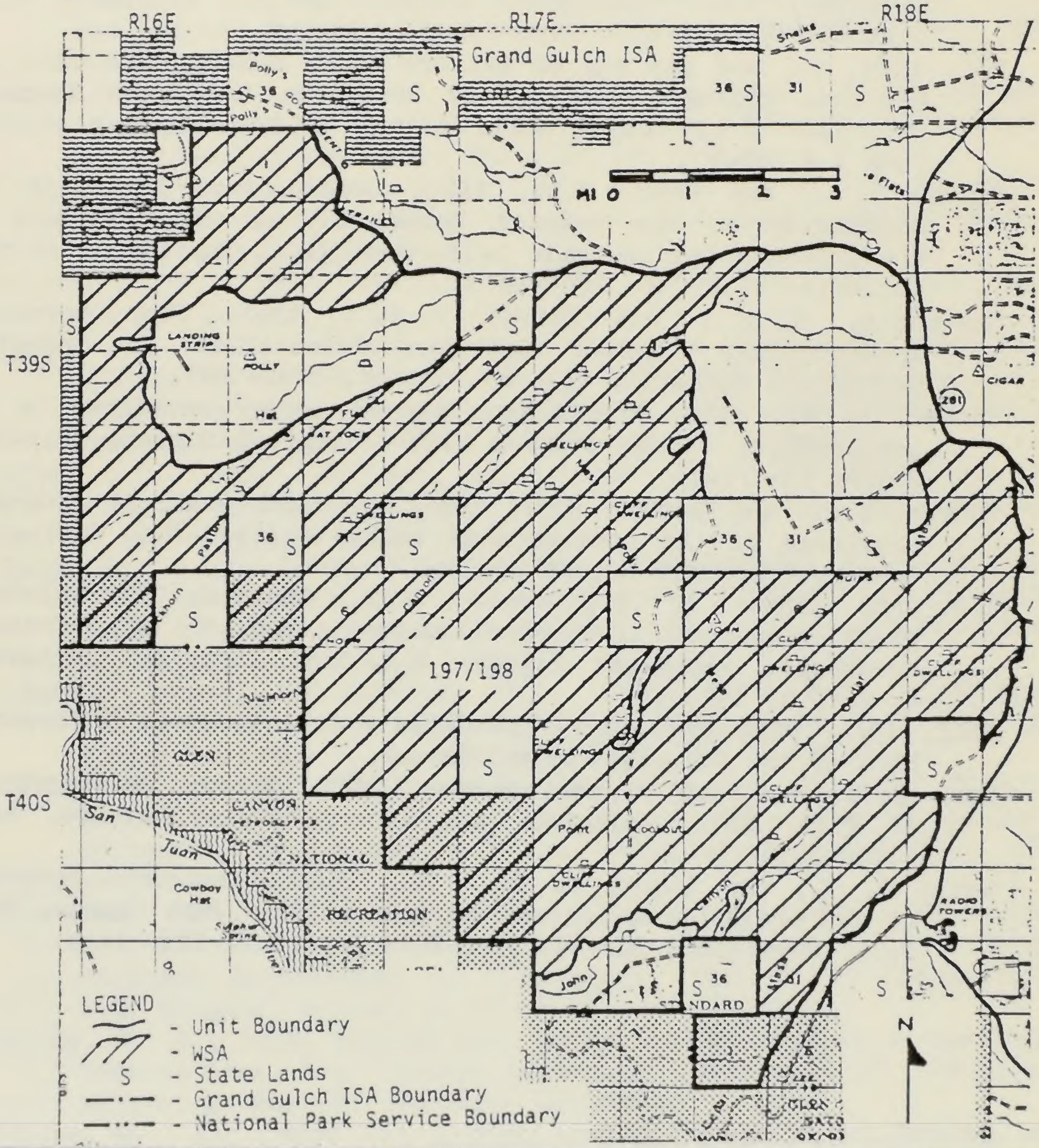
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 197/198, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



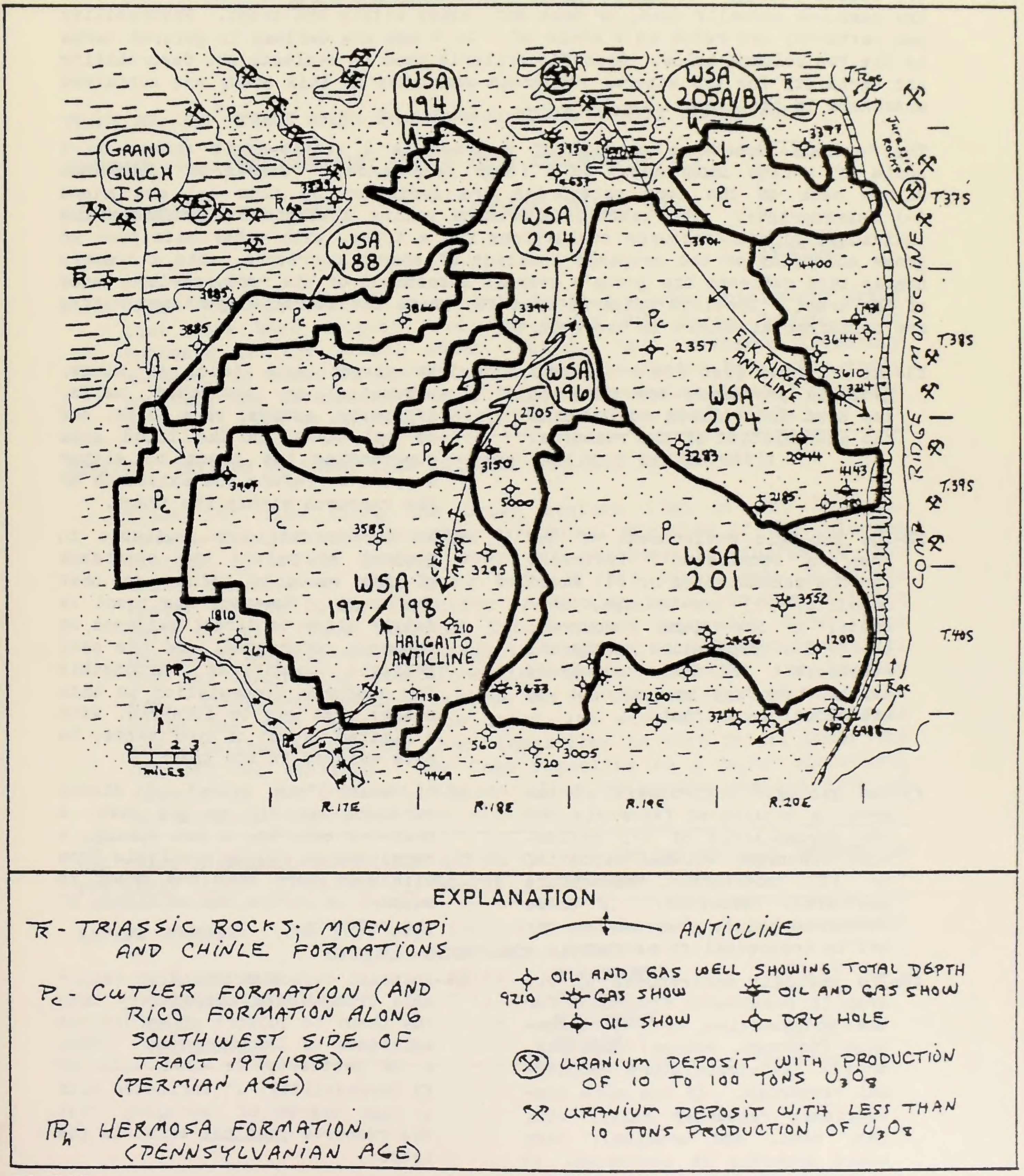
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~5~~3.

SOURCE: BLM (1980), MAP SOURCE

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



SOURCE: GEOLGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 201[*] **TRACT NAME:** Road Canyon **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 65,000 **UNIT ACREAGE:** 76,170

DATE PREPARED: May 1982 **UPDATE:** August 1982

LOCATION

*[The resource evaluation of this tract includes contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract, which includes the intensive inventory acreage, is shown on the attached Geologic Sketch Map. The tract boundary was determined from a "Wilderness Status Report" prepared on May 1, 1981 by the BLM's district office in Moab, Utah.]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 201 lies along the broad eastern limb of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Surface geology over the northern two-thirds of the tract consists of flat-lying beds of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age. In the southern part of the tract, erosion has stripped away the Cedar Mesa Sandstone and exposed the Halgaito Tongue of the Cutler Formation, and the underlying Rico Formation of Pennsylvanian and Permian age. Structural features include the north-trending Comb monocline along the east side of the tract and several broad anticlines and synclines within the tract (described in more detail under the OIL AND GAS section). The Comb monocline is a major structural feature of the Colorado Plateau along which the eastern side of the Monument Upwarp has been elevated.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (<25% __, 25-50% __, 50-75% __, 75-100% ✓).

RATING SUMMARY: (See last page for brief explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 201 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 201 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 201 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 201 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 201, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has

stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Throughout most of Tract 201 the Paradox Formation is less than 1,000 feet below the surface. A short distance south of Tract 201, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 201. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away. In partial support of this hypothesis are the oil seeps in the Mexican Hat area that originally led to the discovery of the Mexican Hat field near the San Juan River in 1908 (Lauth, 1978).

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 201 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 201 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 201 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 201, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 201 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about two dozen exploratory wells had been drilled within a five-mile radius of Tract 201; some drilling was still underway in 1981 (PIC, 1981). Many of the well sites are located within the tract (PIC, 1981). Although all wells in the area have been abandoned (or shut-in such as the one well along the tract's southeast border), some reportedly had oil shows and stains in the lower part of the Paradox Formation (three wells in the southern part of the tract had shows of oil and/or gas; Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 201, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 201 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 201 lies along the east side of the Monument Upwarp. The White Canyon uranium mining district lies about 45 miles to the northwest and the Monument Valley uranium mining district lies about 25 miles to the southwest (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than

1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 201 uranium deposits occur about 8 miles to the northeast in the Recapture Member of the Morrison Formation (Haynes and others, 1972). The deposits occur at the base of the Comb monocline; production from individual deposits has in most cases been less than 20 tons uranium oxide, although some deposits have produced in excess of 100 tons uranium oxide (Haynes and others, 1972). In addition, uranium deposits occur about 15 miles to the northwest in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972). In addition,

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 201 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 201 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 201, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 201 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 201 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 201 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 201 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 201 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 201. The closest identified, undeveloped site is a few miles to the south, along the San Juan River near Bluff, Utah. The development of this site, however, would have no affect on Tract 201, nor would the designation of this tract as wilderness have any affect on the possible development of this hydropower site. On the basis of this information we have assigned Tract 201 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 201 a copper favorability of f1.

The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 201. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 201 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 201 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 2

Tract 201 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only.

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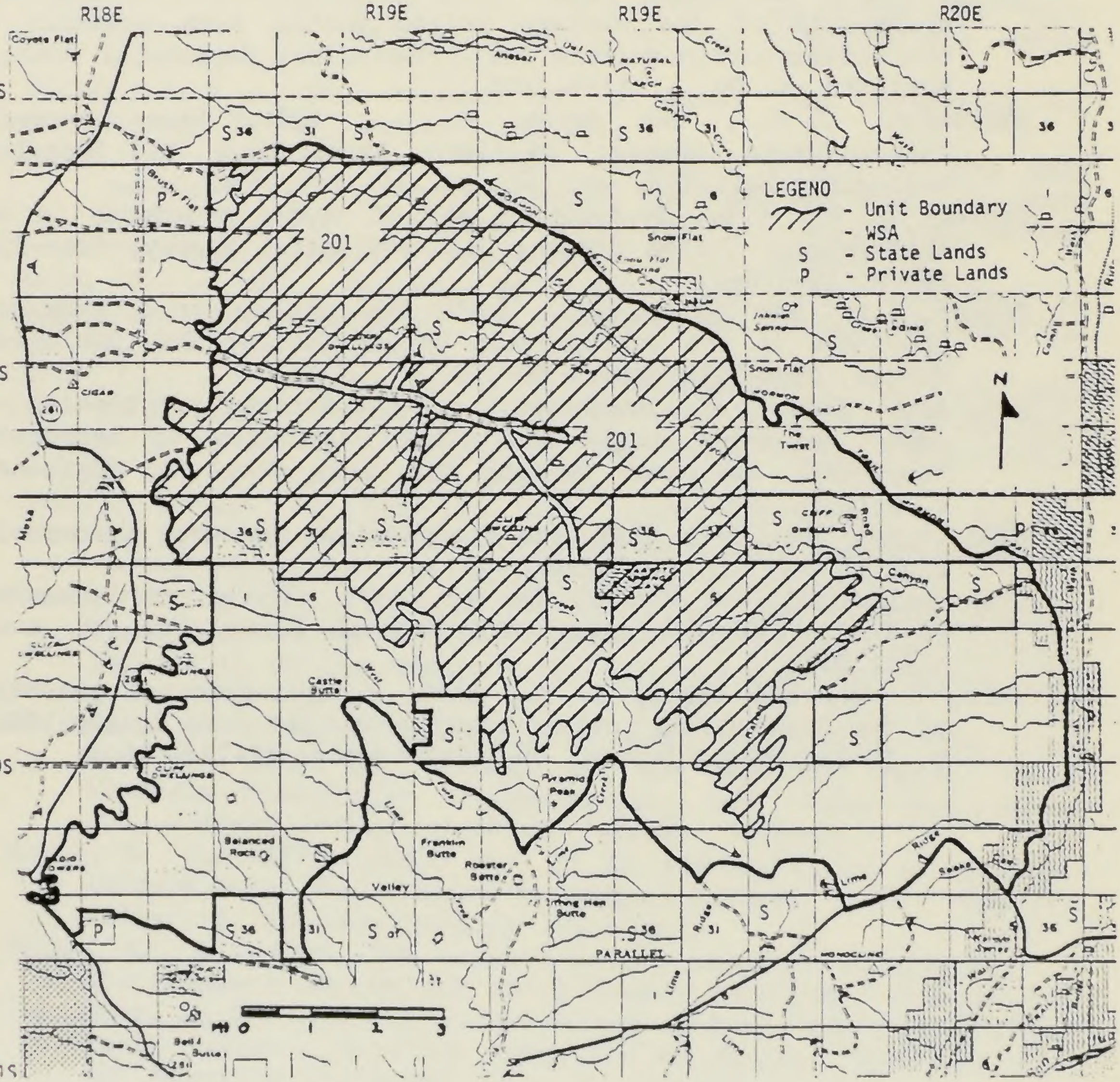
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 201, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



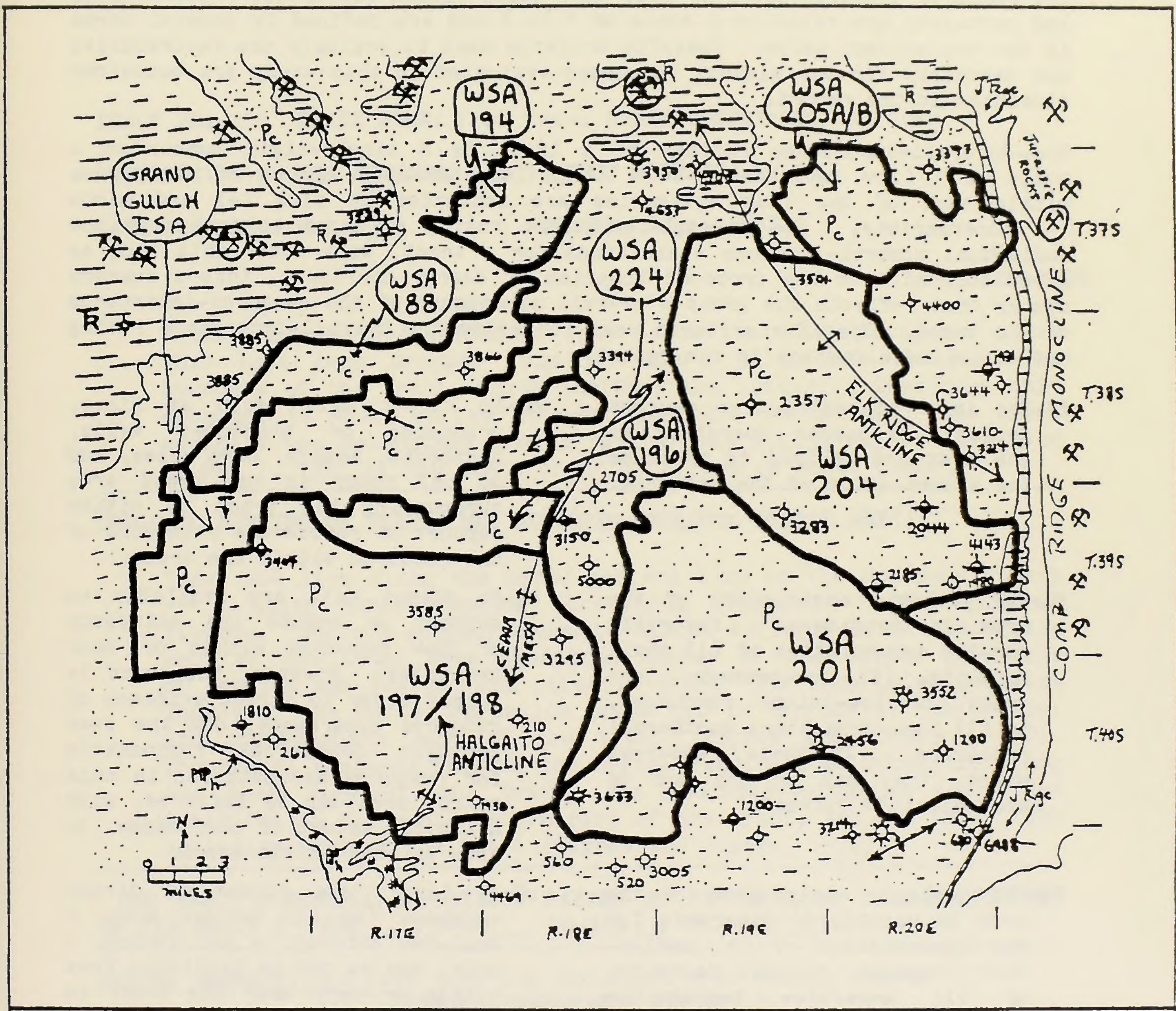
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~5~~3.

SOURCE: BLM, 1980 (MAP SOURCE)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

R - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

Pc - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

Ph - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

OIL AND GAS WELL SHOWING TOTAL DEPTH 9210

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

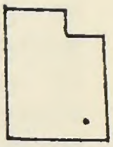
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 204* **TRACT NAME:** Fish Creek **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 48,530 **UNIT ACREAGE:** 52,050

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

*[The resource evaluation of this tract includes contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract, which includes the intensive inventory unit acreage, is shown on the attached Geologic Sketch Map. The tract boundary was determined from a "Wilderness Status Report" prepared on May 1, 1981 by the BLM's district office in Moab, Utah.]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 204 lies along the broad eastern limb of the Monument Upwarp -- a major north-trending structural division of the Colorado Plateau. Surface geology consists almost exclusively of flat-lying beds of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972). The underlying Halgaito Tongue of the Cutler Formation crops out in canyons in the central and southeastern part of the tract (Haynes and others, 1972). Structural features include the north-trending Comb monocline along the east side of the tract, the southeast-plunging Elk Ridge anticline in the northeastern part of the tract, and the Cedar Mesa anticline west of the tract (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 204 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 204 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 204 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 204 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 204, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has

stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 204 the Paradox Formation is probably less than 1,000 feet below the surface. South of Tract 204, most or all of the Paradox Formation (or Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 204. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away. In partial support of this hypothesis are the oil seeps in the Mexican Hat area that originally led to the discovery of the Mexican Hat field near the San Juan River in 1908 (Lauth, 1978).

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 204 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 204 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 204 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 204, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 204 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about two dozen exploratory wells had been drilled within a five-mile radius of Tract 204; some drilling was still underway in 1981 (PIC, 1981). Many of the well sites are located within the tract (PIC, 1981). Although all wells in the area have been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (three of the wells in the southern part of the tract had oil shows; Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. The dominant structural feature within the tract is the Elk Ridge anticline (Haynes and others, 1972). This structure has been drilled north of the tract, and three wells penetrated the anticline just east of the tract (PIC, 1981). Total depths were between 3,100 and 3,700 feet and all the wells were dry. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 204, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 204 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratoy wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 204 lies along the east side of the Monument Upwarp. The White Canyon uranium mining district lies about 45 miles to the northwest and the Monument Valley uranium mining district lies about 30 miles to the southwest (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--

Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 204 are about 8 miles to the northwest in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972). In addition, uranium deposits occur about 10 miles to the east in the Recapture Member of the Morrison Formation (Haynes and others, 1972). The deposits occur at the base of the Comb monocline; production from individual deposits has in most cases been less than 20 tons uranium oxide, although some deposits have produced in excess of 100 tons uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 204 (Hackman and Wyant, 1973; Haynes and others, 1972; on the attached Geologic Sketch Map, the boundary of Tract 204 is shown to extend onto the Comb monocline and encompass a small part of Triassic rocks. With the maps available, it is not known with certainty whether the tract actually includes part of the Chinle Formation. For this evaluation, we have assumed that Tract 204 does not include the Chinle Formation). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 204 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 204, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 204 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 204 consists of sedimentary rocks of Late Paleozoic age that are underlain by a normal sequence of Middle and Lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks ((Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 204 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah, such as hot springs, young igneous rocks, high heat-flow, and crustal instability, but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 204 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Colorado Plateau has probably resulted in extreme depths over much of the Colorado Plateau to even the low-temperature geothermal resources . On the basis of the geologic characteristics of the Colorado Plateau, we have therfore assigned Tract 204 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 204. On the basis of this information we have assigned Tract 204 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 204 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 204 (Haynes and others, 1972). The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 204 a manganese favorability of f1, but with a certainty of occurrence rating of c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin -- called the Paradox Basin -- that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 204, however, lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 2

Tract 204 has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only.

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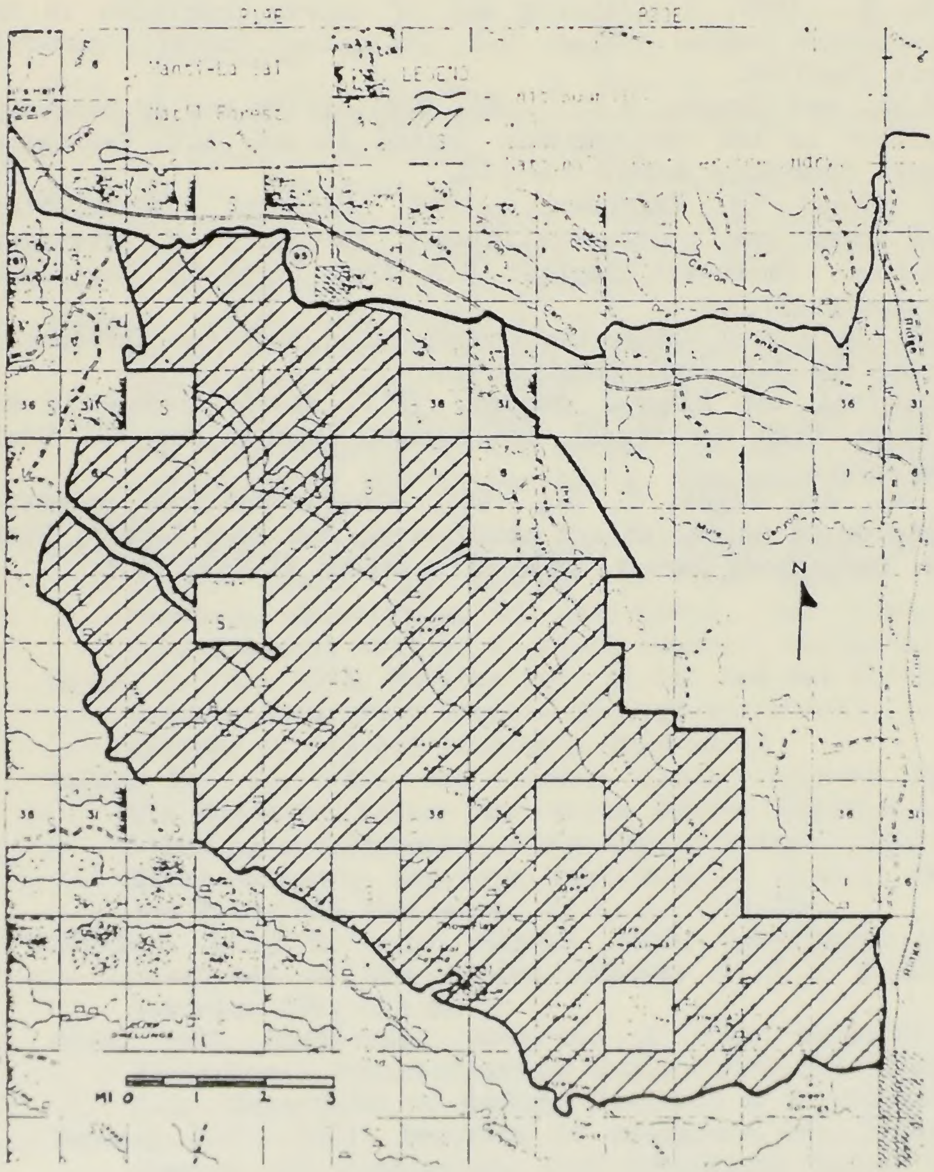
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 204 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



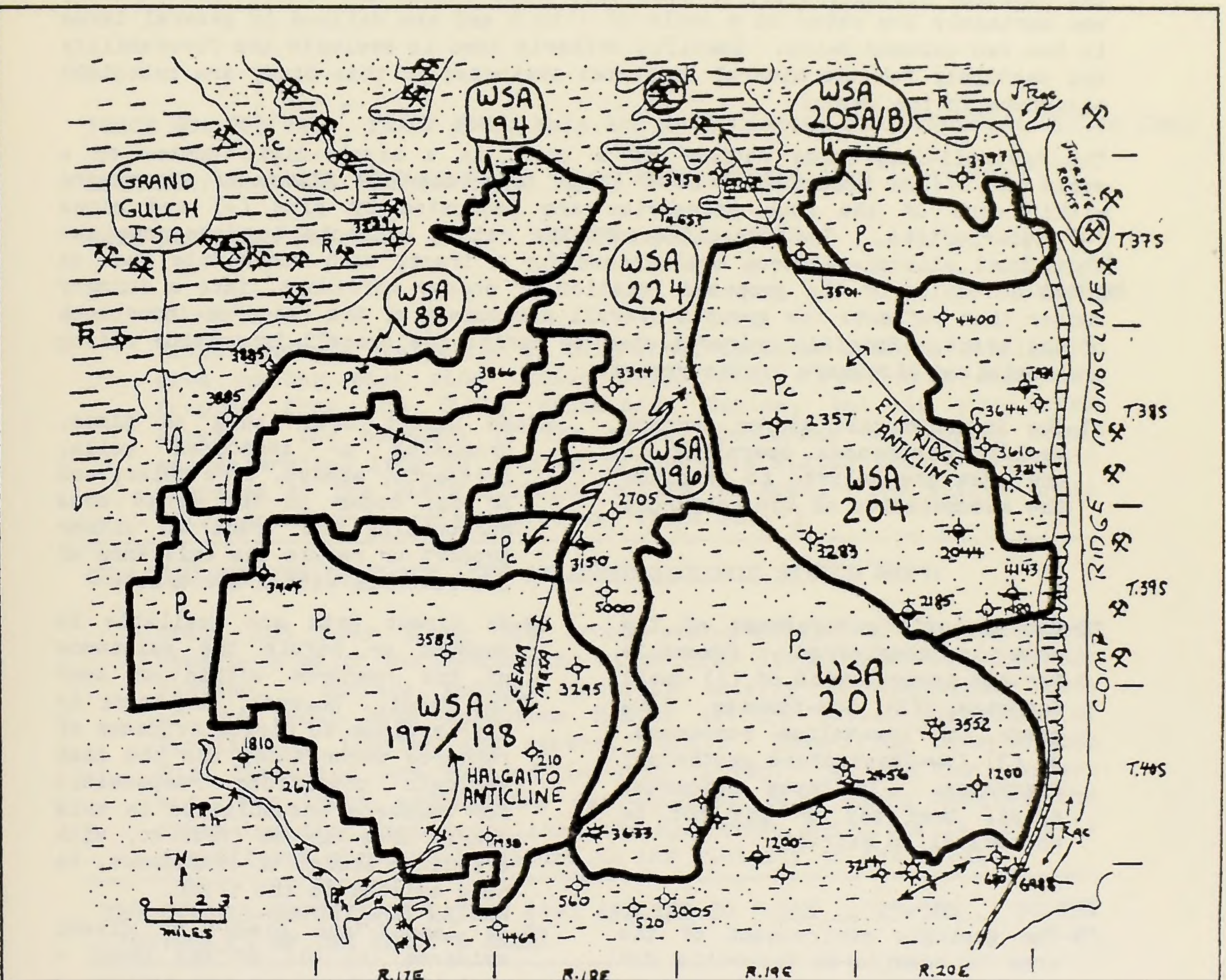
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~F~~ 3

SOURCE: SOURCE OF MAP, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TR - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

P_c - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

IP_h - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

OIL AND GAS WELL SHOWING TOTAL DEPTH
9210

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

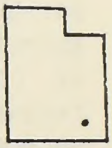
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource <u>does not</u> exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 205(A&B)* **TRACT NAME:** Mule and Arch Canyons **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE (B*):** 5,600 **UNIT ACREAGE (A&B*):** 13,100

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

*[The resource evaluation of this tract includes a large contiguous area on the east side (Tract 205A--7,500 acres) that has been dropped from the BLM's Wilderness Review, but is now under appeal. The boundary of the tract, including the appeal area, was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab. The entire tract will hereafter be referred to as "Tract 205."]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 205 lies along the broad eastern limb of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Surface geology consists chiefly of flat-lying beds of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972). Underlying beds of the Rico Formation are exposed in Arch Canyon. At its far eastern end, the tract encompasses east-dipping beds along Besides the north-trending Comb monocline, the Elk Ridge anticline is the only significant structural feature in the vicinity of the tract.

THE OVERALL-IMPORTANCE RATING (1+) APPLIES TO (<25%__, 25-50%__, 50-75% , 75-100%_✓) OF THE TRACT'S AREA.

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1+

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Tract 205 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 205 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 205 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 205 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 205, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has

stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 205 the Paradox Formation is probably less than 1,000 feet below the surface. About 40 miles south of Tract 205, most or all of the Paradox Formation (or Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). In addition, Pennsylvanian rocks are exposed about 30 miles to the north in Dark Canyon. It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 205. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away. In partial support of this hypothesis are the oil seeps in the Mexican Hat area that originally led to the discovery of the Mexican Hat field near the San Juan River in 1908 (Lauth, 1978).

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 205 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 205 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 205 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 205, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 205 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a half dozen exploratory wells had been drilled in the vicinity of Tract 205 (PIC, 1981). Although all wells in the area have been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (see attached Geologic Sketch Map; Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. The dominant structural features in this area are the Elk Ridge anticline and the Comb monocline (Haynes and others, 1972). The Elk Ridge anticline has been drilled west and south of the tract (see WSA 204), to depths between 3,100 and 3,700 feet and all the wells were reportedly dry (PIC, 1981). The east side of the Comb monocline was drilled about 5 miles south of the tract to a depth of 1,931 feet and reported oil shows in the Paradox Formation (Heylmun and others, 1965). Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 205, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 205 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells near the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 205 lies along the east side of the Monument Upwarp. The White Canyon uranium mining district lies about 40 miles to the northwest and the Monument Valley uranium mining district lies about 35 miles to the southwest (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Tract 205 are about 5 miles to the northwest in the Deer Flat area (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972). In addition, uranium deposits occur about 5 miles to the east in the Recapture Member of the Morrison Formation (Haynes and others, 1972). The deposits occur at the base of the Comb monocline; production from individual deposits has in most cases been less than 20 tons uranium oxide, although some deposits have produced in excess of 100 tons uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 205 (Hackman and Wyant, 1973; Haynes and others, 1972; on the attached Geologic Sketch Map, the boundary of Tract 205 is shown to extend onto the Comb monocline and encompass a small part of Triassic rocks. With the maps available, it is not known with certainty whether the tract actually includes part of the Chinle Formation. For this evaluation, we have assumed that Tract 205 does not include the Chinle Formation). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 205 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 205, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 205 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 205 consists of sedimentary rocks of Late Paleozoic age that are underlain by a normal sequence of Middle and Lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks ((Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 205 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah, such as hot springs, young igneous rocks, high heat-flow, and crustal instability, but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 205 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Colorado Plateau has probably resulted in extreme depths over much of the Colorado Plateau to even the low-temperature geothermal resources . On the basis of the geologic characteristics of the Colorado Plateau, we have therfore assigned Tract 205 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 205. On the basis of this information we have assigned Tract 205 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER <u>f1/c1</u>

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 205 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 205 (Haynes and others, 1972). The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 205 a manganese favorability of f1, but with a certainty of occurrence rating of c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin -- called the Paradox Basin -- that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 205, however, lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 1+

Tract 205 has been assigned an overall importance rating (OIR) of 1+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only. The tract was assigned an OIR of 1+ rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with other Wilderness Study Areas in this part of the Monument Upwarp.

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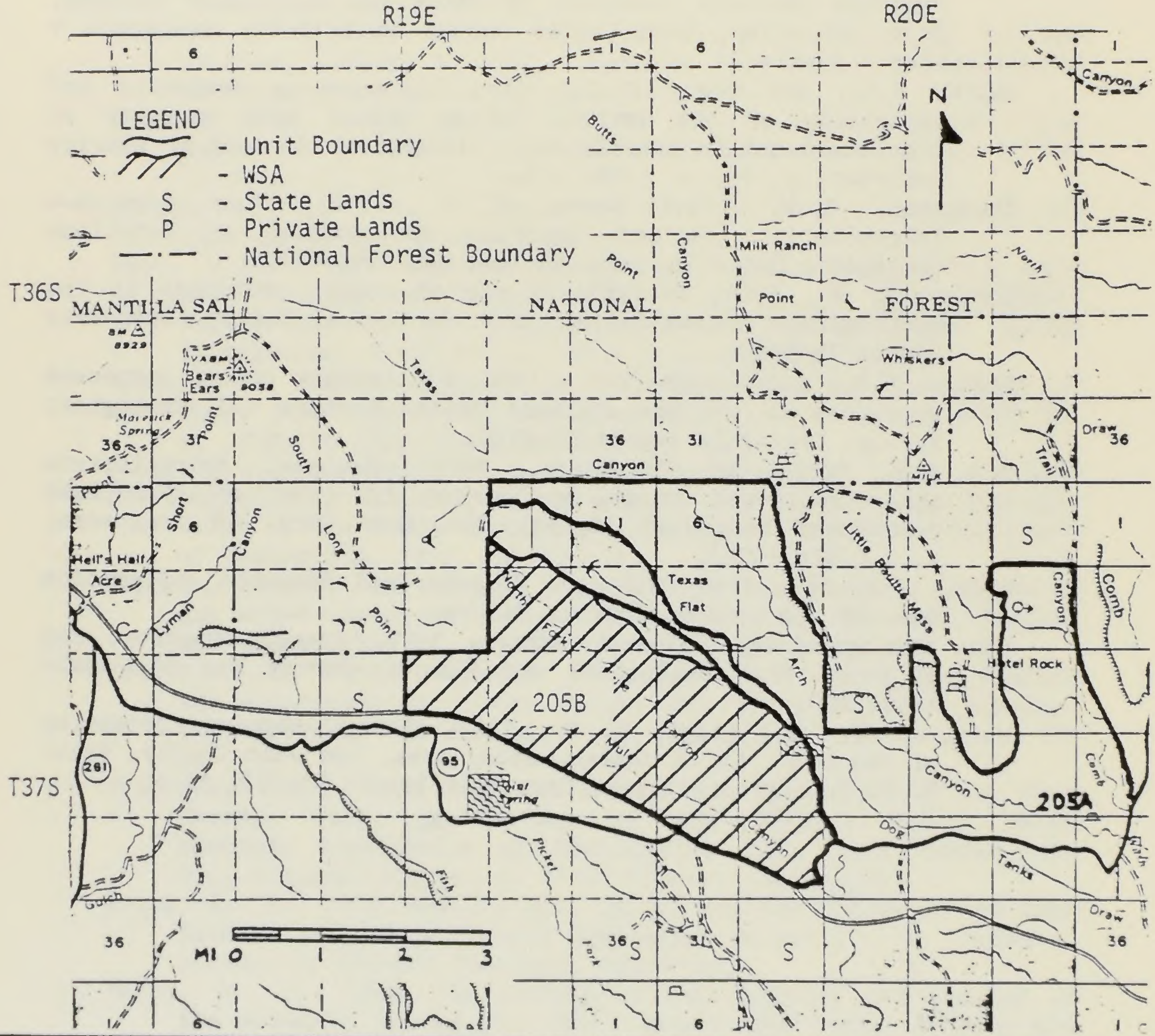
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 205A/B, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



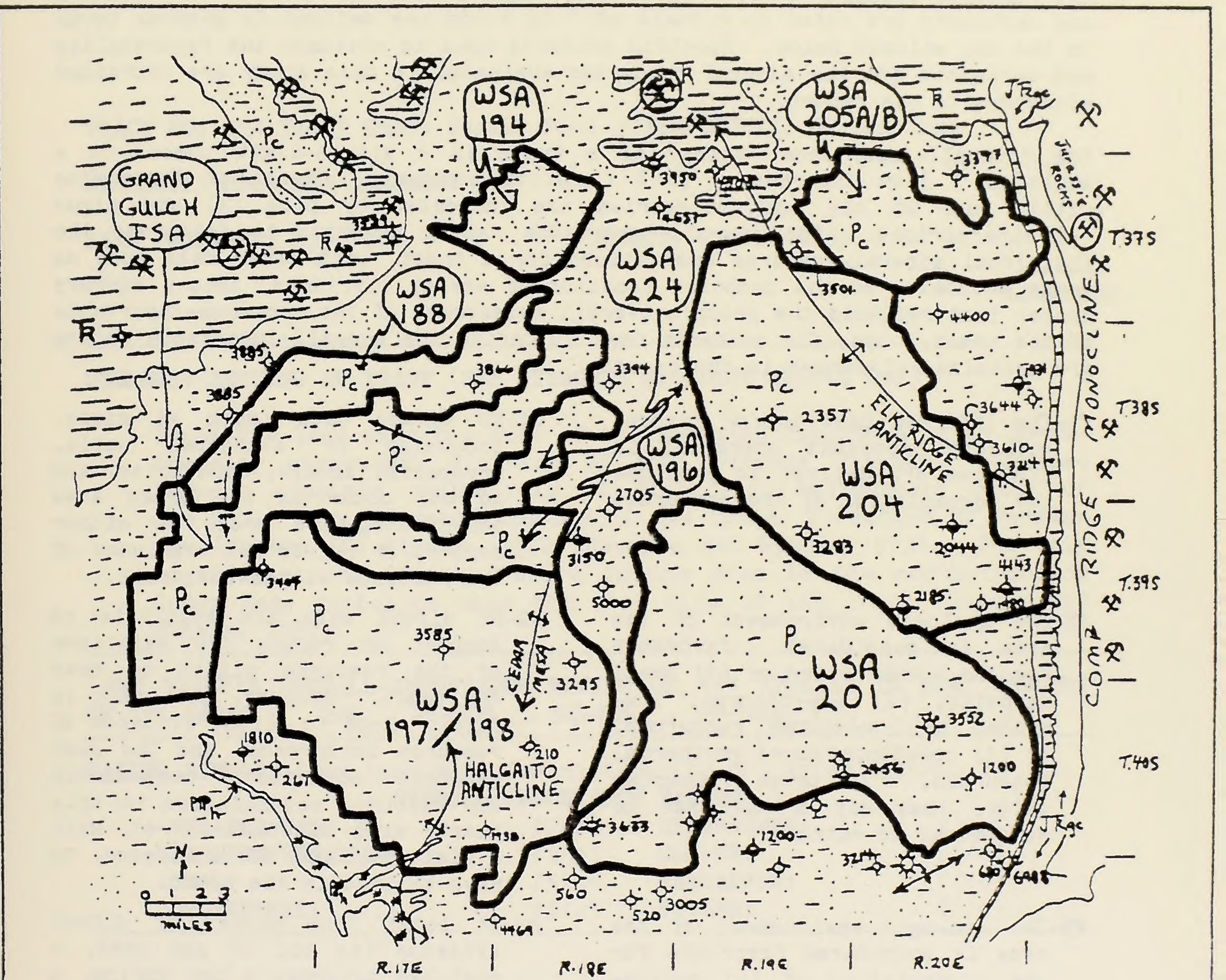
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~5~~3.

SOURCE: MAP SOURCE, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

T̄R - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

Pc - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

IPh - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

9210 OIL AND GAS WELL SHOWING TOTAL DEPTH

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, **"f3"**, estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, **"c2"**, is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

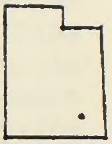
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 224 **TRACT NAME:** Sheiks Flat **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **WSA ACREAGE:** 3,070

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 224 lies near the axis of the Monument Upwarp--a major north-trending structural division of the Colorado Plateau. Exposed bedrock consists exclusively of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). The only significant structural feature in the area is the north-trending Cedar Mesa anticline near the east side of the tract (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "1" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 1

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS <u>f2/c2</u>

Tract 224 lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Tract 224 were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Tract 224 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 224 and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 224, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Tract 224 the Paradox Formation is probably less than 1,000 feet below the surface. South of Tract 224, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Tract 224. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 224 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 224 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 224 is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 224, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 224 is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Tract 224 (PIC, 1981). Although all wells in the area have been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (see attached Geologic Sketch Map; Heylmun and others, 2245). For example, British American Oil drilled a 3,150-foot well along the Cedar Mesa anticline three miles southeast of the tract and reported oil shows in the Paradox/Hermosa and in the underlying Molas Formation (Heylmun and others, 2245). The bulk of the wells were drilled in the late-1950s and early-2240s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 2245; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 224, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Tract 224 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Tract 224 lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 20 miles to the northwest and the Monument Valley uranium mining district lies about 35 miles to the south (Malan, 2248). By mid-2245, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 2248). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 2248). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 2244; Fischer and Vine, 2244). The closest uranium deposits to Tract 224 are about 8 miles to the north in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Tract 224 (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Tract 224 based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Tract 224, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Tract 224 is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 2244; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 224 consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 224 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 224 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 224 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 224. On the basis of this information we have assigned Tract 224 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type

of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 2244). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 2244). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Tract 224 a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 224. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Tract 224 a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH <u>f1/c3</u>

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 2241). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 2244; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 224 lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 2241; Hite and Cater, 1972).

Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 1

Tract 224 has been assigned an overall importance rating (OIR) of 1 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only. The tract was assigned an OIR of 1 rather than 2 (which would correspond to the assigned favorability of oil and gas) because of its small size compared with other Wilderness Study Areas in this part of the Monument Upwarp.

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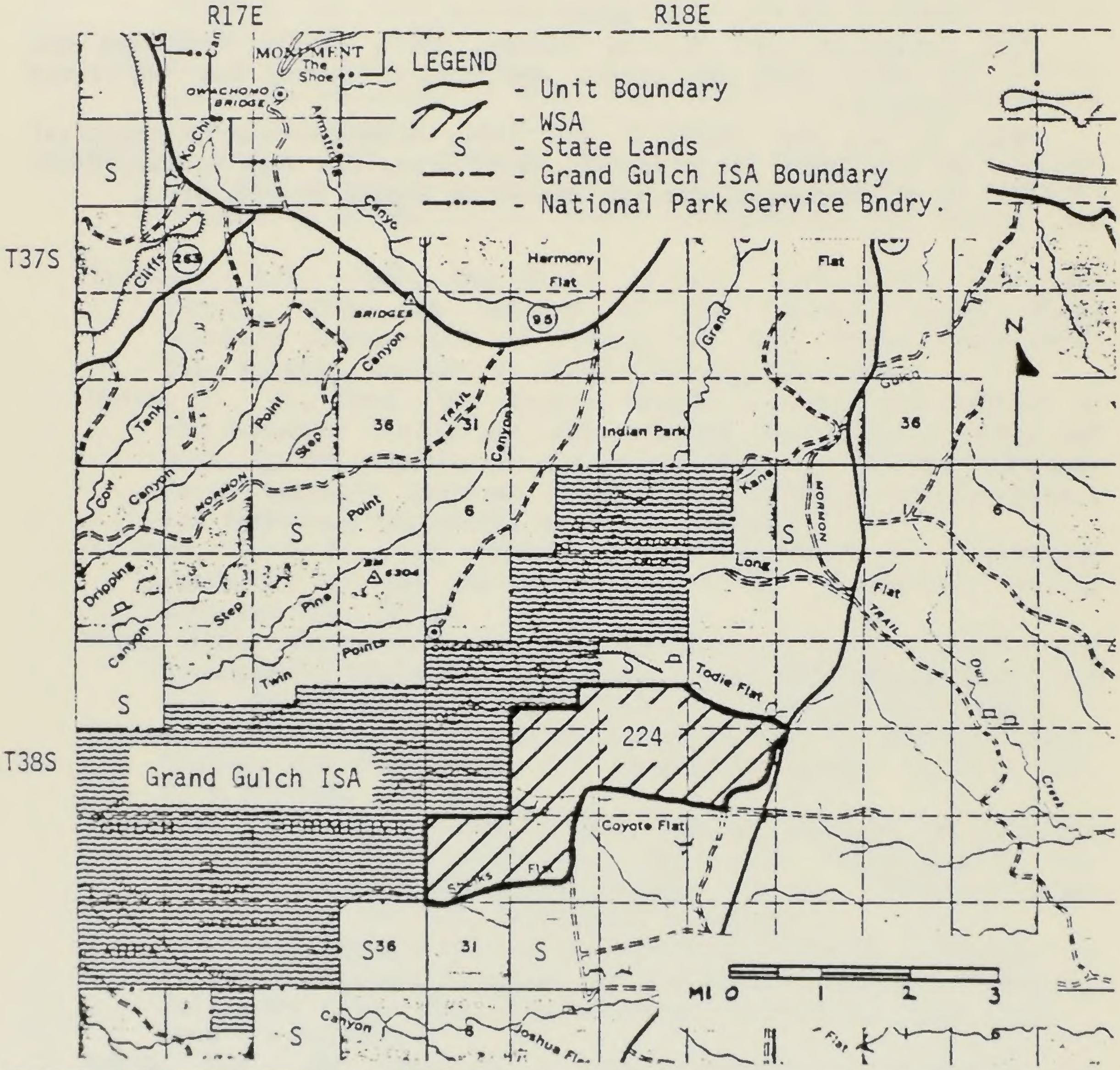
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 224 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



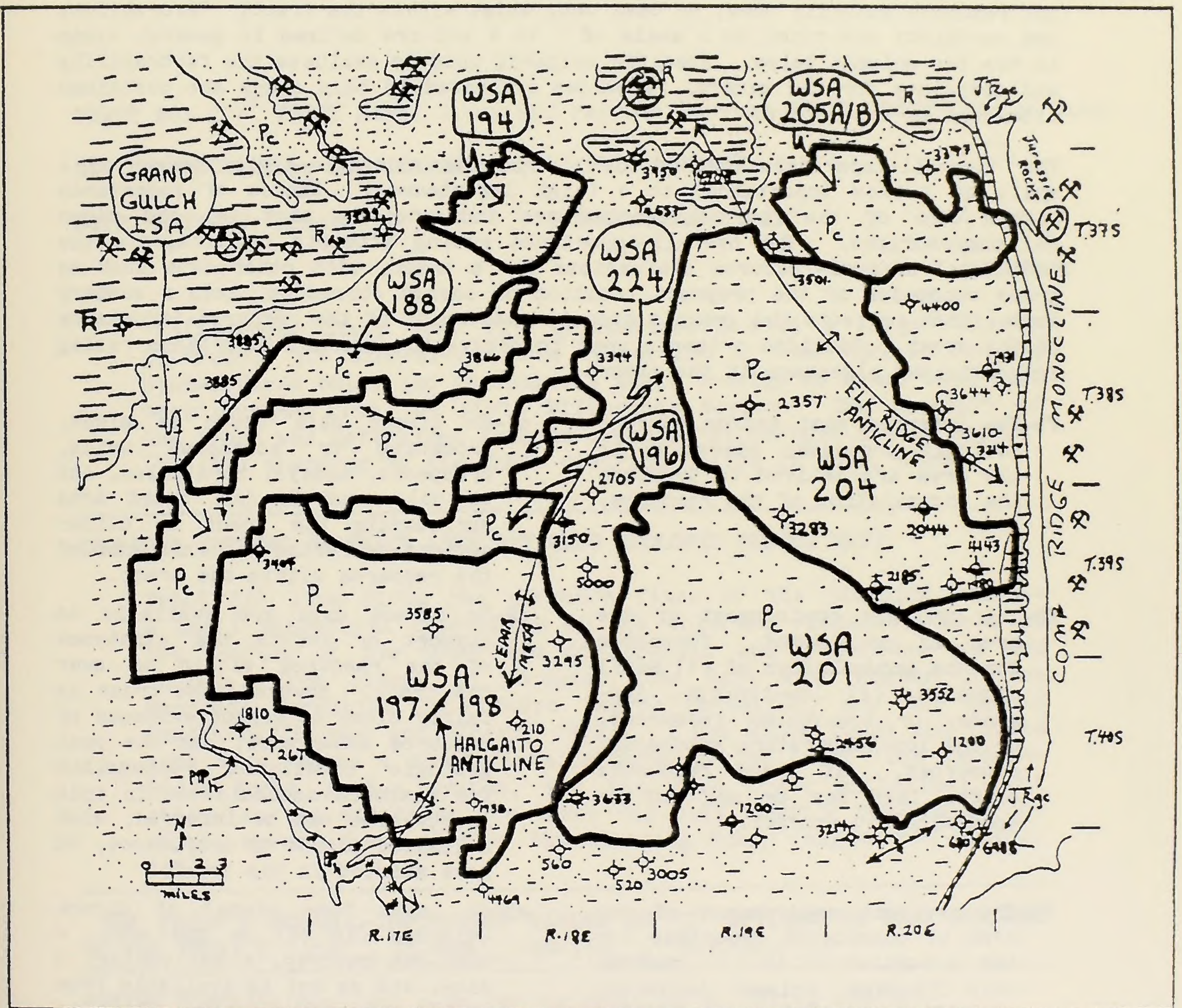
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ~~5~~3.

SOURCE: MAP SOURCE, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TR - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

P_c - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

IP_h - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

⊹ OIL AND GAS WELL SHOWING TOTAL DEPTH
9210 ☼ GAS SHOW ✦ OIL AND GAS SHOW
● OIL SHOW ○ DRY HOLE

⚒ URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

⚒ URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 227* **TRACT NAME:** Squaw and Papoose Canyons **STATE/COUNTY:**UT/San Juan

BLM DISTRICT: Moab **WSA ACREAGE:** 6,580 **UNIT ACREAGE:** 9,670

DATE PREPARED: March 1982 **UPDATE:** August 1982

LOCATION

*[Wilderness Study Area 227 is contiguous with a larger WSA in Colorado. The mineral-resource evaluation of Tract 227 is for the Utah-segment only, and it includes small contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab, Utah].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 227 lies along the northern flank of the Blanding Basin--a small structural depression on the Colorado Plateau. Rocks at the surface of the tract are of Jurassic and Cretaceous age and include, from oldest to youngest, the Salt Wash Member of the Morrison Formation, the Burro Canyon Formation, and the Dakota Sandstone (Haynes and others, 1972). A few minor folds and faults have been mapped a short distance north of the tract (the Verdure-Dodge Point graben system, and the Dove Creek anticline), but otherwise the strata in the tract dip only about 2 degrees to the south, toward the center of the Blanding Basin (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "3" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 3

OIL AND GAS:	f3/c3	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f4/c3	**COPPER:**	f2/c1
COAL:	f2/c2	**MANGANESE:**	f2/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f2/c2

RATING JUSTIFICATIONS

OIL AND GAS f3/c3

Tract 227 lies along the southern edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Cumulative production from the Paradox Basin to 1/1/78 has amounted to approximately 369 million barrels of oil and 653 billion cubic feet of gas (Thomaidis, 1978). Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the Four Corners region have come from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Four Corners area. Most of this production, however, has come from only two fields--Aneth and Lisbon Valley--both located within the Moab district. Tract 227 lies about 10 miles northeast of the Aneth field. The paragraphs below describe the development of the Paradox Basin, and its significance to the petroleum potential of Tract 227.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and "penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The oil-rich Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Alaki Gulch, Barker Creek, and Akah time, sediments deposited chiefly in the hypersaline environment accumulated in the area of Tract 227. During Desert Creek and Ismay time, however, sediments deposited in the vicinity of Tract 227 accumulated in the penesaline environment.

Of particular importance to oil and gas resources in the vicinity of Tract 227 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in this area) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). These mounds may be classified strictly as stratigraphic traps (porosity pinchouts), or they may be enhanced by folding, in which case they may be classified as combination stratigraphic/structural traps. It seems reasonable to assume that algal mounds similar in size and productivity to those at Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin.

Tract 227 lies in the midst of what can only be described as "oil country" in that dozens of fields have been discovered in this area (Brown and Ritzma, 1982; Krivanek, 1981). Drilling activity in this part of the Paradox Basin peaked in the late 1950s and early 1960s after discovery of the Aneth field in 1956 and the Lisbon Valley field in 1960. The Aneth field is by far the largest in this region, with estimated recoverable oil reserves exceeding 375 million barrels (Babcock, 1978; Freeman, 1978; Irwin, 1978); it is considered a "giant" field based on the classification scheme used by Halbouty (1970). Recent discoveries, however, have generated renewed interest in leasing and exploratory drilling in this part of the basin (Stevenson and Baars, 1981; Krivanek, 1981; McCaslin, 1980). Some of the recent discoveries in Utah include Patterson Canyon approximately five miles southwest of Tract 227, Squaw Canyon about two miles to the south, and Bug field, located less than one mile north of the tract (Martin, 1981; Buckner and Green, 1981). Nearby fields in Colorado include Papoose Canyon and Dove Creek, both about six miles northeast of Tract 227 (Krivanek, 1981). All these fields produce from the Paradox Formation (largely from the Ismay and Desert Creek Stages). Although the dimensions of the Patterson and Squaw Canyon fields have not yet been determined (Martin, 1981; Buckner and Green, 1981), most of the fields contain less than 10 million barrels of ultimately recoverable oil or gas-equivalent. [According to Stevenson and Baars (1981), the Bug field contains estimated recoverable oil reserves of 8 to 12 million barrels, whereas Berghorn and Reid (1981) report recoverable oil reserves of Bug field at 2 to 4 million barrels].

Tract 227 lies along the south-dipping northern flank of the Blanding Basin--a structural feature that presumably developed in late Cretaceous and early Tertiary time (Hunt, 1956). The Blanding Basin, however, was superimposed across part of the older Paradox Basin, which in the vicinity of Tract 227 presumably sloped northward toward the depositional center somewhere near the town of Moab. As outlined by Martin (1981), hydrocarbons influenced by the newer southeast dip of this part of the Blanding Basin probably migrated northeastward, up the slope of the Blanding Basin, and eventually became trapped in pinchouts of porous algal-mound structures and carbonate-bank facies as described briefly in preceeding paragraphs.

On the basis of the discussion above, Tract 227 is assigned an oil and gas favorability of f3 (favorable for moderately-large petroleum accumulations--10 to 50 million barrels of oil or gas-equivalent). It is unlikely that another Aneth field could exist in the vicinity of Tract 227 because the results of nearby exploratory drilling have generally been discouraging (PIC, 1981; wells drilled in the "intensive inventory area" of Tract 227 have been dry--see attached Geologic Sketch Map). However, the projected areal extent of fields such as Bug (and others) is small enough that similar size fields could be contained in Tract 227. Based on the abundance of oil fields in this area, and their proximity to the tract, we have assigned Tract 227 a certainty of occurrence rating of c3.

URANIUM f4/c3

The Colorado Plateau, and in particular east-central Utah, contains some of the largest and most important uranium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined largely to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions that were controlled largely by lateral variations in sediment size--such as within organic-rich paleo-channels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation [vanadiferous phosphate and shale deposits are not known to occur in southeastern Utah and they are not discussed further (see Fischer and Vine, 1964)].

The two most important producing areas in the vicinity of the tract are the 15-mile long Big Indian mineral belt near Lisbon Valley, Utah and the 75-mile long Uravan mineral belt in western Colorado (Wood, 1968; Motica, 1968). According to Butler and Fischer (1978), the ore deposits in these two belts have supplied about 25 percent of the uranium and nearly 60 percent of the vanadium produced domestically. Uranium production from the Big Indian belt is derived from the base of the Chinle Formation and the upper part of the underlying Cutler Formation along the southwest flank of the

Lisbon Valley anticline. The ore bodies range in size from 500 to 1,500,000 tons. By the mid-1960s the Big Indian mineral belt had yielded almost 25,000 tons of U_3O_8 (Wood, 1968). The host rock in the Uravan mineral belt is the Salt Wash Member of the Morrison Formation from which uranium and vanadium ores have been obtained. By the mid-1960s the Uravan belt had yielded about 26,000 tons of U_3O_8 and about 144,000 tons of V_2O_5 (Motica, 1968).

In a recent synopsis of the uranium geology of the Cortez 2-degree quadrangle (in which Tract 227 lies), Campbell and others (1980) considered only the Morrison Formation to be favorable for uranium in the vicinity of Tract 227. The discussion below is therefore limited to the Morrison Formation. A rock unit classified as favorable for uranium by Campbell and others (1980) indicates that the unit is less than 1,500 feet from the surface and has a potential to contain deposits with at least 100 tons of U_3O_8 at a minimum average grade of 0.01 percent. Unless stated otherwise, we have adopted these minimum criteria in our evaluation of Tract 227.

The Morrison Formation is exposed throughout most of Tract 227 (Haynes and others, 1972). In the vicinity of the tract, the formation is subdivided into the Tidewell unit at the base, the Salt Wash Member in the middle, and the Brushy Basin Member at the top (Haynes and others, 1972; Campbell and others, 1980). Most investigators consider the Salt Wash Member to be the most favorable unit for uranium and vanadium in this area, and numerous uranium prospects have been reported from this member in Squaw Canyon within Tract 227 (Haynes and others, 1972). The Salt Wash Member in southern Utah originated from streams flowing eastward along a network of coalescing alluvial plains (Campbell and others, 1980).

The size of ore deposits in the Salt Wash Member in this region is distributed as follows: 70 percent contain less that 10 tons U_3O_8 and 93 percent contain less than 100 tons U_3O_8 [data from Butler and Fischer (1978) for the Moab 2-degree quadrangle to the north, but Campbell and others (1980) believe that these data are also applicable to the Cortez 2-degree quadrangle]. The few large uranium deposits in this region (in the Uranan area) contain up to 3,000 tons U_3O_8 and many contain large amounts of vanadium (a V:U average for the Cortez 2-degree quadrangle of about 5:1 according to (Campbell and others, 1980).

Tract 227 lies within the Greater Uranan mineral belt as described by Campbell and others (1980). The mineral belt is concave toward the west and represents the distal alluvial-fan facies of the Salt Wash Member. Farther east, the Salt Wash was deposited in marginal lacustrine environments that are considered to be less favorable for uranium and vanadium because of the lower permeability of these rocks compared with those that originated in the alluvial-fan facies (Campbell and others, 1980). Because Tract 227 lies within the favorable alluvial-fan facies, and because the Salt Wash Member is host to large uranium deposits in this area, we have assigned

Tract 227 a uranium/vanadium favorability of f4. The certainty that uranium/vanadium resources occur in Tract 227 is relatively high (c3) because of the numerous mines and occurrences located close to the tract (many uranium mines are in Montezuma Canyon 8 miles west of the tract).

COAL f2/c2

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Tract 227 lies within the loosely-defined San Juan coal field (Doelling and Graham, 1972). The Dakota Sandstone of Cretaceous age is the only coal-bearing unit in the field, and it forms a protective caprock of a dissected plateau known as Sage plain.

Coal occurs in the middle part of the Dakota Formation, but exposures are very poor due to a blanket of overlying erosional debris. Doelling and Graham (1972) report that where coal beds do crop out, they are almost always less than 14 inches thick and are usually discontinuous. Total coal production from the San Juan field (and the adjacent La Sal field to the north) is estimated to be about 300 tons, and neither field has significant coal reserves (Doelling and Graham, 1972). On this basis, Doelling and Graham (1972) speculated that these fields could never support commercial mining.

The Dakota Sandstone has been removed by erosion throughout most of Tract 227 (Haynes and others, 1972). On this basis, and because of the thinness and poor quality of the coal throughout the San Juan field, we have assigned Tract 227 a coal favorability of f2. The certainty that coal resources occur in the tract is low and is assigned a rating of c2 [Doelling and Graham (1972) do not report coal occurrences south of Coal Bed Canyon about 7 miles north of Tract 227].

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 227 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 227 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 227. On the basis of this information we have assigned Tract 227 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type

of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau (and at depth in the vicinity of Tract 227) are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Nevertheless, copper occurs widely throughout the Plateau and is clearly associated with uranium deposits which are abundant in this area. We have therefore assigned Tract 227 a copper favorability of f2 and a certainty of resource occurrence of c1.

MANGANESE f2/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. With the advent of World War I and increasing prices for most raw materials, mining of manganese in the Little Grand district was resumed. Shortly after the war, however, the district once again became idle. With the outbreak of World War II, and the increasing need for manganese, small-scale development work was conducted on many of the deposits in southeastern Utah, but largely to determine the quality and quantity of the manganese available (Baker and others, 1952). Intermittent mining throughout the first half of this century, largely during the periods 1901 to 1906 and 1915 to 1918, produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952).

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Baker and others (1952) estimate that about 15,000 tons of 30 percent manganese ore could be obtained by hand sorting of widely scattered small deposits in the Summerville Formation. Reserves of lower-grade oxide ore, between 10 and 30 percent manganese, are estimated to aggregate about 150,000 tons, whereas ores containing 10 percent or less manganese total about 350,000 tons in southeastern Utah (Baker and others, 1952). With the information available, Baker and others (1952) concluded that southeastern Utah (which includes all of the Moab district) could not be considered as a source area for large tonnages of manganese ore.

Tract 227 lies far south of the abundance manganese occurrences in the Moab district (Baker and others, 1952; USGS, 1982; Tooker and Cannon, 1980). However, one of the chief host rocks for manganese--the Morrison Formation--is exposed widely in and near tract. On this basis, we have assigned Tract 227 a manganese favorability of f2. The certainty that manganese resources occur in the tract is low and has been assigned a value of c1.

POTASH f2/c2

Potassium is an essential plant nutrient and the fertilizer is commonly referred to as the oxide "potash," or K_2O. The chief source of potash is from bedded deposits of marine origin, commonly within the minerals sylvite, carnallite, and other related potassium minerals. Less important, though still commercial, sources include concentrated brines from wells, relict Pleistocene lakes, and lacustrine sediments in arid regions.

Bedded potash deposits exist in the subsurface over a broad area of east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago. The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 227 lies south of the Paradox fold and fault belt and potash deposits, if they occur at depth, would tend to be relatively thin (Hite and Cater, 1972).

On the basis of the discussion above, we have assigned Tract 227 a potash favorability of f2, with a relatively low certainty (c2) that potash resources exist in this area.

OVERALL-IMPORTANCE RATING 3

Tract 227 has been assigned an overall-importance rating (OIR) of 3 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are considered the most important resources to potentially exist in the tract--an area estimated to be favorable for recoverable accumulations on the order of 10 to 50 million barrels of oil, or gas equivalent (an f3 favorability rating).

Uranium and vanadium are considered favorable at the f4 level. Prospecting in the well-exposed Morrison Formation in Tract 227 has probably been thorough, and to date no significant discoveries have been announced. Although discouraging results certainly do not preclude future discoveries, it nevertheless seems more likely that future large discoveries will be made in unexposed or poorly exposed parts of the Salt Wash Member in this area. Thus, the OIR assigned to Tract 227 does not reflect the f4 favorability assigned to uranium and vanadium, but rather the f3 favorability assigned to oil and gas.

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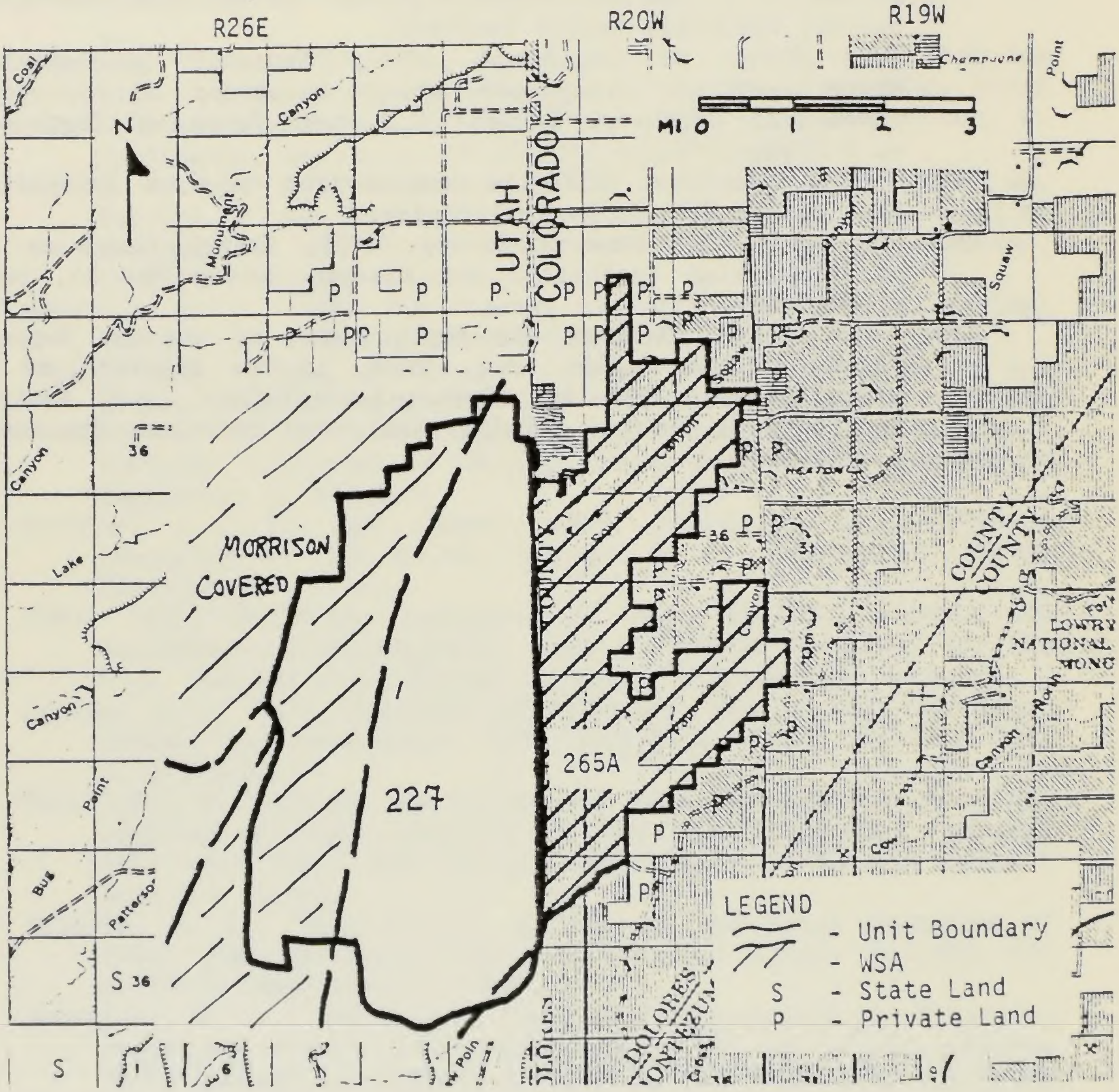
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 227 , UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



EXPLANATION

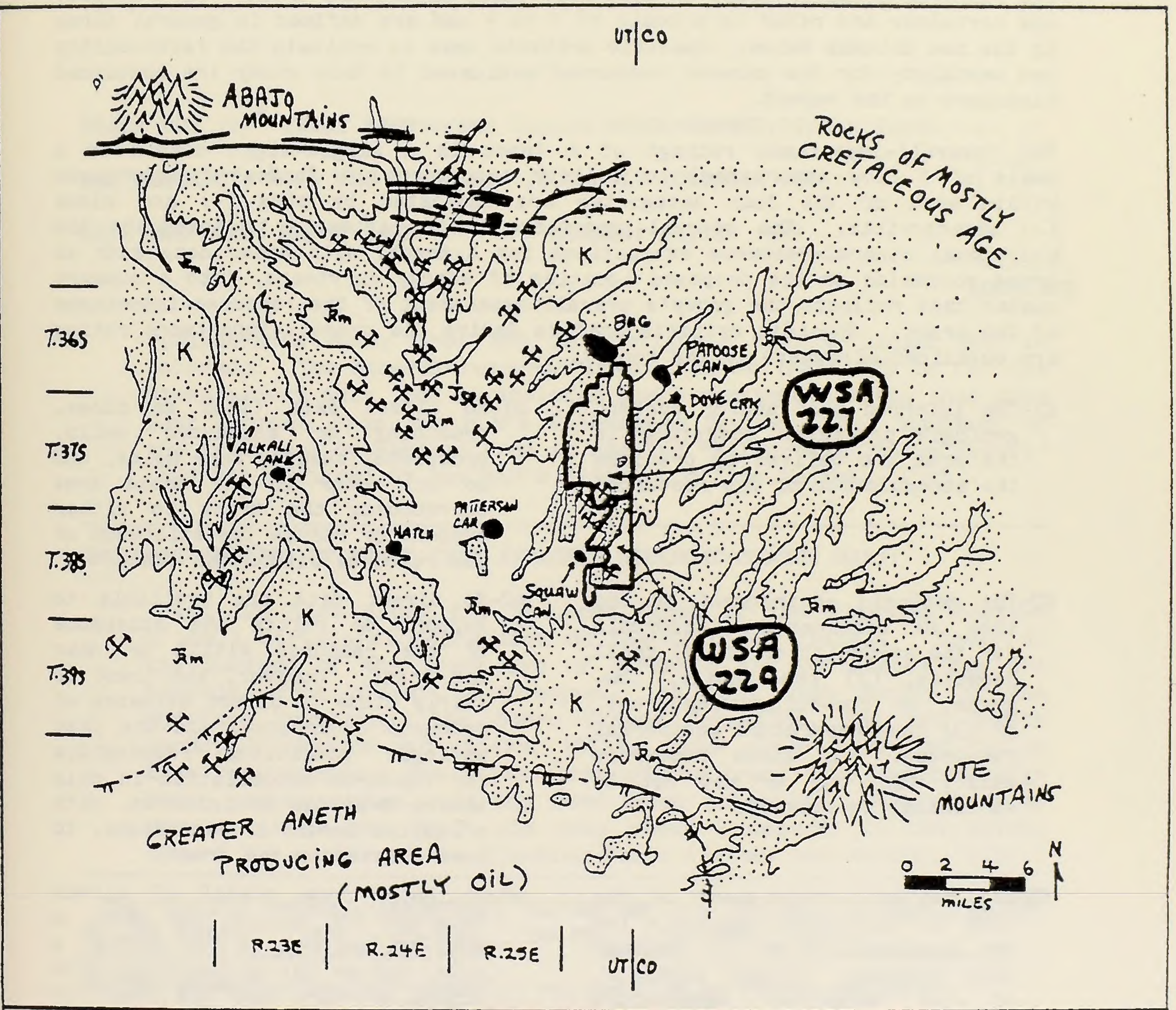
"OIL AND GAS" WAS ASSIGNED A FAVORABILITY OF F3. THE ENTIRE MAP AREA IS EQUALLY FAVORABLE FOR OIL AND GAS.

URANIUM/VANADIUM ARE FAVORABLE THROUGHOUT THE TRACT AT THE F4 LEVEL, ALTHOUGH THE URANIUM-BEARING MORRISON FORMATION IS COVERED ALONG THE WEST SIDE OF THE TRACT.

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 227, 229, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

K - DAKOKA SANDSTONE AND BURRO CANYON FORMATION (CRETACEOUS)

Jm - MORRISON FORMATION (JURASSIC)

● OIL FIELDS

⚒ URANIUM DEPOSITS WITH UP TO 100 TONS PRODUCTION OF U_3O_8 PER DEPOSIT.

(OIL AND GAS EXPLORATION AND DEVELOPMENT WELLS ARE FAR TOO NUMEROUS TO SHOW AT THIS SCALE).

SOURCE: GEOLOGIC BASE FROM HINTZE (1980) AND HAYNES AND OTHERS (1972)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 229* **TRACT NAME:**Cross Canyon **STATE/COUNTY:**UT/San Juan

BLM DISTRICT: Moab **WSA ACREAGE:** 1,000 **UNIT ACREAGE:** 2,112

DATE PREPARED: March 1982 **UPDATE:** August 1982

LOCATION

*[Wilderness Study Area 229 is contiguous with a larger WSA in Colorado. The mineral-resource evaluation of Tract 229 is for the Utah-segment only, and it includes small contiguous areas that have been dropped from the BLM's Wilderness Review. The boundary of the tract was determined from an updated "Wilderness Status Report" (5/1/81) prepared by the BLM's district office in Moab, Utah].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 229 lies along the northern flank of the Blanding Basin--a small structural depression on the Colorado Plateau. Rocks at the surface of the tract are of Jurassic and Cretaceous age and include, from oldest to youngest, the Salt Wash Member of the Morrison Formation, the Burro Canyon Formation, and the Dakota Sandstone (Haynes and others, 1972). Some minor folds and faults have been mapped a few miles north of the tract (the Verdure-Dodge Point graben system, and the Dove Creek anticline), but otherwise the strata in the tract dip only about 2 degrees to the south, toward the center of the Blanding Basin (Haynes and others, 1972).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "3" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 3

OIL AND GAS:	f3/c3	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f4/c3	**COPPER:**	f2/c1
COAL:	f2/c2	**MANGANESE:**	f2/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f2/c2

RATING JUSTIFICATIONS

OIL AND GAS f3/c3

Tract 229 lies along the southern edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Cumulative production from the Paradox Basin to 1/1/78 has amounted to approximately 369 million barrels of oil and 653 billion cubic feet of gas (Thomaidas, 1978). Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the Four Corners region have come from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Four Corners area. Most of this production, however, has come from only two fields--Aneth and Lisbon Valley--both located within the Moab district. Tract 229 lies about 8 miles northeast of the Aneth field. The paragraphs below describe the development of the Paradox Basin, and its significance to the petroleum potential of Tract 229.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and "penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The oil-rich Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Alaki Gulch, Barker Creek, and Akah time, sediments deposited chiefly in the hypersaline environment accumulated in the area of Tract 229. During Desert Creek and Ismay time, however, sediments deposited in the vicinity of Tract 229 accumulated in the penesaline environment.

Of particular importance to oil and gas resources in the vicinity of Tract 229 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in this area) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). These mounds may be classified strictly as stratigraphic traps (porosity pinchouts), or they may be enhanced by folding, in which case they may be classified as combination stratigraphic/structural traps. It seems reasonable to assume that algal mounds similar in size and productivity to those at Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin.

Tract 229 lies in the midst of what can only be described as "oil country" in that dozens of fields have been discovered in this area (Brown and Ritzma, 1982; Krivanek, 1981). Drilling activity in this part of the Paradox Basin peaked in the late 1950s and early 1960s after discovery of the Aneth field in 1956 and the Lisbon Valley field in 1960. The Aneth field is by far the largest in this region, with estimated recoverable oil reserves exceeding 375 million barrels (Babcock, 1978; Freeman, 1978; Irwin, 1978); it is considered a "giant" field based on the classification scheme used by Halbouty (1970). Recent discoveries, however, have generated renewed interest in leasing and exploratory drilling in this part of the basin (Stevenson and Baars, 1981; Krivanek, 1981; McCaslin, 1980). Some of the recent discoveries in Utah include Patterson Canyon approximately five miles west of Tract 229, Squaw Canyon about one-half mile to the west, and Bug field, located six miles north of the tract (Martin, 1981; Buckner and Green, 1981). Nearby fields in Colorado include Papoose Canyon and Dove Creek, both about 10 miles northeast of Tract 229 (Krivanek, 1981). All these fields produce from the Paradox Formation (largely from the Ismay and Desert Creek Stages). Although the dimensions of the Patterson and Squaw Canyon fields have not yet been determined (Martin, 1981; Buckner and Green, 1981), most of the fields contain less than 10 million barrels of ultimately recoverable oil or gas-equivalent. [According to Stevenson and Baars (1981), the Bug field contains estimated recoverable oil reserves of 8 to 12 million barrels, whereas Berghorn and Reid (1981) report recoverable oil reserves of Bug field at 2 to 4 million barrels].

Tract 229 lies along the south-dipping northern flank of the Blanding Basin--a structural feature that presumably develpoed in late Cretaceous and early Tertiary time (Hunt, 1956). The Blanding Basin, however, was superimposed across part of the older Paradox Basin, which in the vicinity of Tract 229 presumably sloped northward toward the depositional center somewhere near the town of Moab. As outlined by Martin (1981), hydrocarbons influenced by the newer southeast dip of this part of the Blanding Basin probably migrated northeastward, up the slope of the Blanding Basin, and eventually became trapped in pinchouts of porous algal-mound structures and carbonate-bank facies as described briefly in preceeding paragraphs.

On the basis of the discussion above, Tract 229 is assigned an oil and gas favorability of f3 (favorable for moderately-large petroleum accumulations--10 to 50 million barrels of oil or gas-equivalent). It is unlikely that another Aneth field could exist in the vicinity of Tract 229 because the results of nearby exploratory drilling have generally been discouraging (PIC, 1981; wells drilled in the "intensive inventory portion" of Tract 229 have been dry--see attached Geologic Sketch Map). However, the projected areal extent of fields such as Bug (and others) is small enough that similar size fields could be contained in Tract 229. Based on the abundance of oil fields in this area, and their proximty to the tract, we have assigned Tract 229 a certainty of occurrence rating of c3.

URANIUM f4/c3

The Colorado Plateau, and in particular east-central Utah, contains some of the largest and most important uranium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined largely to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions that were controlled largely by lateral variations in sediment size--such as within organic-rich paleo-channels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from depsoits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation [vanadiferous phosphate and shale deposits are not known to occur in southeastern Utah and they are not discussed further (see Fischer and Vine, 1964)].

The two most important producing areas in the vicinity of the tract are the 15-mile long Big Indian mineral belt near Lisbon Valley, Utah and the 75-mile long Uravan mineral belt in western Colorado (Wood, 1968; Motica, 1968). According to Butler and Fischer (1978), the ore deposits in these two belts have supplied about 25 percent of the uranium and nearly 60 percent of the vanadium produced domestically. Uranium production from the Big Indian belt is derived from the base of the Chinle Formation and the upper part of the underlying Cutler Formation along the southwest flank of the

Lisbon Valley anticline. The ore bodies range in size from 500 to 1,500,000 tons. By the mid-1960s the Big Indian mineral belt had yielded almost 25,000 tons of U_3O_8 (Wood, 1968). The host rock in the Uravan mineral belt is the Salt Wash Member of the Morrison Formation from which uranium and vanadium ores have been obtained. By the mid-1960s the Uravan belt had yielded about 26,000 tons of U_3O_8 and about 144,000 tons of V_2O_5 (Motica, 1968).

In a recent synopsis of the uranium geology of the Cortez 2-degree quadrangle (in which Tract 229 lies), Campbell and others (1980) considered only the Morrison Formation to be favorable for uranium in the vicinity of Tract 229. The discussion below is therefore limited to the Morrison Formation. A rock unit classified as favorable for uranium by Campbell and others (1980) indicates that the unit is less than 1,500 feet from the surface and has a potential to contain deposits with at least 100 tons of U_3O_8 at a minimum average grade of 0.01 percent. Unless stated otherwise, we have adopted these minimum criteria in our evaluation of Tract 229.

The Morrison Formation is exposed throughout the southern two-thirds of Tract 229 (Haynes and others, 1972). In the vicinity of the tract, the formation is subdivided into the Tidewell unit at the base, the Salt Wash Member in the middle, and the Brushy Basin Member at the top (Haynes and others, 1972; Campbell and others, 1980). Most investigators consider the Salt Wash Member to be the most favorable unit for uranium and vanadum in this area, and numerous uranium prospects have been reported from this member in Squaw Canyon north of Tract 229 (Haynes and others, 1972). The Salt Wash Member in southern Utah originated from streams flowing eastward along a network of coalescing alluvial plains (Campbell and others, 1980).

The size of ore deposits in the Salt Wash Member in this region is distributed as follows: 70 percent contain less that 10 tons U_3O_8 and 93 percent contain less than 100 tons U_3O_8 [data from Butler and Fischer (1978) for the Moab 2-degree quadrangle to the north, but Campbell and others (1980) believe that these data are also applicable to the Cortez 2-degree quadrangle]. The few large uranium deposits in this region (in the Uranvan area) contain up to 3,000 tons U_3O_8 and many contain large amounts of vanadium (a V:U average for the Cortez 2-degree quadrangle of about 5:1 according to (Campbell and others, 1980).

Tract 229 lies within the Greater Uranvan mineral belt as described by Campbell and others (1980). The mineral belt is concave toward the west and represents the distal alluvial-fan facies of the Salt Wash Member. Farther east, the Salt Wash was deposited in marginal lacustrine environments that are considered to be less favorable for uranium and vanadium because of the lower permeability of these rocks compared with those that originated in the alluvial-fan facies (Campbell and others, 1980). Because Tract 229 lies within the favorable alluvial-fan facies, and because the Salt Wash Member is host to large uranium deposits in this area, we have assigned

Tract 229 a uranium/vanadium favorability of f4. The certainty that uranium/vanadium resources occur in Tract 229 is relatively high (c3) because of the numerous mines and occurrences located close to the tract (many uranium mines are in Montezuma Canyon 10 miles northwest of the tract).

COAL f2/c2

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Tract 229 lies within the loosely-defined San Juan coal field (Doelling and Graham, 1972). The Dakota Sandstone of Cretaceous age is the only coal-bearing unit in the field, and it forms a protective caprock of a dissected plateau known as Sage plain.

Coal occurs in the middle part of the Dakota Formation, but exposures are very poor due to a blanket of overlying erosional debris. Doelling and Graham (1972) report that where coal beds do crop out, they are almost always less than 14 inches thick and are usually discontinuous. Total coal production from the San Juan field (and the adjacent La Sal field to the north) is estimated to be about 300 tons, and neither field has significant coal reserves (Doelling and Graham, 1972). On this basis, Doelling and Graham (1972) speculated that these fields could never support commerial mining.

The Dakota Sandstone has been removed by erosion throughout most of Tract 229 (Haynes and others, 1972). On this basis, and because of the thinness and poor quality of the coal throughout the San Juan field, we have assigned Tract 229 a coal favorability of f2. The certainty that coal resources occur in the tract is low and is assigned a rating of c2 [Doelling and Graham (1972) do not report coal occurrences south of Coal Bed Canyon about 12 miles north of Tract 229].

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 229 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Tract 229 a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 229. On the basis of this information we have assigned Tract 229 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type

of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau (and at depth in the vicinity of Tract 229) are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Nevertheless, copper occurs widely throughout the Plateau and is clearly associated with uranium deposits which are abundant in this area. We have therefore assigned Tract 229 a copper favorability of f2 and a certainty of resource occurrence of c1.

MANGANESE <u>f2/c1</u>

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

Manganese ore was first mined in Utah in 1901 from deposits in the Little Grand district, southeast of the town of Green River (Pardee, 1921). Mining was generally unprofitable, and the district was inactive for several years after 1906. With the advent of World War I and increasing prices for most raw materials, mining of manganese in the Little Grand district was resumed. Shortly after the war, however, the district once again became idle. With the outbreak of World War II, and the increasing need for manganese, small-scale development work was conducted on many of the deposits in southeastern Utah, but largely to determine the quality and quantity of the manganese available (Baker and others, 1952). Intermittent mining throughout the first half of this century, largely during the periods 1901 to 1906 and 1915 to 1918, produced less than 20,000 tons of manganese ore (Pardee, 1921; Baker and others, 1952).

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment).

Baker and others (1952) estimate that about 15,000 tons of 30 percent manganese ore could be obtained by hand sorting of widely scattered small deposits in the Summerville Formation. Reserves of lower-grade oxide ore, between 10 and 30 percent manganese, are estimated to aggregate about 150,000 tons, whereas ores containing 10 percent or less manganese total about 350,000 tons in southeastern Utah (Baker and others, 1952). With the information available, Baker and others (1952) concluded that southeastern Utah (which includes all of the Moab district) could not be considered as a source area for large tonnages of manganese ore.

Tract 229 lies far south of the abundane manganese occurrences in the Moab district (Baker and others, 1952; USGS, 1982; Tooker and Cannon, 1980). However, one of the chief host rocks for manganese--the Morrison Formation--is exposed widely in and near tract. On this basis, we have assigned Tract 229 a manganese favorability of f2. The certainty that manganese resources occur in the tract is low and has been assigned a value of c1.

POTASH f2/c2

Potassium is an essential plant nutrient and the fertilizer is commonly referred to as the oxide "potash," or K_2O. The chief source of potash is from bedded deposits of marine origin, commomly within the minerals sylvite, carnallite, and other related potassium minerals. Less important, though still commercial, sources include concentrated brines from wells, relict Pleistocene lakes, and lacustrine sediments in arid regions.

Bedded potash deposits exist in the subsurface over a broad area of east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago. The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Tract 229 lies south of the Paradox fold and fault belt and potash deposits, if they occur at depth, would tend to be relatively thin (Hite and Cater, 1972).

On the basis of the discussion above, we have assigned Tract 229 a potash favorability of f2, with a relatively low certainty (c2) that potash resources exist in this area.

OVERALL-IMPORTANCE RATING 3

Tract 229 has been assigned an overall-importance rating (OIR) of 3 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are considered the most important resources to potentially exist in the tract--an area estimated to be favorable for recoverable accumulations on the order of 10 to 50 million barrels of oil, or gas equivalent (an f3 favorability rating).

Uranium and vanadium are considered favorable at the f4 level. Prospecting in the well-exposed Morrison Formation in Tract 229 has probably been thorough, and to date no significant discoveries have been announced. Although discouraging results certainly do not preclude future discoveries, it nevertheless seems more likely that future large discoveries will be made in unexposed or poorly exposed parts of the Salt Wash Member in this area. The Morrison Formation in the northern part of the tract is not exposed, and on the basis of the discussion above, this area may have a greater likelihood of containing a large uranium/vanadium deposit than the southern part of the tract. Nevertheless, Tract 229 is very small (1,000 acres), and we have therefore assigned it an OIR of 3, rather than 4.

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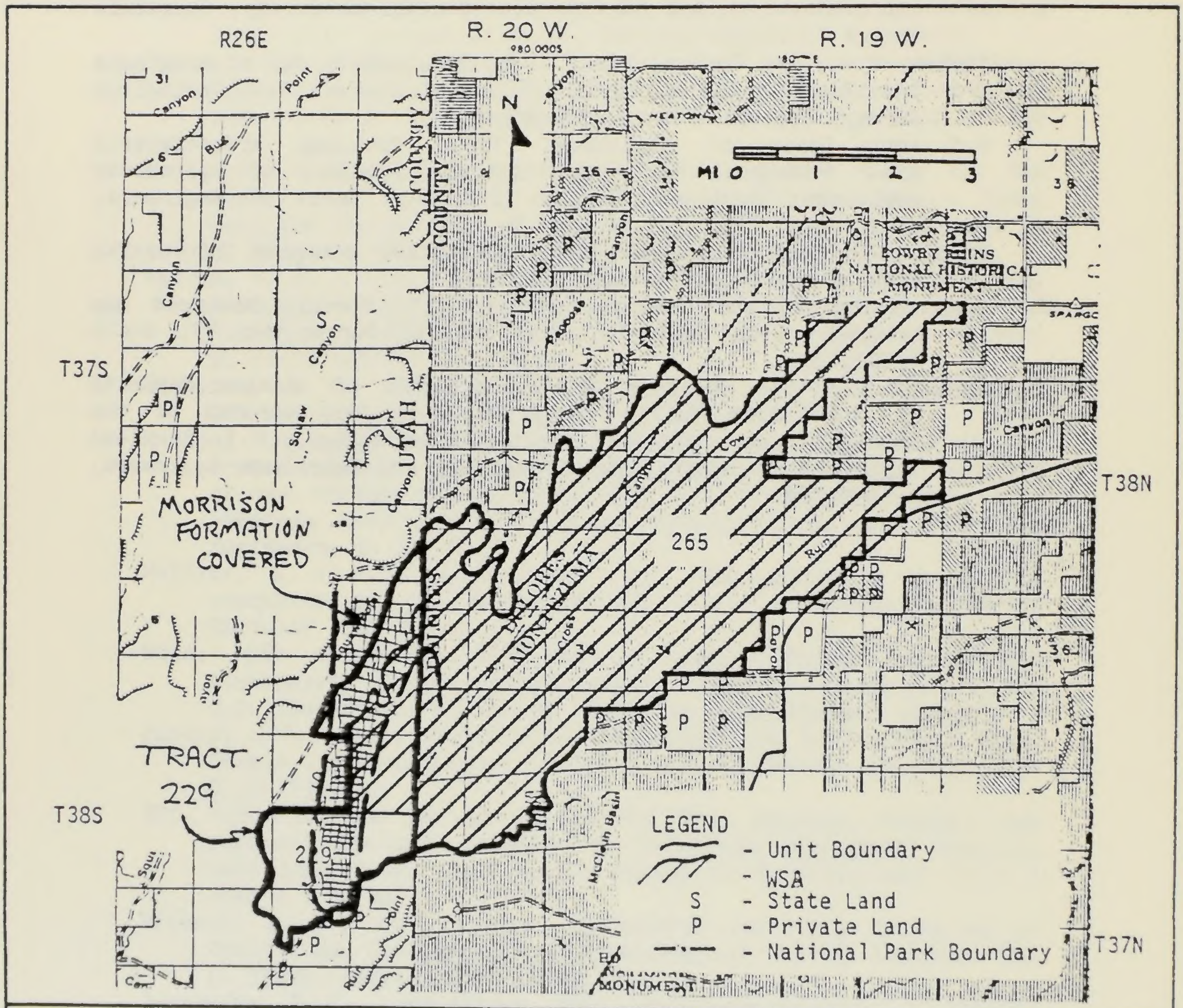
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 229, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



EXPLANATION

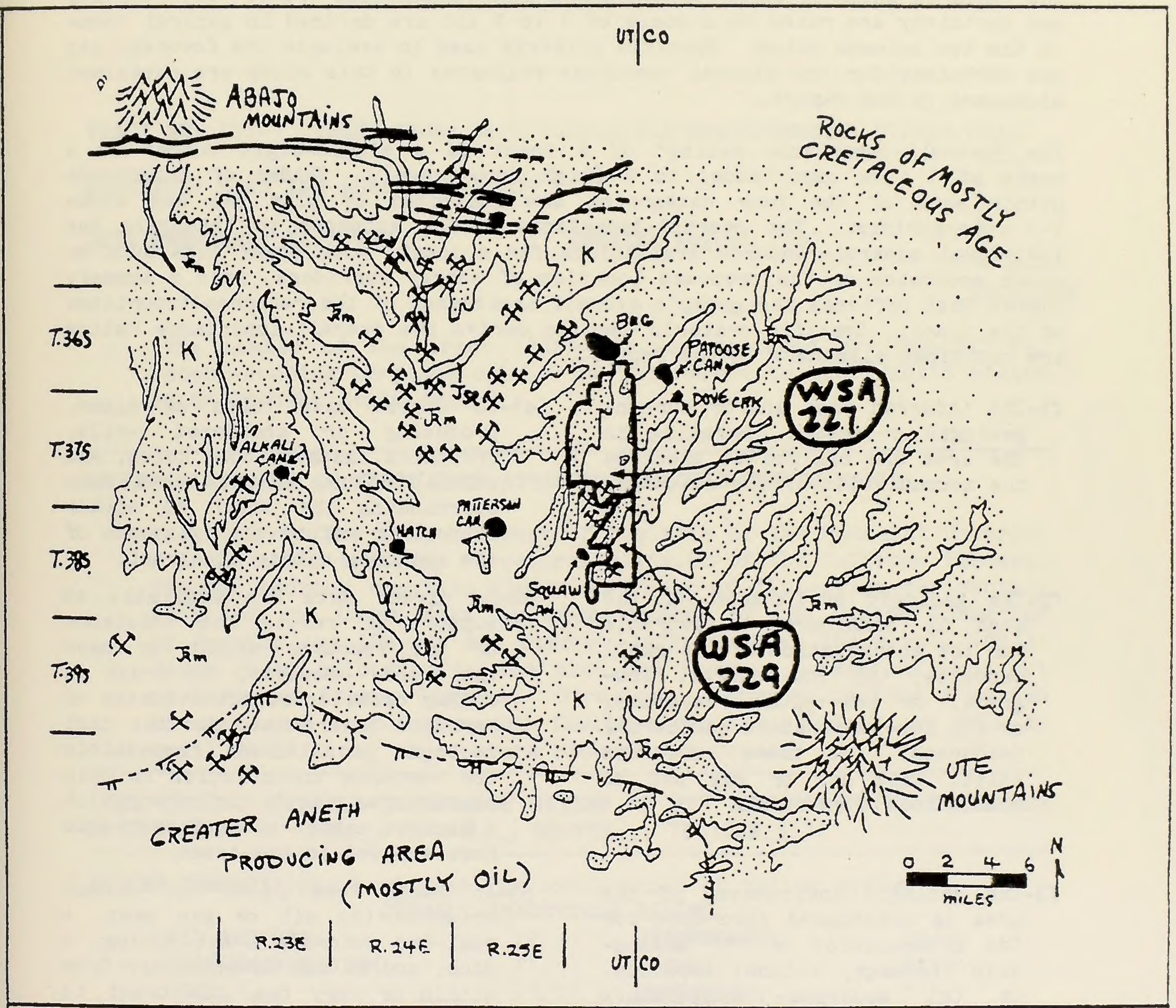
"OIL AND GAS" WERE ASSIGNED A FAVORABILITY OF F3. THE ENTIRE AREA OF THE MAP IS EQUALLY FAVORABLE FOR OIL AND GAS.

"URANIUM/VANADIUM" ARE FAVORABLE THROUGHOUT THE TRACT AT THE F4 LEVEL, ALTHOUGH THE URANIUM-BEARING MORRISON FORMATION IS COVERED ALONG THE CENTER OF THE TRACT (SEE MAP).

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 227, 229, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

K - DAKOKA SANDSTONE AND BURRO CANYON FORMATION (CRETACEOUS)

Jm - MORRISON FORMATION (JURASSIC)

● OIL FIELDS

⚒ URANIUM DEPOSITS WITH UP TO 100 TONS PRODUCTION OF U_3O_8 PER DEPOSIT.

(OIL AND GAS EXPLORATION AND DEVELOPMENT WELLS ARE FAR TOO NUMEROUS TO SHOW AT THIS SCALE).

SOURCE: GEOLOGIC BASE FROM HINTZE (1980) AND HAYNES AND OTHERS (1972)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

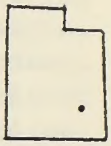
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: ISA-1* **TRACT NAME:** Dark Canyon ISA **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **ISA ACREAGE:** 49,904

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

[The number of the tract ("ISA-1") was assigned by ORNL/SAI for record-keeping purposes only. The ISA refers to the tract's status as an Instant Study Area.]

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Dark Canyon lies slightly west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists almost entirely of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). Older rocks belonging to the Rico and Hermosa Formations crop out in Dark and Gypsum Canyons. Structural features include a system of east-west trending normal faults along Dark Canyon, as well as small folds along the eastern side of the tract.

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, 75-100%_✓_).

RATING SUMMARY:(See last page for explanation of rating system)
OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Dark Canyon lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age (Schneider and others, 1971).

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine "penesaline" environment (Berghorn

and Reid, 1981). The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), the Paradox Formation in Dark Canyon represents deposition in the deeper parts of the penesaline environment during all but Ismay time. During Ismay time, deposition occurred in the shallow parts of the penesaline facies, close to the marine shelf.

Of particular importance to oil and gas resources in the vicinity of Dark Canyon are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Dark Canyon and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Dark Canyon, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Furthermore, about 300 feet of the Paradox Formation, and about 800 feet of the upper part of the Hermosa Group, are exposed within the tract along Gypsum Canyon.

It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Dark Canyon, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Dark Canyon ISA probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into Dark, Gypsum, and Cataract Canyons may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Dark Canyon ISA with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Dark Canyon is probably in excess of 500-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Dark Canyon, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Dark Canyon is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do not suggest that significant pre-salt faults exist in this part of the Monument Upwarp.

As of October 1981, about a half-dozen exploratory wells had been drilled in the vicinity of Dark Canyon (PIC, 1981). Most of the wells were drilled in the late-1950s and early-1960s after the large discoveries at Aneth and Lisbon Valley. Although all wells that have been drilled in this general area are now abandoned, oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981). The oil seeps reported in the Honaker Trail Formation in Dark Canyon by Wengerd and Matheny (1958) were considered by Weitz and Light (1981, p. 12) to be "...only irridescence caused by decaying vegetation in localized spring-fed areas...".

If oil and gas accumulations exist in the immediate area of Dark Canyon, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger anticlines, and many of the smaller anticlines in this area have already been tested. In addition, hydrocarbon accumulations are possible along the east-trending, normal-fault system that extends into the southern part of the tract from north of the Abajo Mountains [referred to by Weitz and Light (1981) as the Dark Canyon-Trail Canyon fault system, and referred to by Kitcho (1981) as the Abajo Grabens]. Displacement along these faults at the surface is minor, as indicated by offset of surface rocks, but it is not known if these are growth faults that penetrate Precambrian rocks.

In summary, the oil and gas favorability of Dark Canyon is considered to be low because of deep erosion that probably resulted in the loss of hydrocarbons and the loss of reservoir pressure. Small fields may nevertheless exist in stratigraphic and structural traps in Pennsylvanian rocks, and perhaps in Mississippian rocks. On this basis, we have assigned Dark Canyon ISA a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is low, because of the sparsity of wells, and has been assigned a rating of c1.

URANIUM/VANADIUM: f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits on the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleochannels.

The principal uranium- and vanadium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the

Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium and most are in the Morrison Formation.

Dark Canyon lies along the west side of the Monument Upwarp. The White Canyon uranium mining district lies about 10 miles to the south (Malan, 1968). By mid-1965, a few thousand tons of uranium oxide had been extracted from the Chinle Formation in this district, although the Happy Jack mine accounts for most of this production (Malan, 1968). Many of the uranium deposits in the White Canyon district contain less than 1,000 tons of ore. Numerous uranium prospects and small deposits occur in the Chinle Formation a few miles south and west of Dark Canyon ISA (Hackman and Wyant, 1973; Haynes and others, 1972). Most of these deposits are contained within the Moss Back and Monitor Butte Members of the Chinle Formation.

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Dark Canyon (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), some parts of the Cutler Formation are favorable for uranium to the north and east of Dark Canyon based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Dark Canyon, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Dark Canyon ISA is low, and has been assigned a rating of c1.

[Note: Weitz and Light (1981) consider Dark Canyon ISA to have some uranium potential in the Shinarump Member of the Chinle Formation in a small area that extends south of N37°45'. This area was not included on the maps provided by the BLM for Dark Canyon ISA, and was therefore not included in this evaluation.]

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Certaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Dark Canyon ISA consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of middle and lower Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks (Hackman and Wyant, 1973; Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Dark Canyon ISA a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal resources do not exist in this ISA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Dark Canyon is deep-seated, low-temperature thermal waters (between 20°C and 90°C). A warm spring (26°C) located in Red Canyon about 15 miles southwest of Dark Canyon is the only visible and naturally-occurring manifestation of geothermal energy in the entire Moab district (NOAA, 1980). Water extracted at these temperatures can be used for direct heating. It seems very unlikely that this resource, even assuming that it exists, would ever become economical to use in the Moab district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has probably resulted in extreme depths over much of the Colorado Plateau to even the low-temperature geothermal resources. On the basis of the geologic characteristics of the Colorado Plateau, we have therfore assigned Dark Canyon a geothermal favorabilty rating of f1 and a moderately-high certainty (c3) that the resource does not exist in this area.

HYDROPOWER <u>f1/c4</u>

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Dark Canyon ISA (the Cataract Canyon hydropower site lies miles to the north of this ISA; designation of Dark Canyon as a wilderness area would have no impact on the potential development of the Cataract Canyon site). On the basis of this information we have assigned Dark Canyon ISA a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER <u>f1/c1</u>

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Weitz and Light (1981) report that samples of the Shinarump Member of the Chinle Formation collected from the Woodenshoe mine about 8 miles southeast of the tract contain as much as 3.10 percent copper (the area evaluted by Weitz and Light (1981) is considerably larger than the area evaluated in this study). The Chinle and other favorable rocks for copper (and uranium) deposits have been removed by erosion from Dark Canyon ISA. We therefore have assigned the tract a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE <u>f1/c1</u>

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout the province, the estimated manganese potential of southeastern Utah is very low [Tooker and Cannon (1980); USGS, 1982; Baker and others (1952); Pardee (1921)].

The favorable host rocks for manganese in southeastern Utah have been removed by erosion from Dark Canyon (Hackman and Wyant, 1973; Haynes and others, 1972). The nearest known manganese deposits are more than 30 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Dark Canyon a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)]. Dark Canyon, however, lies many miles west of the thick potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks did exist in the Paradox Formation in this area, they would probably be very thin and discontinuous, and would not constitute a resource.

On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 2

Dark Canyon ISA has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). The tract was judged to be favorable for small accumulation of oil and/or gas (f2). The geologic environment of the tract was considered unfavorable for all of the other resources evaluated.

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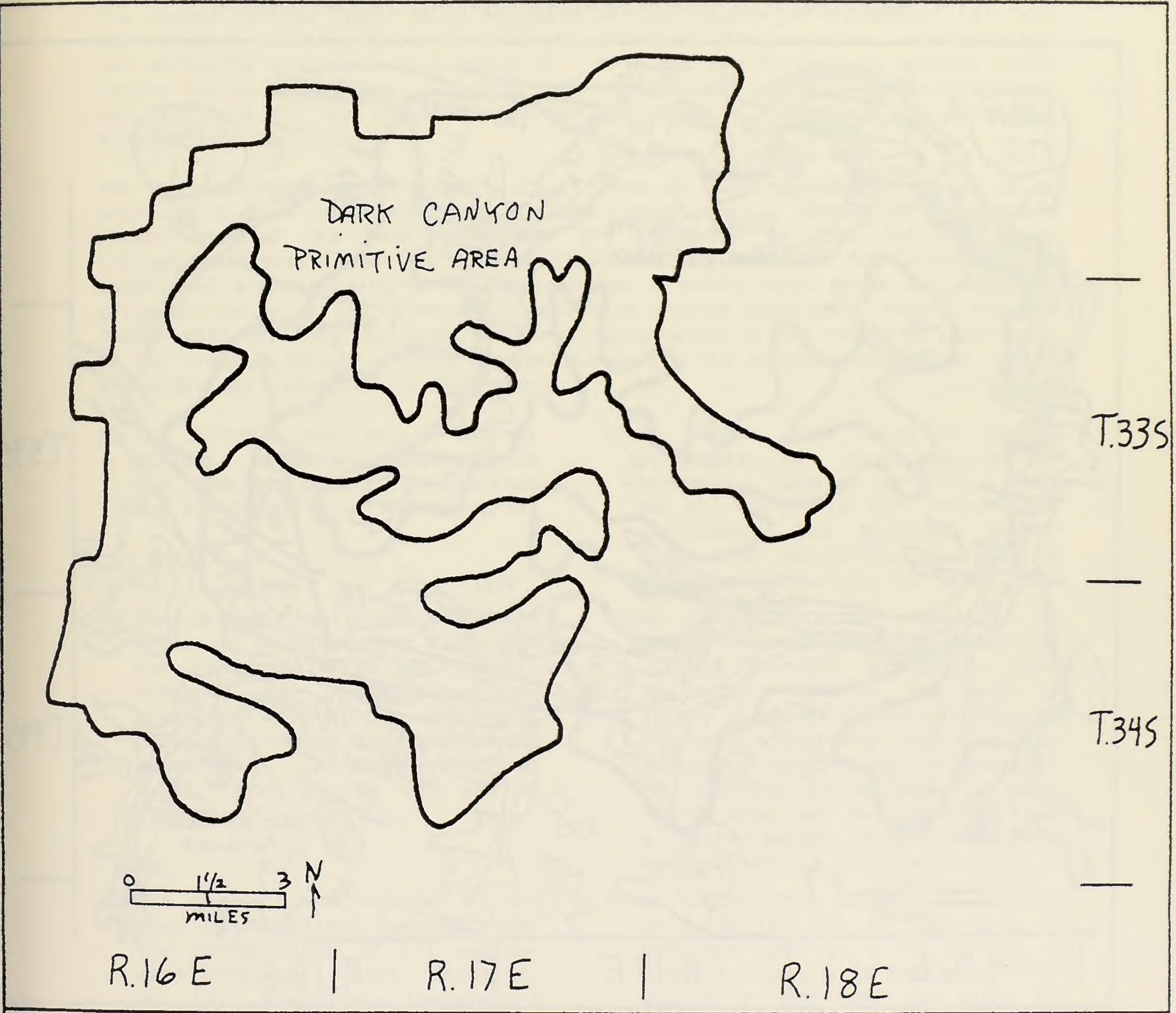
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) DARK CANYON PRIMITIVE AREA, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



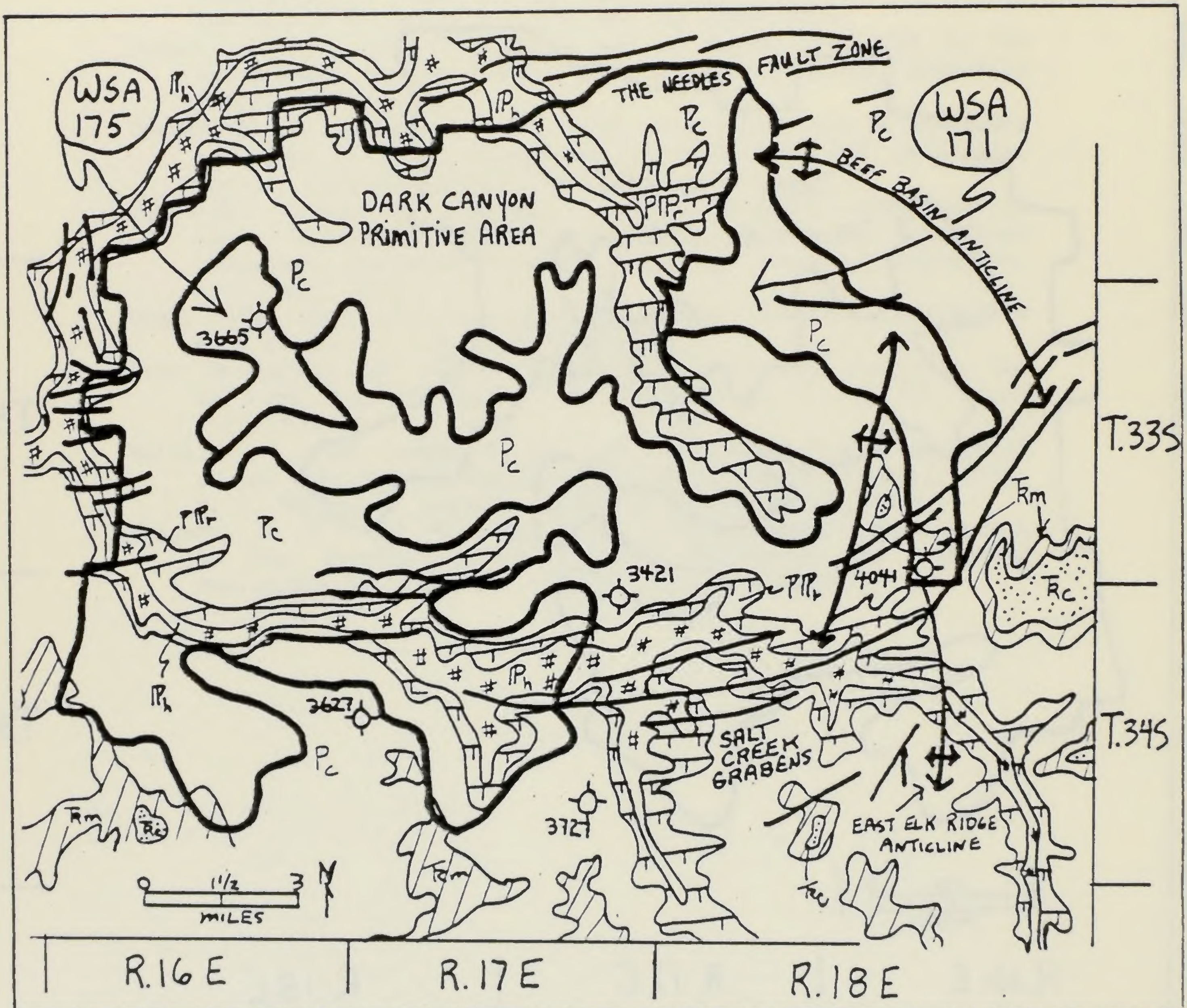
EXPLANATION

ALL MINERAL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN ~~f~~3.

SOURCE:

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 175, 171, AND DARK CANYON

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

TRc - CHINLE FORMATION (TRIASSIC)

TRm - MOENKOPI FORMATION (TRIASSIC)

Pc - CUTLER FORMATION (PERMIAN)

PIPr - RICO FORMATION (PENNSYLVANIAN - PERMIAN)

IPh - HERMOSA FORMATION (PENNSYLVANIAN)

ANTICLINE

FAULT

3727 OIL WELL, SHOWING TOTAL DEPTH (DRY)

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, "**f3**", estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, "**c2**", is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

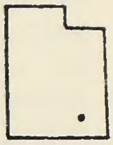
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: ISA-2* **TRACT NAME:** Grand Gulch ISA **STATE/COUNTY:** UT/San Juan

DISTRICT: Moab **ISA ACREAGE:** 34,928

DATE PREPARED: May 1982 **UPDATE:** August 1982



LOCATION

[This tract number ("ISA-2") was assigned by ORNL/SAI for record-keeping purposes only. The ISA refers to the tract's status as an Instant Study Area].

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Grand Gulch ISA lies slightly west of the axis of the Monument Upwarp--a broad north-trending structural division of the Colorado Plateau. Exposed bedrock consists almost entirely of flat-lying sedimentary rocks of the Cedar Mesa Sandstone Member of the Cutler Formation of Permian age (Haynes and others, 1972; Hackman and Wyant, 1973). Older rocks belonging to the Rico and Hermosa Formations crop out in canyons south of the tract that lead into the San Juan River. Structural features include the north-trending Cedar Mesa anticline near the east side of the tract, as well as several smaller folds within the tract (Haynes and others, 1972; Hackman and Wyant, 1973; Weir and Light, 1981).

THE TRACT'S OVERALL-IMPORTANCE RATING OF "2" APPLIES TO WHAT PERCENT OF ITS AREA? (25%__, 25-50%__, 50-75%__, [✓ 75-100%]).

RATING SUMMARY:(See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING: 2

OIL AND GAS:	f2/c2	**HYDROPOWER:**	f1/c4
URANIUM/VANADIUM:	f1/c1	**COPPER:**	f1/c1
COAL:	f1/c4	**MANGANESE:**	f1/c1
GEOTHERMAL:	f1/c3	**POTASH:**	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c2

Grand Gulch ISA lies along the west edge of the petroleum-rich Paradox Basin--a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U.S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U.S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Mississippian rocks at the Lisbon field where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that flowed from the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from inlets to the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, "hypersaline" depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and

"penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the south and west, the penesaline environment merged with a shallow shelf that contained marine waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" achieved its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), during Akah time sediments of the Paradox Formation in Grand Gulch ISA were accumulating chiefly in the penesaline facies. During Alkali Creek, Barker Creek, Desert Creek, and Ismay time, deposition occurred chiefly along the marine shelf [Berghorn and Reid, 1981; the name Hermosa Formation is applied to rocks in this area that are laterally equivalent to the Paradox Formation but do not contain appreciable evaporite deposits].

Of particular importance to oil and gas resources in the vicinity of Grand Gulch ISA are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others in the vicinity of Four Corners) produce from algal mound structures that existed in the penesaline and marine shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume therefore that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Grand Gulch ISA and in the productive areas to the east are in part similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Grand Gulch ISA, broad uplifts beginning in late Cretaceous(?) time have significantly lowered the oil and gas potential of the Paradox

Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp. Within Grand Gulch ISA the Paradox Formation is probably less than 1,000 feet below the surface. A short distance south of Grand Gulch ISA, most or all of the Paradox Formation (or called Hermosa Formation) is exposed along canyon walls along the San Juan River (Hackman and Wyant, 1973; Haynes and others, 1972). It is therefore very unlikely that reservoir pressure exists in Pennsylvanian rocks throughout much of this area; it almost certainly does not exist in Grand Gulch ISA. If oil and/or gas existed in the Paradox Formation in this area, there is a good chance that it has drained away. In partial support of this hypothesis are the oil seeps in the Mexican Hat area that originally led to the discovery of the Mexican Hat field near the San Juan River in 1908 (Lauth, 1978).

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Grand Gulch ISA probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage into the San Juan River may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Grand Gulch ISA with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Grand Gulch ISA is probably in excess of 400-feet thick (Gustafson, 1981). As of January 1980, 13 fields had produced about 44.2 million barrels of oil and 375 billion cubic feet of gas from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field southwest of Moab, however, accounted for about 95 percent of this oil production and 91 percent of the gas production. Devonian rocks are represented in Grand Gulch ISA, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Grand Gulch ISA is probably less than 500 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from six fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississippian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972) do not suggest that significant pre-salt faults exist in the southern part of the Monument Upwarp.

As of October 1981, about a dozen exploratory wells had been drilled in the vicinity of Grand Gulch ISA (PIC, 1981). Although the wells in the area have all been abandoned, some reportedly had oil shows and stains in the lower part of the Paradox Formation (see attached Geologic Sketch Map; Heylmun and others, 1965). For example, in 1959 Sinclair Oil drilled a 3,404-foot well less than a half-mile from the southeast border of the tract that reportedly had oil shows in the Paradox Formation (Heylmun and others, 1965). The bulk of the wells were drilled in the late-1950s and early-1960s to depths generally less than 4,000 feet. Other wells in this area reportedly have had oil and gas shows in Devonian, Mississippian, Pennsylvanian, and Permian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; PIC, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Grand Gulch ISA, they are likely to be associated with stratigraphic traps and small-scale folding--most of the larger structures in this area have already been tested. On this basis, and because of deep erosion, we consider the oil and gas potential of Grand Gulch ISA to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The degree of certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c2 based on oil and gas shows in exploratory wells within the tract.

URANIUM/VANADIUM f1/c1

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the Nation's total uranium reserves and about 36 percent of the Nation's potential uranium resources are contained on the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

The principal uranium-bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau. These other units, however, are of minor importance in terms of cumulative past production if compared with the Morrison and Chinle Formations.

Grand Gulch ISA lies along the crest and west side of the Monument Upwarp. The White Canyon uranium mining district lies about 25 miles to the northwest and the Monument Valley uranium mining district lies about 30 miles to the south (Malan, 1968). By mid-1965, about 8,600 tons of U_3O_8 had been extracted from the Chinle Formation in these two districts (Malan, 1968). Two of the mines--Monument No. 2 and Happy Jack--account for almost half of the total production (Malan, 1968). About half the uranium deposits in the Monument Valley and White Canyon districts contain less than 1,000 tons of ore; those in Monument Valley also contain byproduct and coproduct vanadium (Hilpert and Dasch, 1964; Fischer and Vine, 1964). The closest uranium deposits to Grand Gulch ISA are about 5 miles to the north in the Fry and Red Canyon areas (Utah Geological and Mineral Survey, 1977). Uranium deposits occur chiefly in the Chinle Formation of Triassic age and some of the deposits have produced more than 100 tons of uranium oxide (Haynes and others, 1972).

None of the important uranium-bearing formations on the Colorado Plateau are preserved in Grand Gulch ISA (Hackman and Wyant, 1973; Haynes and others, 1972). Of the formations that are preserved in the tract, only the Cutler Formation has been productive elsewhere in the Moab district (at Lisbon Valley). According to Campbell and others (1980), parts of the Cutler Formation are favorable for uranium to the north and east of Grand Gulch ISA based on stratigraphic and structural features that are similar to Lisbon Valley. The Cutler Formation in Grand Gulch ISA, however, is not considered favorable for uranium or vanadium because it contains no known uranium anomalies in this area, as well as very little organic carbon and mudstone (Peterson and others, 1980; Campbell and others, 1980). On this basis, we have assigned the tract a uranium and vanadium favorability rating of f1. The certainty that uranium and vanadium resources do not occur in Grand Gulch ISA is low, and has been assigned a rating of c1.

COAL f1/c4

Utah is an important coal-producing State, yet almost 98 percent of State's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Grand Gulch ISA consists of sedimentary rocks of late Paleozoic age that are underlain by a normal sequence of Paleozoic sedimentary rocks (Haynes and others, 1972). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Grand Gulch ISA a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this WSA.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the State (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Grand Gulch ISA is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely, however, that this resource would ever become economical to use in this part of the Moab district considering high drilling costs, the great depth to the resource, and the small number of potential users. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael River system has probably increased the depth to even these low-temperature geothermal resources. On the basis of the geologic characteristics of this region, we have therefore assigned Grand Gulch ISA a geothermal favorability rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROPOWER f1/c4

Utah ranks 32nd among the States in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U.S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the State's total installed hydroelectric capacity of 190 megawatts (U.S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and listed by latitude and longitude by the U.S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Grand Gulch ISA. The closest identified, undeveloped site is along the San Juan River near the mouth of Slickhorn Canyon a mile south of the tract [estimated capacity of 62,000 kilowatts; FERC (1981)]. Development of this site would probably not encroach upon the southern boundary of Grand Gulch ISA. We have therefore assigned Grand Gulch ISA a hydropower favorability rating of f1. The certainty that a hydropower resource does not exist within the tract is high, and has been assigned a rating of c4.

COPPER f1/c1

In 1981 Utah accounted for 14 percent of the Nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona which produced 67 percent of the Nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the Nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins (Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium are so closely associated on the Colorado Plateau, and because this area is not favorable for uranium, we have assigned Grand Gulch ISA a copper favorability of f1. The certainty that copper resources do not occur in the tract is low, and has been assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U. S. S. R. (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time the sediments were deposited, mainly the Jurassic, and later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout this region, the estimated manganese potential of southeastern Utah is nevertheless very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The most favorable host rocks for manganese in southeastern Utah have been removed by erosion from Grand Gulch ISA. The nearest known manganese deposits are more than 50 miles to the northeast (Baker and others, 1952). On this basis, and because manganese is not known to be associated with the Paleozoic sequence of the Colorado Plateau, we have assigned Grand Gulch ISA a manganese favorability of f1, but with a certainty of non-occurrence rated at only c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Grand Gulch ISA lies many tens of miles southwest of the potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks do exist at depth in the Paradox Formation in this area, they would probably be very thin and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this WSA.

OVERALL-IMPORTANCE RATING 2

Grand Gulch ISA has been assigned an overall importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Oil and gas are the most important resources potentially within the tract, but the geologic environment is judged to be favorable for small accumulations only.

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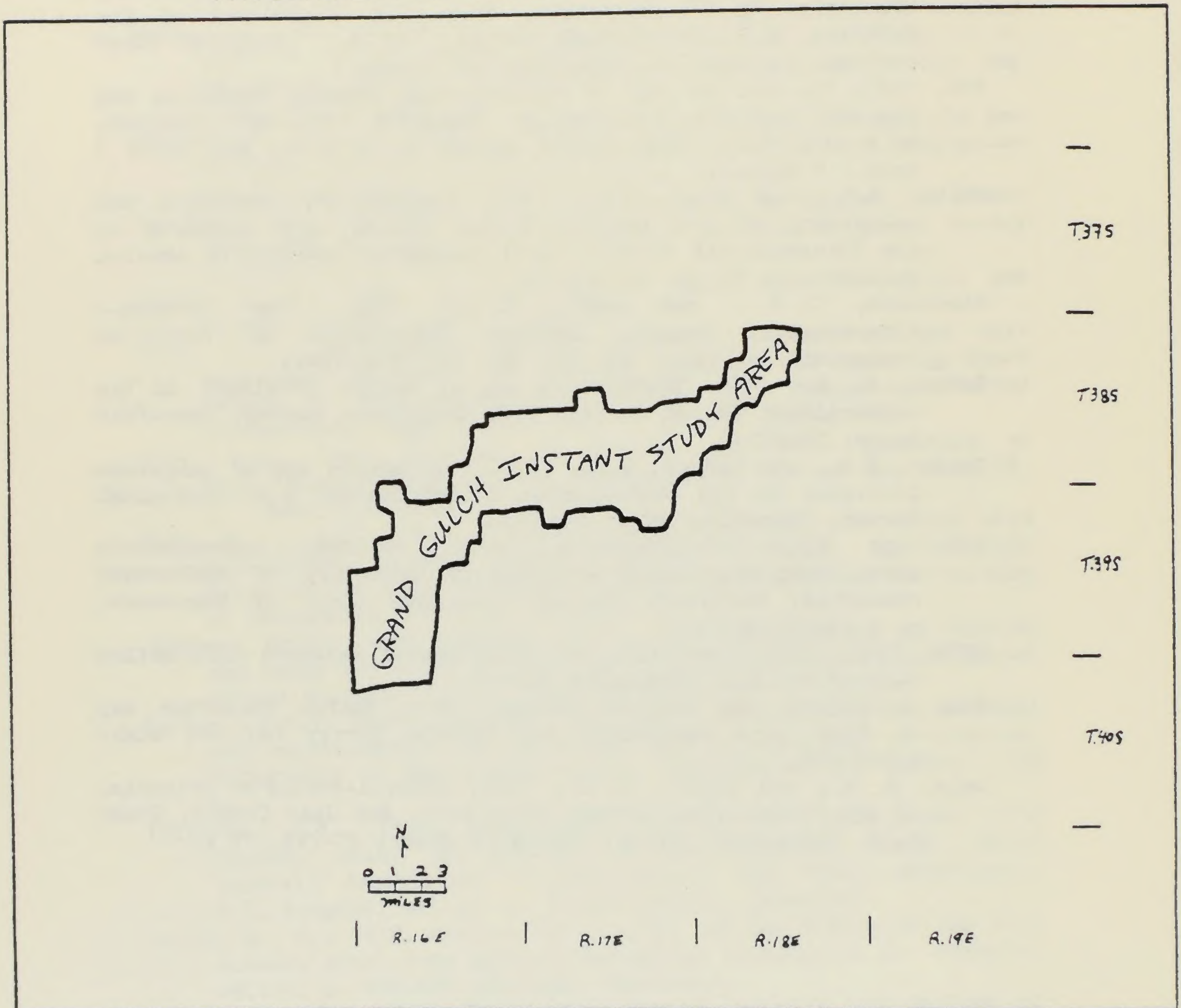
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) GRAND GULCH, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



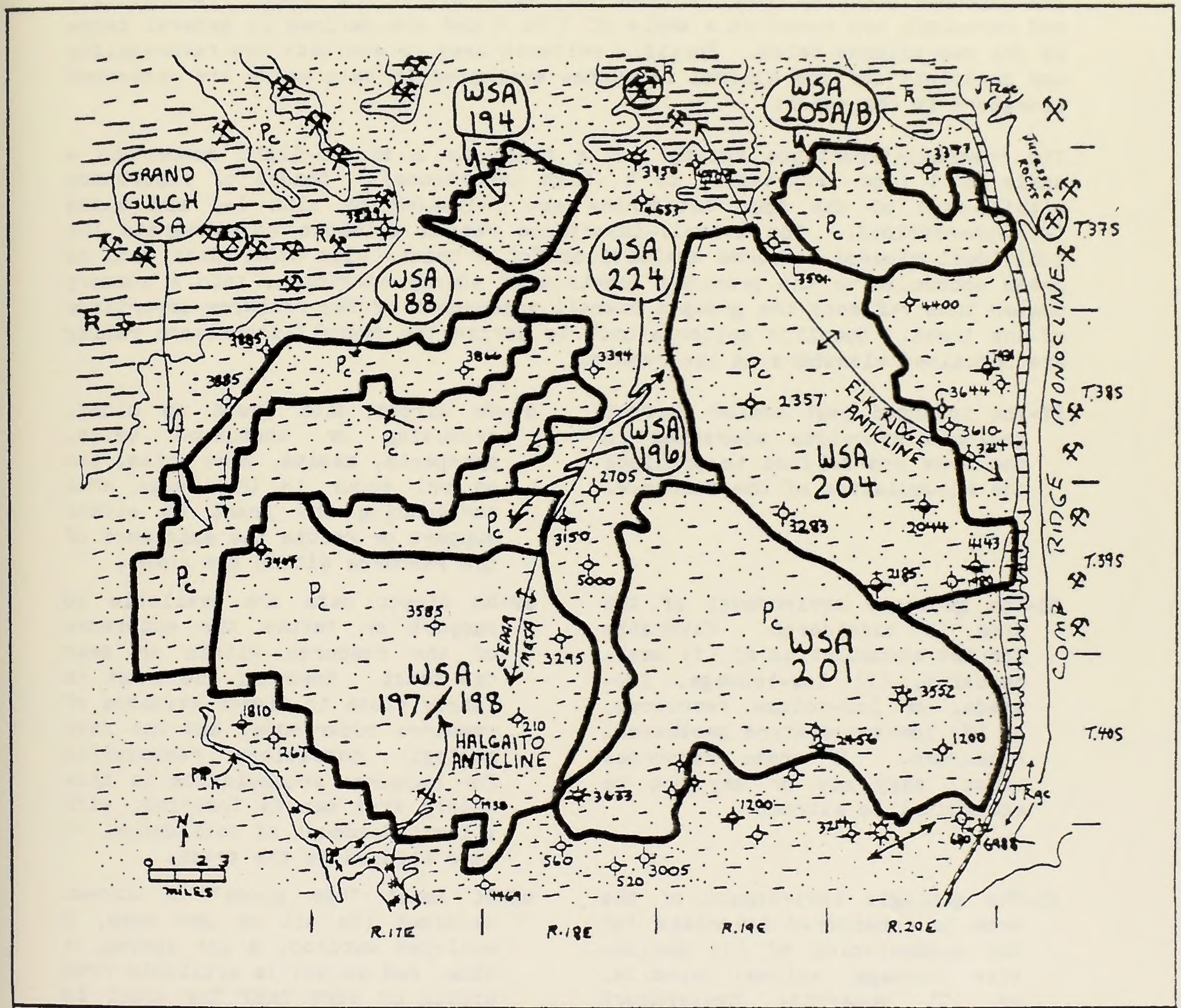
EXPLANATION

EACH MINERAL RESOURCE EVALUATED FOR THIS TRACT WAS ASSIGNED A FAVORABILITY OF LESS THAN ≤3.

SOURCE: SOURCE OF MAP, BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 194, 188, 197/198, 201, 204, 205 A/B, GRAND GULCH, & 224

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

R - TRIASSIC ROCKS; MOENKOPI AND CHINLE FORMATIONS

Pc - CUTLER FORMATION (AND RICO FORMATION ALONG SOUTHWEST SIDE OF TRACT 197/198), (PERMIAN AGE)

Ph - HERMOSA FORMATION, (PENNSYLVANIAN AGE)

ANTICLINE

OIL AND GAS WELL SHOWING TOTAL DEPTH 9210

GAS SHOW

OIL AND GAS SHOW

OIL SHOW

DRY HOLE

URANIUM DEPOSIT WITH PRODUCTION OF 10 TO 100 TONS U_3O_8

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

SOURCE: GEOLOGIC BASE FROM HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. **f3/c2**). The first rating, **"f3"**, estimates the "geologic favorability" (**f**) of the tract for the resource. The second rating, **"c2"**, is an estimate of the "degree of certainty" (**c**) that the resource actually does, or does not, exist within the tract. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained elsewhere in the report.

The "overall-importance rating" of a tract is a single-digit number on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual mineral-resource evaluations for a tract, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall assessment of the resource-importance of the tract. Specific criteria used to derive the overall-importance rating are contained elsewhere in the report.

f1-The inferred past and/or current geologic processes operating in the area are belived to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate- temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the tract to either support or refute the existence of the resource within the tract.

c2-No direct data are available to support or refute the existence of the resource within or near the tract. However, the tract is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the tract.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the tract to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

APPENDIX

APPENDIX

APPENDIX

EXPLANATION OF THE EVALUATION METHOD, WITH SPECIFIC RATING CRITERIA FOR EACH MINERAL RESOURCE AND THE DERIVATION OF THE TRACT'S OVERALL-IMPORTANCE RATING

INTRODUCTION

Oak Ridge National Laboratory and Science Applications, Inc. (ORNL/SAI) have developed a mineral-resource evaluation method for the purposes of characterizing and estimating the mineral-resource importance of tracts of land that may be recommended for wilderness designation. Land-use decisions are often made quickly, without the benefit of up-to-date, readily understandable mineral-resource information. Consequently, we decided that the results of our evaluation method should be (1) available to the land manager before a land-use decision is required, (2) based on publicly-available data, and clearly and adequately documented, and (3) written in a style that is useful to the non-geologist as well as the geologist. In order to meet these goals, we developed a method that can systematically and rapidly evaluate, document, and rate the mineral-resource importance of a large number of tracts. These evaluations are not meant to take the place of detailed field studies. In the event that field studies are not conducted, however, or are not submitted to the land manager in time to influence a land-use decision, we believe that our rapid and systematic evaluations are a reasonable and objective alternative.

The backbone of the evaluation method is a dual-rating system that attempts to judge, and then rate, the **favorability** of the tract's geologic environment for each mineral resource evaluated, and the **degree of certainty** that these resources actually exist within the tract. Because two attributes are measured by the dual-rating system (favorability and certainty), the land-manager has a broader range of options in making complex land-use trade-offs. For example, a land manager might decide that tracts with high resource-favorabilities and with low certainties-of-occurrence are more important than tracts with moderate resource-favorabilities and high certainties of resource occurrence. In this regard, tracts that lie within the poorly known parts of the oil- and gas-prospective "thrust belt" might be considered more important than tracts that are known to contain small- to moderate-size uranium or coal deposits.

The levels of "favorability" and "certainty of resource occurrence" for each mineral resource in each tract are quantified in a tract report on a whole-number scale from 1—low favorability or certainty, to 4—high favorability or certainty. The favorability and certainty ratings are an attempt to quantify our interpretation of the prevailing geologic thought on the resource potential of the area in which the tract is located. Economic considerations, such as access to the tract or the estimated costs of extracting the resource, are not considered at this stage of the evaluation, but they are considered in deriving the tract's overall-importance rating (discussed below). The information used to derive the favorability and certainty ratings is public information, and to the extent possible, all references used to help establish our understanding of the area are cited in the tract report.

The level of favorability of the geologic environment of a tract is based on the abundance and relative value of those geologic characteristics that are commonly associated with the resource being evaluated. The certainty of resource occurrence, on the other hand, is a measure of the amount, quality, and proximity of direct evidence bearing on the actual existence or non-existence of the resource within the tract. The degree of certainty that a resource exists in a tract can be based on proximity to producing areas, assays, geochemical sampling, heat-flow data, coal outcrops, prospects, oil and gas shows and seeps, hot springs and geothermal wells, perennial streams, and so forth.

The rating criteria for the minerals, and the criteria for the overall-importance rating (discussed and listed below), are designed to guide the evaluation group through a systematic procedure by which numerical ratings are ultimately derived. Specific rating criteria for each level of favorability and certainty for all the mineral resources evaluated are contained in tables at the end of this appendix. The criteria are NOT, however, intended to be a complete characterization of each and every possible geologic environment, nor are they intended to provide a step-by-step "cookbook" or "weighted" approach to ratings. We believe that the available data are too limited and oftentimes too unreliable to use or justify such an approach. This was the original reason for using only a 4-fold division for all ratings. This same method could be used to systematically and rapidly evaluate the favorability and certainty of non-mineral resource values that must also be consider by the land manager in the land-use planning process.

THE OVERALL-IMPORTANCE RATING AND ITS DERIVATION

For each tract, a summary judgment of the overall mineral-resource importance is assigned on a whole-number scale of 1 (low importance) to 4 (high importance). This number, along with a discussion of how it was derived, is entered on the tract report. The overall-importance rating (OIR) is a synthesis of the favorability and certainty ratings for each of the evaluated mineral resources, in addition to our judgments related to the strategic nature of specific resources, broad economic aspects of resource development in the immediate area, environmental constraints, the size of the tract, and so forth (criteria used to derive the OIR are listed below). The OIR is developed through the consensus of the evaluation group, which consists of a core team of three to as many as six geologists who are familiar with the criteria used to derive the OIR. Because judgments and subjective inputs are basic to the procedure used to create the OIR, it has the potential of being adversely influenced by such pyschological factors as self-serving interests, dominance of authority figures with incorrect perceptions, and reliance on unstated, nontechnical values. Nevertheless, the literature of policy analysis and management science makes a strong case for the validity of expert opinions as applied to the process of complex decision-making, providing that the process is aided by a systematic procedure. Similar to the favorability and certainty ratings, the reasons used to assign a tract a specific OIR must be stated as clearly as possible in the tract report.

Use of the OIR is justifiable because, by themselves, the favorability and certainty ratings for each mineral resource within a tract are difficult for the land manager to apply directly to land-use decisions. To properly consider the favorability and certainty ratings for a number of tracts, the land manager would be faced with far too much information. For example, 30 tracts, each with a favorability and certainty rating for 8 mineral resources, will force the land manager to process mentally 480 ratings. Because of time limitations, the land-manager might apply a very simple and quick method for determining the level of mineral-resource importance of each tract. One method might be to assign high importance only to those tracts with high certainty ratings. Obviously, such a procedure would undermine other significant facts and considerations about each tract. In addition, some very important tracts, from the standpoint of mineral-resource favorability, might be recommended for wilderness status (other values, of course, could outweigh the importance of mineral resources). Moreover, because the OIR is sensitive to broad economic characteristics of the resource and the tract, whereas the favorability and certainty ratings are not, the OIR can provide additional information that may be useful to land-use decisions.

The discussion above suggests that a hierarchy of synthesis exists in which each level of information is a derviation from the one below. The base of the information 'pyramid' is composed of factual data and interpretations such as geologic maps, reports, and occurrence and production data. This information is then synthesized by the core group into measures of favorability and certainty at the second level of the hierarchy. Finally, the third level of the hierarchy synthesizes the objective measures of level two with other 'agreed-upon' importance measures in order to derive the OIR.

The synthesis of favorability and certainty ratings with other data might suggest to some a numerical process wherein each attribute is weighted (that is, its value is qualified numerically), and an OIR computed by a mathematical formula. Our experience with similar exercises, however, indicates that analytical "multi-attribute" decision methods are not an effective method for determining the OIR. For example, the role of the BLM requires that it consider a tract's mineral potential within the context of multiple-use planning, as well as other factors such as national security, national economic health, governmental energy policy, and the plans and objectives of private developers. These concerns translate into a multitude of tract-specific attributes that must be integrated into the OIR. These attributes are both difficult to identify and quantify adequately. Moreover, considering the inherent uncertainties of mineral data, and the short time available to assess the mineral-resource potential of these tracts, we decided against a rigorous mathematical derivation of the OIR for the following additional reasons: (1) it would be very difficult or impossible to structure adequately; (2) analytical procedures would necessarily exclude many special, yet important, aspects of certain tracts; (3) it might be difficult to explain and justify the results of analytical procedures to decision makers; and (4) a mathematical derivation of the OIR would probably lead to an expansion of the 4-fold OIR rating scale, that in our opinion, would not be justifiable with the available minerals data. Thus, a mathmatical or weighted derivation of the OIR could impart to the reader a false sense of accuracy. Furthermore, an OIR derived by such a method has a good chance of being somewhat wasteful in terms of available time and funds.

Recognizing the need for an OIR and the inability to compute such a rating rigorously, we turned to group judgment, using explicit procedures that focus and guide the group in creating the OIR. To begin with, each tract is assigned an OIR which is equal to the highest favorability rating of any of the individual resources. The OIR is then adjusted up or down by considering, in turn, numerous predetermined criteria and any special factors that may be peculiar to the tract. For example, a large tract with a high favorability for oil and gas is considered to be more important than an equivalent-size tract with a high favorability for only geothermal resources--assuming that all other ratings for each tract are the same (see item #3, below). The following criteria, written in question form, are used to "fine-tune" a tract's OIR:

(1)Are there multiple mineral resources within the tract having favorabilities of 3 and 4? If so, it would tend to raise the OIR.

(2)Is the certainty of occurrence of the resource(s) high? If so, it would tend to raise the OIR. For example, as the certainty of resource occurrence increases, a tract becomes more valuable to the nation because its resource potential becomes less hypothetical and more reliable as a "real source" of raw materials.

(3)Does the size of the tract increase the chances that mineral resources (if they exist in the area) are more likely to occur in the tract? In other words, given two tracts with equal geologic favorabilities and certainties of resource occurrence, the larger tract is more important because it is more likely to actually contain a mineral accumulation.

(4)Can the resource be produced only at costs that are significantly higher than the current market price of the resource? If so, the tract's OIR would generally be lowered. For example, if all potential uranium resources in a tract are estimated to be developable only at costs exceeding $150 per pound of uranium oxide, the OIR might not be as high as the assigned uranium favorability of the tract.

(5)What is the relative importance of the resources that are assigned 3 and 4 favorabilities? We have defined the importance of a resource in terms of (a) the current and anticipated contributions that the resource is likely to make to the energy and (or) mineral requirements of our nation, and (b) the known abundance, availability, and distribution of the resource, both nationally and worldwide. For those tract's to which this criterion is applied, the rationale is explained in the tract report.

(6)Were any factors uncovered in the investigation that would enhance or detract from the likelihood of developing the resource in the tract, assuming that it occurs? Some of these factors include poor accessibility to the tract, limited water supply, large competitive deposits of the resource nearby, or keen interest by industry in the general area. Federal and state policy, as well as public opinion, can also influence prospects for development. These factors, if identified and used to either increase or decrease the the tract's OIR, are explained in the tract report.

(7) Is the tract within an area of a proposed energy project? If so, how will wilderness designation of the tract affect the proposed energy project? Smaller proposed projects, such as coal-slurry pipelines or electrical transmission corridors, may also increase the importance of a tract if the tract lies across or close to the proposed corridor route.

The ORNL/SAI evaluation group considers each of the criteria in turn, and adjusts the initial OIR up or down across a whole-number scale of 1 to 4. Once the whole-number OIR is determined by the group, it can be further refined by the use of plus ("+") or minus ("-") superscripts. The addition of superscripts does not imply the use of a 12-level linear scale ranging from 1- to 4+, but rather that the OIR value is strong or weak relative to the norm for the whole-number OIR.

The team considers the areal distribution of all OIRs as they work with an individual tract. In other words, a tract's OIR and any subsequent adjustments to the OIR must make sense relative to nearby OIRs. For example, tracts of about the same size, with similar favorability and certainty ratings, should have similar OIRs. If these tracts lie within a region of "commonly accepted" high resource potential, a large proportion of high OIRs would be expected. Too small a proportion of high OIRs would suggest that the implicit weights applied to the positive resource factors are too low. This round-table iteration and debate is used over a period of a few days to a week, until a consensus is reached by the team on each tract's OIR. This approach has the inherent flexibility needed to deal with the vagaries of the real world--anomalous situations, special information, unquantifiable input, scaling problems, and the varying degrees of data reliability. Finally, a description of how the OIR was derived is included in each tract evaluation.

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR OIL AND GAS RESOURCES

GENERAL

Favorability--The organic remains that are typically contained in sedimentary rocks such as shale and limestone are considered by many investigators to be the chief source of the world's hydrocarbons. This organic debris is generally more abundant, accumulates more rapidly, and is much better preserved in near-shore marine environments where life is teeming, although some nonmarine environments may also contain significant accumulations of organic debris. Where such accumulations are heated during deeper burial, a series of poorly understood chemical and physical reactions transform part of the organic material into petroleum. Petroleum is an inclusive term applied to substances ranging from gaseous to solid; it includes crude oil and natural gas. Continued compaction during deep burial expels the fluid and gaseous portions of the petroleum, which may then migrate toward zones of lower pressure. (The distance that oil and gas can migrate is a matter of considerable controversy. Some geologists, on the one hand, consider migration on the order of hundreds or even thousands of miles to be possible, whereas other geologists believe that oil and gas migrate very little from the point at which they are generated.) If the transmissivity of the rocks is sufficient, and favorable reservoir rocks and traps are available, oil and gas pools can accumulate. The degree of geologic favorability of a tract for commercial oil and gas pools thus depends on the following regional or provincial characteristics: (1) thickness and volume of sedimentary rocks; (2) the presence of adequate source rock; (3) the level of maturation of the organic matter in the geologic environment; (4) the availability of both porous and permeable reservoir rock; (5) the development of reservoir traps coincident with petroleum migration; and (6) the severity of post-entrapment tectonic and geothermal activity. Many other factors can also influence the apparent favorability of a region, but the factors listed above are essential.

The anticipated size (small, medium, and large) of oil and gas pools in each of the favorability categories listed below are modified from "Reserve Estimates of New-Field Discoveries" prepared by the Committee on Statistics of Drilling of the American Association of Petroleum Geologists. (Johnston, R.R., 1980, North American drilling activity in 1979: Am. Assoc. Petrol. Geol. Bull., v. 64, no. 9, p. 1295-1330.)

Certainty--The degree of certainty of oil and gas occurrence is based on the proximity of direct evidence that either supports or refutes the existence of the resource in the immediate environment of the tract. Direct evidence includes the following: (1) surface oil and gas seeps caused by leakage from fractured reservoirs; (2) tar sands or oil-impregnated rock deposits (oil shales are non-maturated or only partly maturated source rocks and are treated as a separate resource when required); and (3) results from exploration and development (includes wildcat, deeper- and shallower-pool tests, outpost or extension tests, and development wells).

Geophysical data, chiefly seismic, are often mistakenly assumed to provide "proof", or at least a high degree of certainty, that oil and gas resources actually occur in an area. Geophysical data, however, are no more than tools used to interpret the stratigraphy and structure of a region, as a means of determining its degree of "geologic favorability" for oil and gas. As such, geophysical data will be used as a measure of **favorability**--not certainty.

Data on well yield and on oil and gas quality, when and where available, are considered economic information and are used along with other data to estimate the contribution that oil and gas will make to the Overall-Importance Rating of the tract. Such data include: flow or pumping rates for wells; specific-gravity determinations; chemical analyses for sulfur, nitrogen, and the amounts of various metal and mineral contaminants (in the case of crude oil); and hydrogen sulfide, nitrogen, carbon dioxide, helium analyses (in the case of raw gas).

FAVORABILITY

f1: Tracts designated as having the lowest favorability, "f1", for oil and gas will be within a geologic environment dominated by igneous and metamorphic rocks that constitute a regional basement at or near the surface; or by intense recent tectonic activity, particularly where characterized by pervasive fracturing or brecciation. In such areas, source rocks either do not exist or have been strongly altered, with concomitant loss of most of the contained volatiles and, in some cases, the alteration of remnant carbon to graphite. Similarly, traps or reservoir rocks either have not developed or have been altered or destroyed by intense igneous, metamorphic, and tectonic events. Consequently, in most of these present-day geologic environments any pre-existing concentrations of oil and gas would have been vaporized by the intense heat, or lost to the hydrosphere or atmosphere upon a loss of confining pressure during fracturing and brecciation.

f2: The geologic environment of a tract rated at the "f2" level for oil and gas is considered to have a potential only for small, widely scattered oil and gas pools. The size of recoverable hydrocarbon accumulations in such an environment would be anticipated to be less than 10 million barrels of oil or, if gas, no more than 60 billion cubic feet [volume grades D through F (Johnston, 1980, p. 1303)]. The cumulative thickness of sedimentary rocks in the "f2" geologic environment will generally be less than a few thousand feet thick. Such a relatively thin stratigraphic sequence generally limits the volume of both favorable source and reservoir rocks; hence the expected small size and low frequency of oil and gas pools. Moreover, any medium-size or larger accumulations that may have existed in earlier favorable environments in the area have since been destroyed or reduced in size by recent tectonic events and/or fresh water flushing.

f3: Tracts considered favorable for oil and gas at the "f3" level are within an environment that may contain either densely-spaced small pools, or scattered, moderately-large pools. Recoverable fluid hydrocarbons are anticipated to be between 10 and 50 million barrels of oil, or between 60 and 300 billion cubic feet of gas [volume grades B and C (Johnston, 1980, p. 1303)]. The geologic environment deemed likely to host such intermediate quantities of oil and gas would generally contain a sedimentary sequence less than 5,000 feet thick. This rock sequence must be heterogeneous in composition and contain at least one organically-rich marine formation to provide a hydrocarbon source. Moreover, the geologic history of the area must be such that the presence of stratigraphic and structural traps can be reasonably inferred. Finally, evidence of possible fresh-water flushing of potential reservoir rocks must be minimal.

f4: Tracts designated "f4" must be within a geologic environment that is favorable for large accumulations of oil and gas. Recoverable fluid hydrocarbons in such an environment are anticipated to be more than 50 million barrels of oil, or if gas, more than 300 billion cubic feet [volume grade A (Johnston, 1980, p. 1303)]. The geologic environment must include a heterogeneous sequence of sedimentary rocks with a thickness generally well over 5,000 feet. Organically-rich marine source rocks should be relatively abundant. Numerous reservoir rocks and stratigraphic and structural traps must be confidently inferred to exist in the area based on its geologic history. Multiple oil- and gas-reservoirs stacked in vertical succession might be reasonably inferred to occur in this geologic environment. Recent tectonism must be at a minimum, if present at all. There should be no evidence of possible fresh-water flushing of potential reservoir rocks.

CERTAINTY

c1: In the lowest level of certainty for oil and gas, "c1", no direct data are available to support or refute the occurrence of petroleum within the tract, regardless of the level of geologic favorability. No wells have been drilled in or near the tract, nor are any oil or gas seeps, tar sands, or oil-impregnated sandstone deposits known in the vicinity. Positive evidence of resource occurrence is far removed from the tract, or is on a trend considered unrelated to the geology of the tract. Accordingly, the tract will not be within an "established" or generally accepted "potential" petroliferous province.

c2: A lower-intermediate level of certainty, "c2", for oil and gas again implies that no direct data (seeps, exploratory wells, or producing wells) occur within or very near the tract being evaluated. However, positive occurrence data must be available from the vicinity of the tract; thus the tract will probably be within a petroliferous province (basin) with at least one producing or formerly commercial oil and/or gas field. Seeps, shows, or productive wells that are present at some distance along a known productive trend are considered as stronger evidence for certainty than closer-in occurrences known to be off-trend. Thus, oil and gas shows as much as several miles away on-trend are better indications of certainty than those less than a mile distant but off-trend. Positive-occurrence data on parallel similar-type trends, although at some distance, are considered evidence for at least a "c2" certainty.

c3: The "c3", or higher-intermediate, degree of certainty for oil or gas requires the recognition of at least one seep, a show in an exploratory well, or a producing well from within or very near the tract being evaluated. Moreover, the tract will likely be within an established petroleum-producing province. If several wells have been drilled in or near the tract, at least one must have a strong show. A "c3" rating can also be used if the rating-team consensus deems that the extrapolation of nearby positive-direct data is stronger than for a "c2" certainty. [If a number of wells from within or near the tract have been drilled and all were dry, a c3 or c4 certainty rating would be applied in conjunction with a low favorability rating.]

c4: The highest level of oil and gas certainty, "c4", is used only when the tract being evaluated lies within a well-known, productive petroliferous province. Abundant and direct evidence such as seeps, shows, or producing wells occur within or immediately adjacent to the tract. [By definition, when a "c4" certainty is used with an "f1" favorability, the dual rating indicates with a high-degree of certainty that commercial quantities of oil and gas do not occur in or near the tract.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR OIL-IMPREGNATED ROCK DEPOSITS

GENERAL

Favorability--The term "petroleum" applies to many substances ranging from gaseous, to liquid, to solid. The gaseous and liquid forms are referred to as natural gas and crude oil, respectively. The semi-solid and solid forms of petroleum consist of heavy hydrocarbons; that is, petroleum that has lost its volatile or lighter constituents because of exposure to the atmosphere. These deposits are variously referred to as asphalt, tar, pitch, albertite, gilsonite, grahamite, or other terms depending on the individual characteristics of the deposits and depending upon local terminology.

Heavy oils in Utah are referred to as "oil-impregnated rock deposits" by members of the Utah Geological and Mineral Survey. These deposits are breached oil fields--accumulations of once-fluid hydrocarbons that are now at or near the land surface. For this study, we have adopted the Utah Survey's terminology, as well as the deposit-size classification developed by Ritzma (1979, Utah Geological and Mineral Survey, Map 47).

The favorability criteria for "Oil and Gas" (this appendix) are generally applicable to oil-impregnated rock deposits. However, the oil-impregnated rocks are not now economical to develop, and a direct volumetric comparison with undiscovered recoverable petroleum is, in our opinion, not justifiable. Therefore, the volume of oil assigned to the various favorability levels under oil-impregnated rocks is substantially higher than the volume assigned to the corresponding favorability categories for crude oil.

Certainty.--Oil-impregnated rocks, unlike many other mineral resources, usually occur over large areas, parts of which commonly intersect the land surface. Thus, the degree of certainty that oil-impregnated deposits exist can be as high as 100 percent using detection methods no more sophisticated than visual inspection. Nevertheless, for those tracts that are not known with 100 percent assurance to contain oil-impregnated rock, but are within obviously favorable environments, such as extensions of known deposits, the certainty of occurrence is something less than 100 percent. Consequently, the degree of certainty that oil-impregnated rocks exist in a tract can be based on: (1) visible, reported occurrences (2) the proximity of the tract to known areas of oil-impregnated rock, and the inferred continuity of these deposits to the tract; and (3) the results of drill tests.

FAVORABILITY

f1: An "f1" favorability rating for oil-impregnated rock is assigned to a tract in areas where porous and permeable rocks do not exist, chiefly in igneous and metamorphic terranes. It can also be assigned to rocks of sedimentary origin that are not considered to be suitable reservoir rocks.

f2: Tracts assigned an "f2" rating are within a geologic environment favorable for oil-impregnated deposits containing less than 10 million barrels of oil-in-place [size categories "minor" and "medium" according to the classification developed by Ritzma (1979, Utah Geological and Mineral Survey, Map 47). According to Ritzma (1979), open-pit mining of these deposits could yield as much as 90 percent of the oil-in-place, compared with a yield of only 10 to 20 percent by in-situ methods. (See the "Oil and Gas" criteria in this appendix for additional details on oil generation, migration, and entrapment which are also applicable to oil-impregnated rock deposits.)

f3: Tracts assigned an "f3" rating are within a geologic environment favorable for oil-impregnated deposits containing between 10 million and 500 million barrels of oil-in-place [size categories "large" and "very large" according to the classification developed by Ritzma (1979, Utah Geological and Mineral Survey, Map 47). We chose to assign Ritzma's "large" and "very large" deposits to the f3 rather than the f4 favorability category because the lower-limit of Ritzma's "large" deposit corresponds to the lower-limit of our f3 category for recoverable fluid petroleum (see oil and gas criteria). The upper limit of estimated recoverable fluid petroleum at the f3 level is 50 million barrels (see oil and gas criteria). Our decision to place the f3 upper-limit for oil-impregnated deposits at 500 million barrels is based chiefly on the uneconomic nature of these deposits, and because a direct volumetric comparison of these deposits with undiscovered recoverable petroleum is, in our opinion, not justifiable].

f4: Tracts assigned an "f4" rating are within a geologic environment favorable for oil-impregnated deposits containing more than 500 million barrels of oil-in-place [a "giant" according to the classification developed by Ritzma (1979, Utah Geological and Mineral Survey, Map 47). See the discussion contained within brackets under f2 and f3 above].

CERTAINTY

c1: In the lowest level of certainty, "c1", no direct data are available to support or refute the occurrence of oil-impregnated rock within the tract, regardless of the level of geologic favorability. No oil-impregnated rocks are known from the region surrounding the tract, nor can any be reasonably inferred to exist based on lateral continuity with known deposits at great distances from the tract.

c2: A lower-intermediate level of certainty, "c2", indicates that no direct data (outcrops and exploratory drill-tests) occur within or very near the tract being evaluated. Some positive occurrence data, however, must be available from the vicinity of the tract, and the intervening geology must be such that the inference of continuity between these known occurrences and the tract is reasonable.

c3: The "c3", or higher-intermediate degree of certainty requires the recognition of at least one oil-impregnated rock unit near the tract being evaluated. These nearby occurrences should usually be no more than a few miles from the tract, and the postulated lateral continuity of the oil-saturated formation at depth below the tract should be relatively high. Assigning a tract a "c3" rating requires a much higher degree of confidence that oil-impregnated rocks actually occur in the tract compared with a "c2" rating.

c4: The highest level of certainty, "c4", is used only when the tract being evaluated is known to contain oil-impregnated rocks, regardless of the associated favorability. [By definition, when a "c4" certainty is used with an f1-favorability, the dual rating indicates with a high-degree of certainty that oil-impregnated rocks do not occur in or near the tract.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR OIL SHALE

GENERAL

Favorability--Oil shale is a fine-grained sedimentary rock containing organic matter that, upon heating, can yield a large volume of oil. The United States contains an enormous amount of identified oil shale although the bulk of the resource occurs in the Green River Formation in Colorado, Wyoming, and Utah. The U.S. Geological Survey estimates that more than 2 trillion barrels of oil occur in oil shales in the United States having an average yield of 15 or more gallons of oil per ton of rock. (Culbertson and Pitman, 1973; U.S. Geological Survey Professional Paper 820, p. 497-503).

Deposits of oil shale occur in many parts of the country and they range in age from Ordovician to Tertiary. Most oil shales are associated with lacustrine rocks, marine shales, and shale deposited with coal-bearing rocks. The organic fraction of the lacustrine shales is derived from algae and other microorganisms that flourished in the central part of large shallow lakes that existed in subtropical climates. Oil shales originating in this environment, such as the Parachute Creek Member of the Green River Formation, can contain up to 2,000 feet of alternating rich and lean beds of oil shale.

The oil shales of marine origin consist of two types--those associated with continental platforms and those associated with geosynclinal basins. The volume of marine oil shale (and the contained potential oil) far exceeds that of oil shales of lacustrine origin. Nevertheless, these deposits (such as the Chattanooga Shale and equivalent shales in the Eastern and Central United States) are typically less than 100 feet thick and have an average oil yield of only about 5 gallons per ton of rock.

The oil shales associated with coal beds (sometime called carbonaceous shales) are generally thin, of limited areal extent, and exhibit considerable lateral variation in organic content. Some of those shales may locally yield up to 100 gallons of oil per ton of rock, but most yield less than 10 gallons.

[We emphasize that the geologic favorability for oil shale, even at the highest level of favorability, is not dependent upon whether these deposits can be developed economically. In fact, recent announcements by the oil shale industry, such as Exxon's cancellation in 1982 of a large-scale mining operation in the Piceance Creek Basin in northwestern Colorado, have raised many questions regarding the profitability of oil shale through at least the end of this century. The economics of developing oil shale are not considered in the favorability ratings, but they are taken into account at the time the WSA is assigned an Overall-Importance Rating.]

Certainty.--Oil shales, unlike many other mineral resources, occur over large areas, parts of which commonly intersect the land surface. Thus, the degree of certainty that oil shales exist can be as high as 100 percent using detection methods no more sophisticated than visual inspection. Nevertheless, for those tracts that are not known with 100 percent assurance to contain oil shale, but are within obviously favorable environments, such as extensions of known deposits, the certainty of occurrence is something less than 100 percent. Consequently, the degree of certainty that oil shales exist in a tract can be based on: (1) visible, reported occurrences (2) the proximity of the tract to known areas of oil shale, and the inferred continuity of these deposits to the tract; and (3) the results of drill tests.

FAVORABILITY

f1: An "f1" favorability rating for oil shale is assigned to a tract in areas composed of igneous and metamorphic rocks. It can also be assigned to a tract where the rocks, although of sedimentary origin, originated in environments that are not normally associated with oil shale, such as eolian environments. [Favorable geologic environments for oil shale at depths exceeding a few hundred feet below the surface are not considered in the evaluation, unless there are compelling reasons to do so.]

f2: Tracts assigned an "f2" rating are within a geologic environment favorable for thin beds of oil shale (a few tens of feet thick, regardless of the potential oil yield), or within a geologic environment favorable for moderately thick beds of low-yield oil shale (beds exceeding 100 feet thick, but with an oil yield of less than 15 gallons per ton of shale). Geologic environments at the f2 level could include (1) shallow continental shelves, (2) parts of a miogeosyncline that are associated with deposits of limestone, phosphorite, and chert, and (3) the periphery of large, shallow lakes that existed in sub-tropical environments.

f3: Tracts assigned an "f3" rating are within a geologic environment favorable for moderately-thick beds of oil shale (a few hundred feet thick) with an estimated average oil yield of about 15 gallons per ton of shale. In general, only the more central parts of pre-existing lacustrine environments, and some miogeosynclinal sub-basins, would meet these criteria.

f4: Tracts assigned an "f4" rating are within a geologic environment favorable for thick and rich deposits of oil shale--at least a few hundred feet thick, with an estimated average oil yield of at least 25 gallons per ton of shale. In general, only the central, organic-rich parts of pre-existing lacustrine environments would meet these criteria.

CERTAINTY

c1: In the lowest level of certainty, "c1", no direct data are available to support or refute the occurrence of oil shale within the tract, regardless of the level of geologic favorability. No oil shales are known from the region surrounding the tract, nor can any be reasonably inferred to exist based on lateral continuity with known deposits at great distances from the tract.

c2: A "c2" degree of certainty indicates that no direct data (outcrops of oil shale, or exploratory drill-tests) occur within or very near the tract being evaluated. Some positive occurrence data, however, must be available from the vicinity of the tract, and the intervening geology must be such that the inference of continuity between these known occurrences and the tract is reasonable.

c3: A "c3" degree of certainty requires the recognition of at least one bed or zone of oil shale (or carbonaceous shale) near the tract being evaluated. These nearby occurrences should usually be no more than a few miles from the tract, and the postulated lateral continuity of the oil shales at depth below the tract should be relatively high. Assigning a tract a "c3" rating requires a much higher degree of confidence that oil shales actually occur in the tract compared with a "c2" rating.

c4: The highest level of certainty, "c4", is used only when the tract being evaluated is known to contain oil shale, regardless of the associated favorability. [By definition, when a "c4" certainty is used with an f1-favorability, the dual rating indicates with a high-degree of certainty that oil shales do not occur in or near the tract.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR URANIUM RESOURCES

GENERAL

Assessment of the Nation's uranium resources is the responsibility of the National Uranium Resource Evaluation (NURE) program within the Department of Energy. The definitions of potential uranium resource used herein (speculative, possible, and probable) are those defined and used by NURE geologists (Department of Energy, 1980, An assessment report on uranium in the United States: U.S. Department of Energy, Grand Junction Office, Report GJO-111(80), 150 p.)

Favorability-- Commercial uranium deposits are those that have a sufficient uranium content to be mined economically now or in the next several decades by existing or predictable technologies. The chief type of uranium deposit currently mined domestically is the epigenetic accumulation in relatively young sandstones of the Colorado Plateau and Wyoming basins. Other, much larger, types of deposits are exploited throughout the world, chiefly from Precambrian rocks. Some of these larger types that have potential in the United States include (1) vein and related deposits in igneous and metamorphic rocks; (2) concentrations in quartz-pebble conglomerates; and (3) unconformity-related deposits. In addition, low-grade (less than 0.01 percent uranium oxide) accumulations in phosphorites and Paleozoic black shales could also contribute to our domestic needs in the future.

The geologic favorability for uranium in a tract is based on the tonnage of potential uranium resources estimated to occur within the tract. These estimates are based chiefly on NURE data that are then combined with other geologic data to determine the tract's favorability. The tonnage values used to help establish geologic favorability are as follows: f1=unfavorable for uranium; f2=less than 500 tons uranium oxide; f3=500 to 1,000 tons uranium oxide; and f4=more than 1,000 tons uranium oxide.

The costs of producing a specified amount of uranium are called "forward costs." They include capital and operating costs that are incurred in producing the uranium, but not the costs of acquiring the land, exploration, mine development, and mill construction, or taxes, profit, and other items. The forward costs, being entirely economic factors, are used (when available) to estimate uranium's contribution to the tract's Overall-Importance Rating (see criteria for determining "Overall Importance" in this appendix).

The origin of large uranium deposits requires the coincidence of several geologic conditions: 1) a source rock with readily leachable uranium, or with uranium-mineral resistates; 2) sufficient water and adequate conduits to transport the uranium in solution, or as solid detrital mineral grains (complexing agents are needed to form the solute if the transporting solutions are oxidizing); and 3) a geologic environment where suitable reducing agents can combine with the transporting solutions to precipitate uranium minerals, or where detrital resistates can be concentrated. The absence of any one of these conditions in or near a tract being evaluated will preclude the accumulation of most types of uranium deposits, and thus reduce the tract's geologic favorability for uranium resources.

Because of the variety of geologic environments in which uranium can occur, it would be far too lengthy to characterize each and every environment in terms of the four favorability levels listed below. Nevertheless, the reasons used to assign a tract a specific favorability level must be clearly stated in the tract report.

Certainty-- Certainty of uranium-resource occurrence is based on the proximity of direct evidence that either supports or refutes the presence of uranium within the tract. The following evidence can be used to support the four certainty levels: (1) the visible occurrence of uranium minerals, as in mineralized fault breccias; (2) active or once productive uranium mines, or known deposits or prospects; (3) geochemical sampling, including water, sediment, soil and rock; (4) geophysical data which can selectively measure uranium content (this does not include standard gamma-ray bore-hole logs which measure all types of radioactivity); and (5) uranium assays from core samples.

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[*] For the mineral evaluation of WSAs in the BLM's Moab district in southeastern Utah, the potential for vanadium resources is almost completely dependent upon the uranium potential. Therefore, separate rating criteria for vanadium were not developed. In general, the ratings assigned to uranium for a WSA also apply to vanadium.

FAVORABILITY

f1: Tracts assigned to the "f1" category are unfavorable for uranium. In general, the geologic environment of the tract contains none of the three general favorability criteria cited above.

f2: Tracts assigned to the "f2" favorability category are estimated to contain potential resources of less than 500 tons uranium oxide. A review of relevant geologic data shows the prominence of only one of the three favorability criteria mentioned above under "General," with but minimal evidence for the other two. Thus, the geologic environment is only marginally favorable for uranium. For example, a thick sandstone aquifer may be assigned an f2 favorability if only limited amounts of both source and reducing materials are available.

f3: Tracts assigned an "f3" favorability are estimated to contain potential resources of 500 to 1,000 tons uranium oxide. Thus, the three conditions for a uranium accumulation--a source, transport mechanisms and conduits, and chemical precipitation and concentration--must be identified. For sandstone-type deposits, the geologic sequence must contain at least one porous sandstone and a zone of readily leachable uranium (such as felsic tuffaceous debris) to provide the uranium source and transport mechanism. In addition, a reductant, such as carbonaceous debris, coal fragments, or fluid hydrocarbons, must be reasonably inferred to exist along or within this sandstone body.

f4: Tracts assigned an "f4" rating are within a geologic environment favorable for uranium resources in excess of 1,000 tons uranium oxide. For a tract to be assigned an f4 rating, all three of the primary criteria mentioned previously must be present in sufficient abundance to indicate the tonnages of potential resources indicated. In the case of sandstone-type deposits, this would imply multiple-source and -conduit zones with an abundance of reductants.

CERTAINTY

c1: No direct data are available to either support or refute the existence of uranium in the tract, regardless of the level of geologic favorability. There are no surface occurrences, mines, or known deposits in the vicinity of the tract. The rock formations which underlie the tract are not known to contain uranium in the host geologic province, and therefore the tract is well outside of any generally recognized resource area. Geochemical surveys and/or exploration drilling are not known to have been conducted in the area.

c2: The "c2" level of certainty implies that positive data, though somewhat limited, exist in the vicinity of the tract. At a minimum, one prospect, uranium assay, or deposit is known in the area, but the extrapolation of "continuity" from this occurrence to the tract is tenuous. The results of an initial geochemical sampling program can be used at this certainty level to either support or refute the existence of uranium deposits within the tract. This level of certainty would generally correspond to the part of NURE's "speculative potential" classification wherein the potential resources are reported as "undiscovered" deposits.

c3: Visible occurrences of uranium minerals, prospects, a mine, or assays from within or near the tract must be identified in order to assign a tract a certainty rating of "c3." Uranium assays of core samples taken in the vicinity of the tract from several exploration holes, or a cluster of anomalously high uranium values from geochemical samples, would be evidence for a "c3" rating. A "c3" certainty level would generally correspond to the part of NURE's "possible potential" resources anticipated in "undiscovered" deposits; it would also include "speculative potential" resources assigned to "partly defined" deposits. [If a relatively complete drilling or sampling program had been conducted in the vicinity of the tract with negative results, a high certainty rating (c3 or c4) would be applied in conjunction with a low favorability rating.]

c4: The highest degree of certainty, "c4", is applied to those tracts which lie in a well established uranium district, with at least one mine or deposit (from which uranium is or has been produced) within the tract boundaries. The "c4" level of certainty would correspond not only to NURE's "probable potential" resource classification, but also to the "partly defined" deposits of the "possible potential" class; it will obviously also include any uranium resources classified as reserves.

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR COAL RESOURCES

GENERAL

Favorability--The raw material that is eventually transformed into coal originates in deltaic, swampy, lagoonal, and near-shore lacustrine environments where huge quantities of organic debris accumulate and are then slowly buried in a reducing environment. With the passage of time, the organic material is compacted into coal under the weight of overlying sediments. The eventual rank of the coal is defined by the fixed carbon and heat content on a mineral-free basis. Changes in coal rank from lignite to subbituminous, bituminous, and finally anthracite, are related to a progressive decrease in the content of moisture and other volatiles. This change is the result largely of the rate, duration, and severity of metamorphism of the organic matter by the depth and heat of burial, and by the degree of structural deformation through time. Grade, on the other hand, is a measure of the quality or purity of the coal and is determined by the content of ash, sulfur, and other deleterious materials.

Based on the discussion above, the level of favorability of the geologic environment for coal resources depends on (1) the geologic age of the rocks (considering that abundant plant life is clearly necessary); (2) the lithology of the rock units and the environment of deposition of the original sediments; and (3) the intensity of diagenetic and/or structural changes since initial deposition of these sediments.

Certainty--Coal, unlike many other resources, usually occurs as large tabular bodies, parts of which commonly intersect the land surface. Also in contrast to other mineral resources, coal is a primary deposit formed contemporaneously with the enclosing sediments. Thus, the degree of certainty that the resource occurs, even over very large areas, can be as high as 100 percent using detection methods no more sophisticated than visual inspection. Nevertheless, for those tracts that do not contain outcrops of coal, but are within obviously favorable environments such as a coal basin, the certainty of occurrence is something less than 100 percent. Consequently, the degree of certainty that coal occurs in a tract can be based on (1) visible, reported occurrences, which includes formerly or currently productive deep mines; (2) the proximity of the tract to known coal beds, and the inferred continuity of these coal beds at depth within the tract; and (3) the results of drill tests.

FAVORABILITY

f1: An "f1" favorability rating for coal is assigned to a tract in areas where extensive igneous and metamorphic rocks are at or near the surface. It can also be assigned where rocks, although sedimentary in origin, were deposited in environments not normally associated with coal, such as in off-shore marine environments. Moreover, any areas that consist only of pre-Devonian sedimentary rocks can be designated as f1, because land plants, the prime requisite for coal, did not evolve until that time.

f2: Tracts rated "f2" are within a geologic environment favorable for only small tonnages of coal, or in thin, discontinuous seams (considerably less than 28 inches thick for bituminous or higher ranks, and considerably less than 5 feet thick for subbituminous or lower rank coals). Such coals would more than likely have formed in lagoonal or deltaic channel-fill marshes, and the age of these coals might not be equivalent to the age of the major coal-bearing rocks in the region.

f3: Tracts rated "f3" are within a geologic environment favorable for moderate tonnages of coal (approximately 28 inches thick for bituminous or higher ranks, or about 5 feet thick for subbituminous or lower rank coals). The major coal-bearing units in the region should be recognized within the tract, but the tract will probably be located in the more peripheral parts of the original coal basin(s).

f4: Tracts rated "f4" are within a geologic environment favorable for large tonnages of coal (greater than 28 inches thick for bituminous or higher ranks, or greater than 5 feet thick for subbituminous or lower rank coals). The major coal-bearing units in the region should be recognized within the tract, and the tract will be located in the more central parts of the original coal basin(s) where the coal deposits are likely to be thicker and more continuous.

CERTAINTY

c1: In the lowest level of certainty, "c1", no direct data are available to support or refute the occurrence of coal within the tract, regardless of the level of geologic favorability. No coal outcrops are known from the region surrounding the tract, nor can any coal beds be reasonably inferred to exist based on lateral continuity with known coal beds at great distances from the tract. Accordingly, the tract will be far removed from any established or prospective coal basins.

c2: A lower-intermediate level of certainty, "c2", for coal again implies that no direct data (outcrops, exploratory drill-tests, or former coal mines) occur within or very near the tract being evaluated. However, positive occurrence data must be available from the vicinity of the tract, and the intervening geology must be such that the inference of continuity between these known occurrences and the tract is reasonable. Accordingly, a tract assigned a "c2" certainty rating will probably be within a generally recognizable coal basin.

c3: The "c3", or higher-intermediate, degree of certainty for coal requires the recognition of at least one coal-bearing formation, or an abandoned or active coal mine, very near the tract being evaluated. Nearby occurrences should usually be no more than 5 miles from the tract, although site- or area-specific information may indicate the use of greater or lesser distances. Assigning a tract a "c3" rating requires a much higher degree of confidence that coal actually occurs in the tract compared with a "c2" rating.

c4: The highest level of coal certainty, "c4", is used only when the tract being evaluated is known to contain coal beds, regardless of the associated favorability. [By definition, when a "c4" certainty is used with an f1-favorability, the dual rating indicates with a high-degree of certainty that commercial quantities of coal do not occur in or near the tract.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR GEOTHERMAL RESOURCES

GENERAL

Favorability--Most investigators consider recent crustal instability, high heat-flow, and young igneous rocks as favorable criteria for geothermal resources of commercial proportions. In contrast, low-temperature hydrothermal resources occur widely and have apparently originated from deep ground-water circulation in regions with normal, or slightly higher-than-normal, geothermal gradients. Because of the widespread occurrence of low-temperature geothermal resources, land withdrawals for wilderness will generally have little or no impact on the availability and use of this particular resource. Moderate- and high-temperature resources, on the other hand, occur much less frequently and are therefore considered to be more important by the ORNL/SAI evaluation group from the standpoint of potential land withdrawals. Therefore, in the criteria below, "low favorabilities" correspond to geologic environments favorable for low-temperature geothermal resources, whereas "high favorabilities" correspond to geologic environments favorable for high-temperature geothermal resources. In general, the favorability of a region for geothermal resources depends on: (1) the type, extent, and age of igneous activity; (2) the degree of recent tectonism; (3) the region's heat flow and geothermal gradient; and (4) geochemical and some geophysical data that reflect the presence and composition of fluid systems normally associated with elevated temperatures.

Certainty.--The certainty of occurrence of geothermal resources within a tract is based on the amount and proximity of direct evidence of resource occurrence, such as hot springs and their deposits, thermal wells, and geophysical methods that directly measure the temperatures of geothermal systems.

FAVORABILITY

f1: Tracts designated as having the lowest favorability, "f1", for geothermal resources will generally be within a geologic environment that lacks igneous rocks younger than Tertiary age, has minimal seismic activity, contains geologic structures which originated largely in pre-Tertiary time, and is characterized throughout the region by a very low heat-flow (less than 1.5 heat flow units), and a shallow geothermal gradient (less than 25 degrees C per kilometer).

f2: The geologic environment of a tract rated at the "f2" level for geothermal resources is considered to be favorable for low-temperature geothermal resources (less than 90 degrees C at depths generally less than 1 kilometer). These environments are likely to contain widespread occurrences of lower- and middle- Tertiary igneous rocks, widespread Paleozoic deformation, minor seismic activity, low heat-flow (between 1.5 and 2.0 heat flow units) and average geothermal gradients (25-30 degrees C per kilomete In all likelihood, most thermal waters in an f2 environment will be of meteoric origin rather than of magmatic origin.

f3: A tract considered favorable for geothermal resources at the "f3" level must have a potential for moderate-temperature resources (between 90 and 150 degrees C at depths generally less than 1 kilometer). The geologic environment of such a tract will generally contain widespread middle- and upper-Tertiary igneous rocks, evidence of Paleozoic and/or Mesozoic deformation, moderate seismic activity, moderate heat-flow (2.0 to 2.5 heat flow units), an above-averaged geothermal gradients (30 to 45 degrees C per kilometer).

f4: A tract designated "f4" must have the potential to contain high-temperature geothermal resources (more than 150 degrees C). The geologic environment of such a tract will generally contain young volcanic and igneous intrusive rocks of silicic composition (less than 1 million years old), evidence of late-Cenozoic tectonism, moderate to intense seismic activity, high heat-flow (more than 2.5 heat flow units), and steep geothermal gradients (more than 45 degrees C per kilometer).

CERTAINTY

c1: In the lowest certainty level, "c1", no direct data are available to either support or refute the existence of the resource within the tract, regardless of the level of geologic favorability. Hot springs, thermal wells, and any other indicators of resources presence, are not known from the region surrounding the tract.

c2: The "c2" certainty level also indicates that no direct data are available to support or refute the existence of the resource within the tract being evaluated. However, direct evidence of resource occurrence must be nearby, and such that extrapolation of resource occurrence to the tract can be made with a moderate degree of confidence (certainty). r).

c3: The "c3" level of certainty requires the identification of at least one thermal spring or well within or very near the tract being evaluated. Areas identified as "Potential Geothermal Resource Areas" by state or federal agencies, however, can usually be assigned to this certainty level. Moreover, a "c3" rating can be used if the rating-team consensus deems that nearby direct data for resource occurrence more closely support a "c3", rather than "c2", rating.

c4: The highest level of certainty for geothermal resources, "c4", is used only when the tract lies within an area of abundant hot springs and/or thermal wells. Moreover, the tract may lie within or very near to a "Known Geothermal Resource Area" as identified by federal agencies.

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR HYDROPOWER RESOURCES.

GENERAL

Hydropower resources are more related to the hydrologic and topographic environments, rather than to the geologic environment (except to the extent that the geology influences the topography which then can influence the climate). Because of this distinction, the favorability of the environment for hydropower resources is rated in terms of the hydrologic environment--not the geologic environment as is done with other mineral resources. The favorability for other uses of surface water, such as irrigation and industrial purposes, is not considered in this resource evaluation.

The distinction between the favorability of a tract's hydrologic environment, and the degree of certainty that the resource does, or does not, exist within the tract can be ambiguous for hydropower resources. This is because hyrdopower, unlike the other mineral resources, **exist only at the surface.** For example, a tract that contains a small perennial stream may be favorable for a small-scale hydroelectric development, and at the same time the certainty that the water occurs is obviously high. On the other hand, tracts that do not contain streams are, with a high degree of certainty, very unfavorable for hydropower resources.

Based on the discussion above, a 4-part subdivision of "certainty" as used for the other mineral resources is not readily applicable to hydropower resources. Therefore, the certainty of occurrence of hydroelectric resources is based on a 2-part subdivision, as follows: (1) c1--data are not available to estimate the certainty of occurrence; and (2) c4--data indicate with a high degree of certainty that a resource does, or does not, occur within the tract.

The favorability of the hydrologic environment is based on: (1) the size (measured in discharge of cubic feet of water per second) of streams within the tract; (2) the climate of the area as one measure of the probable maximum and minimum flow rates of streams within the tract; (3) the topography; and, when the information is available, (4) the gross theoretical power at potential hydroelectric sites (these estimates are assigned only to those sites that have been evaluated by either the Army Corps of Engineers, the Water Power and Resources Administration, the Federal Energy Regulatory Commission, or the U.S. Geological Survey). If no data are obtainable from these sources, the hydroelectric-resource favorability is judged from the available general knowledge of the geology, topography, and climatic conditions of the region wherein the tract lies.

FAVORABILITY	CERTAINTY
f1: The tract has low average annual precipitation and essentially no surface runoff, except during short, infrequent periods of heavy rainfall. Thus, there is little or no favorability for the development of hydropower resources.	c1: No data or very few data are available to determine whether or not sufficient streamflow occurs in the tract to characterize its hydropower potential.
f2: The tract is estimated to have a potential only for the development of "small-scale" (0.05 to 15 megawatts) hydroelectric capacity. The tract should contain one or more small perennial streams.	c2: Not Applicable
f3: The tract is estimated to have a potential for "moderately-large" (15 to 25 megawatts) hydroelectric capacity. Relatively large streams should flow through the tract, and the topography and geology should be such that construction of a dam is feasible.	c3: Not Applicable
f4: The tract is estimated to have a potential for "large-scale" (in excess of 25 megawatts) hydroelectric capacity. A major river must flow through the tract, or the tract must be located below maximum-pool level of the potential reservoir site.	c4: Perennial streams are known to exist in the tract; or, if used with a favorability of f1, streams are known not to exist within tract.

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR COPPER RESOURCES

GENERAL

Favorability--Economic copper deposits are those that can be mined profitably now or in the near future. According to Cox and others (1973; USGS Professional Paper 820), the five chief types of copper deposits are: (1) porphyry and genetically related types, (2) strata-bound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. More than 90 percent of the world's copper resources are contained in the first two deposit-types listed above (Cox and other, 1973).

Copper is transported to the earth's crust by igneous intrusions and mineralized solutions. Ore deposits that result directly from these processes include porphyry and vein-type deposits. Copper can also be remobilized by chemical and mechanical weathering, and reconcentrated as strata-bound accumulations in favorable sedimentary rocks.

Crustal rocks average contain about 50 parts per million copper, but much larger concentrations can occur in a variety of geologic environments as outlined briefly above. A complete characterization of each deposit type for the favorability levels listed below (f2, f3, and f4) would therefore be very lengthy. Furthermore, such detailed characterizations would probably not be of immediate use to the geologist trying to assist the land manager with a land-use decision. Thus, as a first step in determining WSA-favorability for copper, we have adopted for use the "copper province map" prepared recently by Tooker (1980; USGS Open-File Report 79-576-D). This map, similar to other previously published mineral and metallogenic maps, illustrates favorable areas (provinces) in the conterminous United States for copper deposits. To the extent possible, Tooker characterized the type and size of copper deposits that could be anticipated within each province, as well as the overall copper-resource potential of each province. The favorability levels listed below are therefore based partly on Tooker's work, even though additional information is used during the copper-resource evalution of a WSA. The deposit sizes associated with the f2, f3, and f4 favorability levels are based on data in Guild (1981, Preliminary metallogenic map of North America: U.S. Geological Survey).

In practice, the copper favorability of a WSA is evaluated for each type of copper deposit, regardless of whether or not the WSA lies within a copper province defined by Tooker. These evaluations, however, can usually be done rapidly because it is very unlikely that a WSA will contain all the geologic environments that are favorable for the various types of copper deposits. In general, and unless stated otherwise, only the surface and near-surface rocks within a WSA--those to depths of about 1000 feet--are evaluated for copper favorability. Favorable rocks that may exist at greater depths within the WSA are not considered in these evaluations unless there are compelling reasons to do so.

Certainty--The degree of certainty that copper resources occur, or do not occur, in a WSA is based on the proximity, type, and abundance of direct evidence that either supports or refutes the existence of copper in the area. The following data can be used to support the various certainty levels: (1) the reported visible occurrence of copper minerals in or near the WSA, (2) active or once-productive mines, or known deposits and prospects, (3) the results of geochemical sampling of water, sediment, soil, or rock, and (4) the results of rock assays. Geophysical surveys, particularly the various types of electrical methods frequently used in copper exploration, can merely enhance (or reduce) the geologic favorability--the results of these studies do not affect the certainty of occurrence.

FAVORABILITY

f1: WSAs assigned to the "f1" category are unfavorable for copper. None of the geologic characteristics that are normally associated with the major types of copper deposits can be identified in the area being evaluated.

f2: WSAs assigned an f2 rating are marginally favorable for copper. If deposits exist in this geologic environment, they will generally be small--less than 50,000 tons of contained copper metal. In general, a WSA assigned an f2 copper favorability will be within a copper province considered by most investigators to have a low resource potential. In general, igneous intrusive rocks will not occur in the area, thus precluding porphyry- and replacement-type deposits. The geologic environment is at best favorable for small copper deposits associated with late Paleozoic and Mesozoic sandstones such as those on the Colorado Plateau that generally do not occur in large, high-grade, and isolated accumulations (the cumulative tonnage of low-grade, red-bed copper deposits, however, may be very large because they can occur over broad areas).

f3: WSAs assigned an f3 rating are moderately favorable for copper. If deposits exist in this geologic environment, they can be expected to contain between 50,000 and 1,000,000 tons of contained copper. In general, a WSA assigned an f3 copper favorability will be within a copper province considered by most investigators to have at least a moderate resource potential. The geologic environment of the WSA should be similar, in many respects, to the geology of areas that contain deposits of this size, regardless of the distance from the WSA. Some of the more specific characteristics, however, such as zones of highly fractured rock in the case of porphyry deposits, may be lacking. In any case, the specific deposit types (models) that are applied to the WSA must be stated clearly in the WSA report, along with the reasons for the estimated favorability.

f4: WSAs assigned an f4 rating are the most favorable for copper. If deposits do occur in this geologic environment, they can be expected to contain more than 1,000,000 tons of contained copper. In general, a WSA assigned an f4 copper favorability will be within a copper province considered by most investigators to have a high resource potential. The specific geologic characteristics of the WSA should be similar in almost all respects to the geology of areas that contain deposits of this size, regardless of the distance separating these deposits from the WSA.

CERTAINTY

c1: No direct data are available to either support or refute the existence of copper in the WSA, regardless of the assigned copper-favorability rating. There are no surface occurrences, mines, or known deposits in the vicinity of the WSA. The rock formations underlying the WSA are not known to contain copper deposits or occurrences in this geologic province. Geochemical surveys and/or exploration drilling for copper are not known to have been conducted in the area. The WSA will be well outside of any generally recognized copper-mining region.

c2: The c2 certainty level implies that some data, though somewhat limited, exist in the vicinity of the WSA. At a minimum, one prospect, rock assay, or deposit is known from the area, but the extrapolation of "continuity" from this occurrence to the WSA is at best tenuous. The results of an initial geochemical survey can be used at this certainty level to either help support or refute the existence of copper resources within the WSA.

c3: At the c3 certainty level, visible occurrences of copper minerals, prospects, mines, or rock assays must be reported from within or near the WSA. In general, the WSA will be within or very near an established copper-mining district. A c3 rating can also be used if the rating-team consensus deems that the extrapolation of nearby direct data warrants a c3 rather than a c2 rating.

c4: The c4 certainty for copper can be applied to those WSAs that lie in a well established copper-mining district, providing that a mine, deposit, or significant occurrence is within or very near the WSA (and assuming, of course, that the geology of the WSA is similar to the geology of the areas containing the copper deposits). All things being equal, a c4 rather than a c3 rating is applied if copper occurrences and prospects occur abundantly in the general vicinity of the WSA. [By definition, when a c4 certainty is used with an f1 favorability, it indicates with a high-degree of certainty that copper resources do not underlie the WSA.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR MANGANESE RESOURCES

GENERAL

Favorability--Economic manganese deposits are those that can be mined profitably now or in the near future. At current prices, economic deposits must contain between 25 and 50 percent manganese. In the United States, manganese occurs in a variety of geologic environments, but all resources are subeconomic because of either too low a grade or because the deposits contain too little manganese to be extracted economically. Although the United States has no manganese reserves, world reserves are more than adequate to meet world demand for the next several decades, providing of course that suppliers are willing to continue to sell these reserves (DeHuff and Jones, 1980; U.S. Bureau of Mines Bulletin 671).

According to Dorr and others (1973; USGS Professional Paper 820), the three chief types of manganese deposits are: (1) sedimentary deposits laid down as oxides and carbonates (includes deep-sea nodules), (2) deposits that are genetically related to volcanism, and (3) deposits related to hydrothermal activity. The conceptual boundary between these deposit types is not well defined, and it is not uncommon for one type of deposit to grade into another, especially in areas characterized by secondary and supergene enrichment. In general, deposits associated with sedimentary rocks [type (1) above] contain the bulk of the world's manganese resources, chiefly in the form of oxides.

Manganese in the 12th most abundant element. It is most abundant in mafic igneous rocks (0.16 percent) where it substitutes for other elements in certain minerals rather than forming separate manganese minerals. Under weathering, the mafic minerals readily decompose, freeing manganese in its ionic form. The manganese can then be transported great distances in reducing or near-normal ground- and surface- waters and eventually deposited in oxidizing environments as manganese oxides and carbonates.

Economic manganese deposits can occur in a variety of geologic environments, as outlined briefly above. A complete characterization of each deposit type for the favorability levels listed below (f2, f3, and f4) would therefore be lengthy. Furthermore, such detailed characterizations would probably not be of immediate use to the geologist trying to assist the land manager with a land-use decision. Thus, as a <u>first step</u> in determining WSA-favorability for manganese, we have adopted for use "manganese province map" prepared recently by Tooker and Cannon (1980, USGS Open-File Report 79-576-0). This map, similar to other previously published mineral and metallogenic maps, illustrates favorable areas (provinces) in the conterminous United States for manganese deposits. To the extent possible, Tooker and Cannon characterized the type and size of manganese deposits that could be anticipated within each province, as well as the overall manganese-resource potential of each province. The favorability levels listed below are therefore based partly on work of Tooker and Cannon, even though additional information is used during the manganese-resource evalution of a WSA. The deposit sizes associated with the f2, f3, and f4 favorability levels are based on data in Guild (1981, Preliminary metallogenic map of North America: U.S. Geological Survey).

In practice, the manganese favorability of a WSA is evaluated for each type of manganese deposit, regardless of whether or not the WSA lies within a manganese province defined by Tooker and Cannon. These These evaluations, however, can usually be done rapidly because it is very unlikely that a WSA will contain all the geologic environments that are favorable for the various types of manganese deposits. In general, and unless stated otherwise, only the surface and near-surface rocks within a WSA--those to depths of about 1000 feet--are evaluated for manganese favorability. Favorable rocks that may exist at greater depths within the WSA are not considered in these evaluations unless there are compelling reasons to do so.

Certainty--The degree of certainty that manganese occurs, or does not occur, in a WSA is based on the proximity, type, and abundance of direct evidence that either supports or refutes the existence of manganese in the area. The following types of data can be used to support the certainty levels: (1) reports of visible and significant occurrences of manganese minerals in or near the WSA, (2) active or once productive mines, or known deposits and prospects, (3) the results of geochemical sampling of water, sediment, soil, or rock, and (4) the results of rock assays.

FAVORABILITY

f1: WSAs assigned to the "f1" category are unfavorable for manganese. None of the geologic characteristics that are normally associated with the major types of manganese deposits can be identified in the area being evaluated.

f2: WSAs assigned an f2 rating are marginally favorable for manganese. If deposits do occur in this geologic environment, they will generally be small--less than 100,000 tons of 40 percent manganese. In general, a WSA assigned an f2 manganese favorability will be within a province considered by most investigators to have a low resource potential, such as a volcanic environment capable of supporting volcanogene-type deposits.

f3: WSAs assigned an f3 rating are moderately favorable for manganese. If deposits do occur in this geologic environment, they can be expected to contain between 100,000 and 10,000,000 tons of 40 percent manganese. In general, a WSA assigned an f3 manganese favorability will be within a manganese province considered by most investigators to have at least a moderate resource potential. The geologic environment of the WSA will be favorable chiefly for sedimentary-type deposits, and the geology of the WSA should be similar, in many respects, to the geology of areas that contain deposits of this size regardless of their distance from the WSA.

f4: WSAs assigned an f4 rating are the most favorable for manganese. If deposits do occur in this geologic environment, they can be expected to contain more than 10,000,000 tons of 40 percent manganese. In general, a WSA assigned an f4 manganese favorability will be within a manganese province considered by most investigators to have a high resource potential. The specific geologic characteristics of the WSA should be similar in almost all respects to the geology of areas that contain deposits of this size regardless of their distance from the WSA.

CERTAINTY

c1: No direct data are available to either support or refute the existence of manganese in the WSA, regardless of the assigned manganese-favorability rating. There are no surface occurrences, mines, or known deposits in the vicinity of the WSA. The rock formations underlying the WSA are not known to contain manganese deposits or occurrences in the geologic province containing the WSA. Geochemical surveys and/or exploration drilling are not known to have been conducted in the area. The WSA will therefore be well outside of any generally recognized manganese province.

c2: The c2 certainty level implies that some data, though somewhat limited, exist in the vicinity of the WSA. At a minimum, one prospect, rock assays, or one deposit is known from the area, but the extrapolation of "continuity" from this occurrence to the WSA is tenuous at best. The results of an initial geochemical survey can be used at this certainty level to either help support or refute the existence of manganese within the WSA.

c3: At the c3 certainty level, visible occurrences of manganese minerals, prospects, mines, or rock assays must be reported from within or near the WSA. Furthermore, the WSA will be within or very near a generally recognized manganese province. A c3 rating can also be used if the rating-team consensus deems that the extrapolation of nearby direct data warrants a c3 rather than a c2 rating.

c4: The c4 certainty for manganese can be applied to those WSAs that lie in a well established manganese-mining area, providing that a mine, deposit, or significant occurrence is within or very near the WSA (and assuming, of course, that the geology of the WSA is similar to the geology of the areas containing the manganese deposits). All things being equal, a c4 rather than a c3 rating is applied if manganese occurrences and prospects occur abundantly in the general vicinity of the WSA. [By definition, when a c4 certainty is used with an f1 favorability, it indicates with a high-degree of certainty that manganese resources do not underlie the WSA.]

SPECIFIC CRITERIA USED TO DERIVE LEVELS OF FAVORABILITY AND CERTAINTY FOR POTASH RESOURCES

GENERAL

Potassium (or "potash," K_2O) is a vital chemical element used to promote plant growth and increase crop yield. About 95 percent of the potash consumed in the United States is used in fertilizers.

Most potash is obtained from bedded deposits by underground mining. Where the deposits are too deep, generally more than 3,000 or 4,000 feet below the surface, solution mining methods are used. Smaller amounts of potash are also derived from evaporation of salt lakes and from subsurface brines.

Potassium occurs in igneous, metamorphic, and sedimentary rocks. About 95 percent of potash reserves, however, are contained in bedded sedimentary deposits of various geologic ages that originated from evaporation of restricted bodies of sea water. The potassium is contained largely in the mineral sylvite (KCl), and in other potassium-magnesium minerals, that occur in tabular bodies a few tens of feet thick covering several square miles (Smith and other, 1973; USGS Professional Paper 820). The other 5 percent of potash reserves are contained in natural brines that originated largely by evaporation of Pleistocene lakes. Potash reserves of both the world and North American are enormous.

Favorability--The favorability of a geologic environment for potash is based on the identification of paleo-evaporitic basins. Of the 69 evaporite deposits (basins) identified in the United States by Smith and others (1973; USGS Professional Paper 820), only 7 are known to contain potassium minerals. The scarcity of potash in evaporitic basins is the result of the order in which minerals are precipitated from sea water. In general, potash minerals precipitate only after extreme evaporation, and always within the sodium-rich (halite) facies of an evaporite sequence. Thus, in the most favorable geologic environments for potash, a suitable paleo-topography and paleo-climate that tend to favor extreme evaporation, barred basins, and characteristic sediments (halite, gypsum, anhydrite, etc.) should be identifiable.

The tonnage of potash assigned to the various favorability levels listed below come from Guild (1981, Preliminary metallogenic map of North America: U.S. Geological Survey).

Certainty--The degree of certainty that potash occurs in a WSA is based on the proximity, type, and abundance of direct evidence that either supports or refutes the existence of potash within the WSA. The following data can be used to support the various certainty levels: (1) the reported occurrence of potash from oil and gas exploration, and (2) active or once-productive mines.

FAVORABILITY

f1: WSAs assigned to the "f1" category are unfavorable for potash. None of the geologic characteristics that are normally associated with bedded potash deposits, such as a paleo-evaporitic basin, can be identified within the WSA.

f2: WSAs assigned an "f2" rating are within a marginally favorable geologic environment for potash. Although the WSA will contain some rocks that originated in an evaporitic environment, the geologic data suggest that the climate within the basin was not particularly arid, or long-lived. If, on the other hand, a large paleo-evaporitic basin is believed to have existed in the region, geologic data suggest that the WSA lies along the basin's periphery. If deposits occur in this environment, they will generally contain less than about 1,000,000 tons of potash.

f3: WSAs assigned an "f3" rating are within a moderately favorable geologic environment for potash. The WSA will contain some evaporite deposits such as halite and gypsum, and the geologic data suggest that the climate within the basin was sufficiently arid and long-lived so that widespread, moderately thick beds of relatively pure potash accumulated. If deposits occur in this environment, they will generally contain between 1,000,000 and 10,000,000 tons of potash.

f4: WSAs assigned an "f4" rating are within a highly favorable geologic environment for potash. The WSA will contain evaporite deposits such as halite and gypsum, and the geologic data suggest that the climate and topography within the basin was sufficiently arid and long-lived so that widespread, thick beds of very pure potash accumulated. If deposits occur in this environment, they will generally contain more than 10,000,000 tons of potash.

CERTAINTY

c1: In the lowest level of certainty, "c1", no direct data are available to support or refute the occurrence of potash within the WSA, regardless of the level of geologic favorability. No beds of potash-bearing rocks are known from the region surrounding the WSA, nor can any be reasonably inferred to exist in the WSA based on lateral continuity with known potash-bearing rocks at great distances from the WSA. Accordingly, the WSA will be far removed from an established or prospective evaporite basin.

c2: A c2 certainty level for potash again implies that no direct data occur within or very near the WSA being evaluated (data such as exploratory oil and gas wells, exploratory drill-tests, or former mines and prospects). Some data must be available from the vicinity of the WSA, and the intervening geology must be such that an inference of continuity between these known occurrences and the WSA is reasonable. Accordingly, a WSA assigned a c2 certainty rating will be within a recognized evaporite basin.

c3: The c3 degree of certainty for potash requires the subsurface recognition (on the basis of well data) of at least one potash-bearing formation, or an abandoned or active potash mine, very near the WSA being evaluated. Nearby occurrences should usually be no more than a few miles from the WSA, although site- or area-specific information may indicate the use of greater or lesser distances. Assigning a WSA a c3 rating requires a much higher degree of certainty that potash-bearing rocks actually occur in the WSA, compared with a c2 rating.

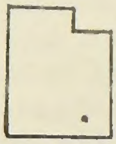
c4: A c4 is assigned only when it is known that potash-bearing rocks underlie the WSA, regardless of the assigned favorability. (By definition, when a c4 certainty is used with an f1 favorability, it indicates with a high-degree of certainty that potash-bearing rocks do not underlie the WSA.)

ORNL/SAI MINERAL-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 181 NAME: Mancos Mesa STATE/COUNTY: UT/San Juan

BLM DISTRICT: Moab WSA ACREAGE: 51,440

DATE PREPARED: November 1982 UPDATE:



LOCATION

GEOLOGIC SETTING OF TRACT (SEE ATTACHED GEOLOGIC SKETCH MAP):

Tract 181 lies between the Monument Upwarp to the east and the Henry Mountains Basin to the northwest. The tract consists chiefly of flat-lying beds belonging to the Navajo Sandstone, Wingate Sandstone, and Kayenta Formation of Triassic and Jurassic age (Hackman and Wyant, 1973). A series of high-angle faults trend northward through the eastern side of the tract, but displacement along individual faults is minor.

THE OVERALL-IMPORTANCE RATING (3) APPLIES TO (<25%____, 25-50%____, 50-75%____,75-100% ✓) OF THE TRACT'S AREA.

RATING SUMMARY: (See last page for explanation of rating system)

OVERALL-IMPORTANCE RATING:

OIL AND GAS:	f2/c1	HYDROPOWER:	f1/c4
URANIUM/VANADIUM:	f3/c2	COPPER:	f2/c1
COAL:	f1/c4	MANGANESE:	f1/c1
GEOTHERMAL:	f1/c3	POTASH:	f1/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 181 lies along the west edge of the petroleum-rich Paradox Basin -- a large structural depression that existed in southeastern Utah and southwestern Colorado during late Paleozoic time. At its maximum extent, the Paradox Basin encompassed much of the surface area of the present-day Moab district that lies southwest of the Uncompaghre Plateau. The U. S. Geological Survey estimates that this part of southeastern Utah and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (mean estimates; Dolton and others, 1981). These estimates indicate that, overall, southeastern Utah is moderately to highly favorable for future oil and gas discoveries in comparison to other provinces evaluated by the U. S. Geological Survey. The bulk of the undiscovered petroleum in this region will probably come from rocks of middle and upper Paleozoic age.

Berghorn and Reid (1981) estimate that 77 percent of the oil and 63 percent of the gas produced from the region of the Moab district comes from rocks of Pennsylvanian age that originated within the Paradox Basin. If production figures are included from older rocks that are associated with development of the Paradox Basin (such as production from Missisippian rocks at the Lisbon field, where the source rocks are believed by many investigators to be of Pennsylvanian age), the Paradox Basin probably accounts for about 90 percent of the oil and 85 percent of the gas produced in the vicinity of the Moab district.

The physiography of southeastern Utah during Pennsylvanian time consisted of a broad, slowly-subsiding, northwest-trending seaway. The axis of the seaway (the deepest part) was near the town of Moab. About 25 miles to the northeast, an abrupt northwest-trending mountain range (the Uncompaghre Uplift) stood several thousand feet above sea level and shed huge amounts of coarse debris into the Paradox Basin. Southwest of the town of Moab, the basin gradually became shallower, and an irregular, fluctuating shoreline existed along the southwestern and western parts of what is now the Moab district. At the same time, streams that headed in the surrounding highlands to the west, north, and south carried large volumes of debris into the subsiding Paradox Basin.

On many occasions, the sea water that flowed into and out of the Paradox Basin from the west, north, and south was cut off, either because of a drop in sea level, broad uplifts, or a combination of the two. During these times, the water in the Paradox Basin became very saline as a result of intense evaporation, and thick deposits of gypsum, anhydrite, halite, and potash were deposited in the deep parts of the basin. This deep, hypersaline depositional environment merged to the south and west with a less saline marine environment [the "hypersaline" and "penesaline" environments of Berghorn and Reid, (1981)]. The rocks that eventually formed from sediment deposition in the penesaline environment now consist of limestone, dolomite, anhydrite, and black shale. Farther still to the southwest, the penesaline environment merged with a shallow marine shelf containing waters of normal salinity.

The Paradox Formation is the name applied by geologists to the rocks that eventually formed from sediment deposition in the Paradox Basin. The Paradox Formation is commonly divided by petroleum geologists into five major substages (the time during which the strata accumulated). The names of the substages, in ascending order, are the Alkali Creek, Barker Creek, Akah, Desert Creek, and Ismay. In general, the substages correspond to major advances and retreats of the hypersaline, penesaline, and marine-shelf environments. [For example, the penesaline environment or "facies" reached its maximum lateral extent during Barker Creek time (Berghorn and Reid, 1981).] According to maps prepared by Berghorn and Reid (1981), Tract 181 occupied the marine-shelf environment during most of Paradox time.

Of particular importance to oil and gas resources in the vicinity of Tract 181 are the mounds of algal limestone and bioclastic debris (algae, brachiopods, crinoids, etc.) that accumulated in the shallow parts of the penesaline and marine-shelf environments. The algal mounds apparently trapped sedimentary debris that was being eroded from the marine shelf and swept to the northeast toward the deeper parts of the Paradox Basin. The Aneth field and the recently discovered Bug field (as well as many others) produce from algal mound structures that existed in the penesaline and marine-shelf environments during Paradox time (Babcock, 1978; Krivanek, 1981). It seems reasonable to assume that algal mounds similar in size and productivity to those at the Bug field await discovery in the penesaline and marine-shelf environments elsewhere in the basin [recoverable oil reserves at the Bug field are 8 to 12 million barrels according to Stevenson and Baars (1981), and 2 to 4 million barrels according to Berghorn and Reid (1981)]. Berghorn and Reid (1981) state that the most likely fields still to be discovered in these environments will have recoverable oil reserves on the order of a few million barrels. Thus, the depositional environments of the Paradox Formation in Tract 181 and in the productive areas to the east are similar.

Despite the favorable Pennsylvanian stratigraphy in the vicinity of Tract 181, broad uplifts beginning in Cretaceous time have significantly lowered the oil and gas potential of the Paradox Formation in this area. As a result of this uplift, erosion has stripped away overlying Mesozoic sedimentary rocks across most of the Monument Upwarp (remnants of these Mesozoic rocks are preserved in Tract 181). Furthermore, much of the Pennsylvanian section is exposed to the north in Cataract Canyon and to the south along the San Juan River. It is therefore unlikely that reservoir pressure exists in Pennsylvanian rocks in this area. If oil and/or gas existed in the Paradox Formation and overlying units in Tract 181, there is a good chance that it has drained away.

On the basis of the discussion above, Pennsylvanian and Permian rocks in and near Tract 181 probably do not contain large reserves of oil and/or gas. On the other hand, small accumulations that were effectively sealed from drainage may still exist in Pennsylvanian rocks underlying the tract.

The only other rocks in Tract 181 with hydrocarbon potential are of Devonian and Mississippian age. Mississippian rocks are represented by the Redwall Limestone, which in the vicinity of Tract 181 is probably in excess of 600-feet thick (Gustafson, 1981). As of January 1980, about 44.2 million barrels of oil and 375 billion cubic feet of gas from 13 fields had been produced from Mississippian rocks in the Four Corners region (Gustafson, 1981). The Lisbon field in Utah, however, accounted for about 95 percent of the oil production and 91 percent of the gas production. Devonian rocks are represented in Tract 181, in ascending order, by the Aneth Formation, the Elbert Formation, and the Ouray Limestone. Cumulative thickness of Devonian rocks in the vicinity of Tract 181 is probably about 400 feet (Baars, 1972). Total production from Devonian rocks in the Four Corners region has amounted to only 0.51 million barrels of oil and 577 million cubic feet of gas from 6 fields (Gustafson, 1981). Once again, however, the Lisbon field accounts for a large percentage of this production--77 percent of the oil and 100 percent of the gas (data as of January 1980; Gustafson, 1981).

Essentially all production from Mississppian and Devonian rocks in the Four Corners region is from structural traps, such as the pre-salt (pre-middle Pennsylvanian) fault that controls production at the Lisbon field. As demonstrated by Baars (1966), pre-salt faulting during Cambrain, Devonian, and Mississippian times was generally minor, but fairly widespread throughout the central Colorado Plateau. Geophysical investigations by Case and Joesting (1972), however, do not suggest that significant pre-salt faults exist in that part of the Monument Upwarp or Henry Mountains Basin surrounding Tract 181.

As of October 1981, a few exploratory wells had been drilled in the vicinity of Tract 181 (PIC, 1981; one well was drilled near the tract's southern border, and another was drilled near the eastern border). Most of the wells in this region were drilled in the late-1950s and early-1960s, after the large discoveries at Aneth and Lisbon Valley. Although all wells that have been drilled in this general area are now abandoned, oil staining and shows have been reported from Devonian, Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981; Weir and Light, 1981).

If oil and gas accumulations exist in the immediate area of Tract 181, they are likely to be associated with stratigraphic traps and small-scale folding. On this basis, and because of nearby deep erosion, we consider the oil and gas potential of Tract 181 to be low, and have assigned it a favorability rating of f2 (accumulations of less than 10 million barrels of recoverable oil, or if gas, less than 60 billion cubic feet). The certainty that oil and gas resources exist in this area is relatively low and has been assigned a rating of c1.

URANIUM/VANADIUM: f3/c2

The Colorado Plateau contains some of the largest and most important uranium and vanadium deposits in the United States. DOE (1980) estimates that about 50 percent of the nation's total uranium reserves, and about 36 percent of the nation's potential uranium resources, are contained in the Colorado Plateau. In terms of past production and future potential, the Colorado Plateau, especially the part coinciding with the Moab district, is very important for uranium and vanadium.

Uranium and vanadium deposits of the Colorado Plateau are confined chiefly to fluvial sandstones, conglomerates, and mudstones of Mesozoic age. The source of the uranium and vanadium is considered by many investigators to be the tuffaceous and granitic debris included with the sediments during original deposition in Mesozoic time. The uranium and vanadium presumably became mobile under oxidizing conditions, were transported in solution, and were later deposited under reducing conditions controlled largely by lateral variations in sediment size--such as within organic-rich paleo-channels.

The principal uranium- and vanadium-bearing units of the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. Locally within the Moab district, the Cutler Formation is also productive, as are other units in other parts of the Plateau, but regionally these units are of minor importance if compared with cumulative past production from either the Morrison or the Chinle Formations. About 80 percent of Utah's uranium production has come from deposits in the Chinle Formation, 15 percent from the Morrison Formation, and the remaining 5 percent from other units (Hilpert and Dasch, 1964). The uranium ore in the Chinle Formation in some areas contains large amounts of vanadium--such as at Lisbon Valley, Monument Valley, and the San Rafael Swell (U:V ratios about 1:3; Hilpert and Dasch, 1964). Uranium ores in the Morrison Formation are nearly all vanadiferous. On the Colorado Plateau, vanadium has been recovered as a byproduct or coproduct from most of the sandstone-type uranium deposits containing 1 percent or more V_2O_5. These are the only types of deposits in Utah that have produced vanadium, and most are in the Morrison Formation.

The Morrison Formation has been removed by erosion from Tract 181. The Chinle Formation crops out to the east and south of Tract 181, and it underlies the entire tract at depths up to 1,000 feet (Hackman and Wyant, 1973). Favorable parts of the Chinle Formation, namely the Shinarump, Monitor Butte, and Moss Back Members, lie even deeper (Peterson and others, 1980). As outlined by Thaden and others (1964), the White Canyon mining district lies a few miles east of Tract 181.

Deposits in the White Canyon district range in size from a few tons of ore to more than 800,000 tons, at a grade of about 0.25 percent U_3O_8 (Campbell and others, 1980; Malan, 1968; Thaden and others, 1964). More than 95 percent of the deposits, however, contain less than 50,000 tons of ore (Malan, 1968).

Uranium deposits in this district are concentrated in the Shinarump Member of the Chinle Formation, and they generally contain copper as a byproduct. According to Thaden and others (1964, p. 1) "...Most of the uranium and copper is localized in medium- to coarse-grained and conglomeratic sandstone interbedded with mudstone that fills channels cut into the Moenkopi Formation....Channels range in width from 30 to 1,000 feet and are as much as 50 feet deep...." White Canyon is one of the most productive districts that produce uranium from the Chinle Formation.

Uranium deposits occur within the Chinle Formation a few miles east of Tract 181 (Hackman and Wyant, 1973). Some of these deposits have produced more than 100 tons of U_3O_8. Peterson and others (1980) do not consider Mancos Mesa in their "favorable" area, but considering that the Chinle underlies the entire tract, it would seem prudent to expand this favorable area westward to include Tract 181.
On the basis of the size of deposits in this area, we have assigned Tract 181 a uranium/vanadium favorability of f3. The certainty that uranium resources occur in the tract is low and has been assigned a rating of c2.

COAL f1/c4

Utah is an important coal-producing state, yet almost 98 percent of the state's coal production comes from a few large underground mines in Emery and Carbon Counties (Averitt, 1964; Doelling, 1972). The bulk of Utah's coal is contained in rocks of Cretaceous age, with minor deposits in rocks of early Tertiary age.

Bedrock at the surface in Tract 181 consists of sedimentary rocks of Triassic and Jurassic age that are underlain by a normal sequence of Paleozoic sedimentary rocks and Precambrian igneous and metamorphic rocks (Hackman and Wyant, 1973). Because these rocks are not known to be favorable for coal resources anywhere in the region, we have assigned Tract 181 a coal favorability of f1 (unfavorable), along with a relatively high certainty (c4) that coal resources do not exist in this area.

GEOTHERMAL f1/c3

Utah's geothermal-energy potential is very large. Features that are commonly associated with geothermal resources are readily apparent in Utah--such as hot springs, young igneous rocks, high heat-flow, and crustal instability--but these features occur mainly in the western half of the state (Hintze, 1980; Utah Geological and Mineralogical Survey, 1977; NOAA, 1980; Muffler and others, 1978; Blackwell, 1978; Smith and Sbar, 1974). Eastern Utah, particularly the Colorado Plateau, contains very few of these favorable features (only a few low-temperature hot springs are known to occur within the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including all of the Moab district, is therefore considered to be very low.

The only geothermal potential associated with Tract 181 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). The only thermal spring in this region discharges at the mouth of Red Canyon, about three miles north of Tract 181 (NOAA, 1980). Water extracted at these temperatures can be used for direct heating purposes. It seems very unlikely that this resource would ever become economical to use in the Moab district, considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Monument Upwarp by the San Rafael and Colorado River systems has probably increased the depth to even these low-temperature geothermal resources throughout this area. On the basis of the geologic characteristics of this part of the

Colorado Plateau, we have therefore assigned Tract 181 a geothermal favorabilty rating of f1 and a moderately high certainty (c3) that the resource does not exist in this area.

HYDROELECTRIC f1/c4

Utah ranks 32nd among the states in installed hydroelectric power, but 11th in hydropower potential at undeveloped sites (U. S. Army Corps of Engineers, 1979). Most hydroelectric facilities in Utah are small (less than 15 megawatts) and are located in and near the Great Salt Lake basin. The largest facility, Flaming Gorge, lies along the Green River in northeastern Utah. In 1979, Flaming Gorge accounted for 57 percent of the state's total installed hydroelectric capacity of 190 megawatts (U. S. Army Corps of Engineers, 1979).

Potential hydropower sites in Utah are shown on maps in Johnson and Senkpiel (1964) and FERC (1981), and are listed by latitude and longitude by the U. S. Army Corps of Engineers (1979). A survey of this information indicated that no potential hydropower sites have been identified in or near Tract 181. On the basis of this information we have assigned Tract 181 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

COPPER f2/c1

In 1981, Utah accounted for 14 percent of the nation's total copper production of 1.5 million tons (Butterman, 1982). Second only to Arizona, which produced 67 percent of the nation's copper in 1981, Utah has had a long and important history of copper mining.

About 5 percent of the nation's apparent copper consumption in 1981 was supplied by foreign imports (Butterman, 1982). More than half of the copper consumed in the United States is devoted to electrical applications (particularly wire), with smaller amounts used in construction, for industrial machinery, and in transportation.

Copper mines have produced, in addition to copper, all domestic production of primary arsenic, selenium, and tellurium; most of the primary platinum and palladium; about 43 percent of primary gold; about 37 percent of primary silver; and almost 33 percent of primary molybdenum (Butterman, 1982). Thus, depending on the type of copper deposit, copper mining can contribute large quantities of other important minerals.

According to Cox and others (1973), the five chief types of copper deposits are (1) porphyry and genetically related types, (2) stratabound deposits in sedimentary rocks, (3) sulfide deposits in volcanic rocks, (4) deposits associated with nickel ores in mafic igneous rocks, and (5) native copper deposits. Most domestic copper production, as well as the by- and co-products described above, has been derived from porphyry-type deposits.

In Utah, almost all copper production has come from the western half of the state, chiefly from copper porphyries, igneous intrusive contacts, replacement deposits in carbonate rock, and fissure veins

(Roberts, 1964). On the Colorado Plateau in eastern Utah, only small amounts of by-product copper have been produced from sandstones that have been mined for uranium and vanadium.

Copper production from the Moab district has come largely from four areas: (1) near the town of Moab, (2) the Big Indian/Lisbon Valley area, (3) the White Canyon area, and (4) the Monument Valley area (Roberts, 1964). The deposits are confined chiefly to the Chinle Formation of Triassic age, particularly the Shinarump Member. Cumulative copper output from each of the four areas has been far less than 50,000 tons.

Gregory (1938, p. 107) states that copper prospecting in the White Canyon area may have begun about 1880. After much activity in 1906 and 1907 due to high copper prices, a copper processing plant was planned for Fry Canyon about ten miles east of Tract 181. The plant was never built, and the area again became idle. The first shipment of copper ore was sent to the mill in 1816 for testing. The ore was extracted from the Happy Jack mine, but the results were not encouraging, and the district remained idle until the mid-1940s (Gregory, 1938; Butler and others, 1920; Thayden and others, 1964; Malan, 1968). In 1946, two truckloads of copper ore were sent to the smelter in Garfield, Utah, but the ore was unacceptable because of its uranium content. Then in 1948, after recognition of the uranium potential of the area, a truckload of uranium ore was sent to the uranium mill in Monticello, Utah. Ironically, the ore was unacceptable because of its copper content (Thayden and other, 1964). Large uranium deposits were later found in the late 1940s and early 1950s, with copper as the chief byproduct. Copper content of the uranium deposits in the White Canyon area is generally between 0.12 and 1.3 percent (Malan, 1968).

On the basis of the discussion above, the Chinle and other red-bed sandstones throughout the Colorado Plateau are not very favorable for large, or even moderate, accumulations of copper (Tooker, 1980). Because copper and uranium deposits in this part of the Colorado Plateau are so closely associated (and are related in a historical sense), we have assigned Tract 181 a copper favorability of f2. The certainty that copper resources occur in the tract is low and is assigned a value of c1.

MANGANESE f1/c1

The United States is almost 100-percent dependent upon foreign sources for manganese--an essential ingredient in the production of steel (Jones, 1982). Although land-based manganese resources in the identified category are very large, more than 80 percent of these resources occur in the Republic of South Africa and in the U.S.S.R (Jones, 1982). Sea-based manganese resources in the form of nodules are apparently enormous, but have yet to be exploited by any country.

The bulk of the manganese deposits in southeastern Utah are oxides (mostly pyrolusite) that occur in the Morrison and Summerville Formations of Jurassic age (Baker and others, 1952). The most important deposits are lens-shaped masses a few inches thick and up to a few hundred feet long that are associated with beds of limestone or with the strata immediately below these limestone beds. Ore grade in parts of these deposits can exceed 50 percent manganese. In addition, manganese nodules an inch or more in diameter, commonly containing as much as 50 percent manganese, occur randomly in thick, massive beds of claystone in the Morrison and Chinle Formations. Less frequently the manganese occurs as vein filling and impregnations of the country rock along faults and joints. Detrital deposits, those eroded chiefly from the blanket-type deposits and that now litter the present-day surface, supplied the bulk of the manganese produced from the Little Grand district in the early part of the century. According to Baker and others (1952), the detrital deposits have largely been exhausted.

The origin of the manganese in southeastern Utah is poorly known. Because no local source for the manganese can be identified, Pardee (1921) and Baker and others (1952) speculate that the manganese was deposited as a finely disseminated carbonate at the time that the sediments were deposited, mainly during the Jurassic, and was later enriched by descending solutions (supergene enrichment). Despite the wide occurrence of manganese deposits and favorable sedimentary host rocks throughout the province, the estimated manganese potential of southeastern Utah is very low (Tooker and Cannon, 1980; USGS, 1982; Baker and others, 1952; Pardee, 1921).

The favorable host rocks for manganese in southeastern Utah have been removed by erosion from Tract 181, except for the Chinle Formation at depth within the tract (Hackman and Wyant, 1973). The nearest known manganese deposits are more than 60 miles to the northeast (Baker and others, 1952). On this basis, we have assigned Tract 181 a manganese favorability of f1, but with a certainty of non-occurrence of c1.

POTASH f1/c3

Bedded potash deposits exist in the subsurface over a broad area in east-central Utah and southwestern Colorado (Hite, 1961). If projected to the surface in just Utah, these deposits would encompass an area of about 4,500 square miles, entirely within the BLM's Moab district (Hite, 1964; Hite and Cater, 1972).

The only known potash-bearing unit in the Moab district is the Paradox Formation of Pennsylvanian age. This formation originated in a slowly-subsiding, northwest-trending basin--called the Paradox Basin--that existed in the Moab region about 300 million years ago (see paragraphs 3 and 4 in the OIL AND GAS section of this report for a description of the physiography and history of the Paradox Basin). The potash deposits in the Paradox Formation are thickest and nearest to the surface along a series of northwest-trending anticlines within a structural zone approximately 100 miles long and 30 miles wide in Utah and Colorado [the Paradox fold and fault belt of Kelley (1955); see also Hite (1964), and Hite and Cater (1972)].

Tract 181, however, lies many west of the thick potash-bearing zones in the Paradox Formation (Hite, 1961; Hite and Cater, 1972). Even if potash-bearing rocks did exist in the Paradox Formation in this area, they would probably be very thin and discontinuous, and would not constitute a resource. On this basis, we have assigned the tract a potash favorability of f1, and a certainty of c3 that potash resources do not exist in this area.

OVERALL-IMPORTANCE RATING 3

Tract 181 has been assigned an overall importance rating (OIR) of 3 (on a scale of 1 to 4 where 4 is equated with high mineral-importance). The chief reason for this rating is the uranium favorability (f3), along with the tract's large size (51,440 acres).

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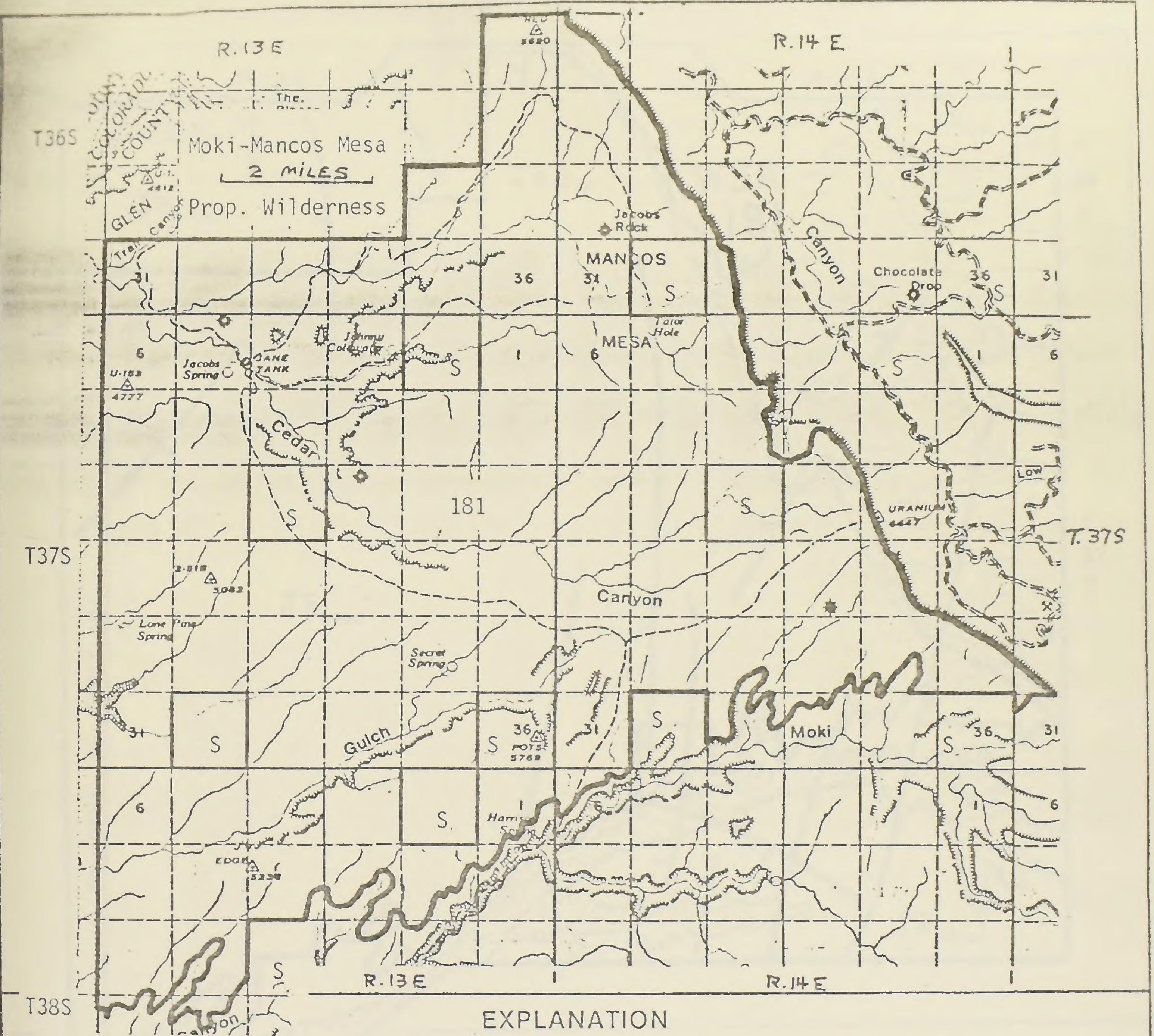
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 181, UTAH

SHOWING THE PROJECTED AREAL EXTENT OF EACH POTENTIAL MINERAL RESOURCE WITH AN ASSIGNED FAVORABILITY RATING OF 3 OR 4.



EXPLANATION

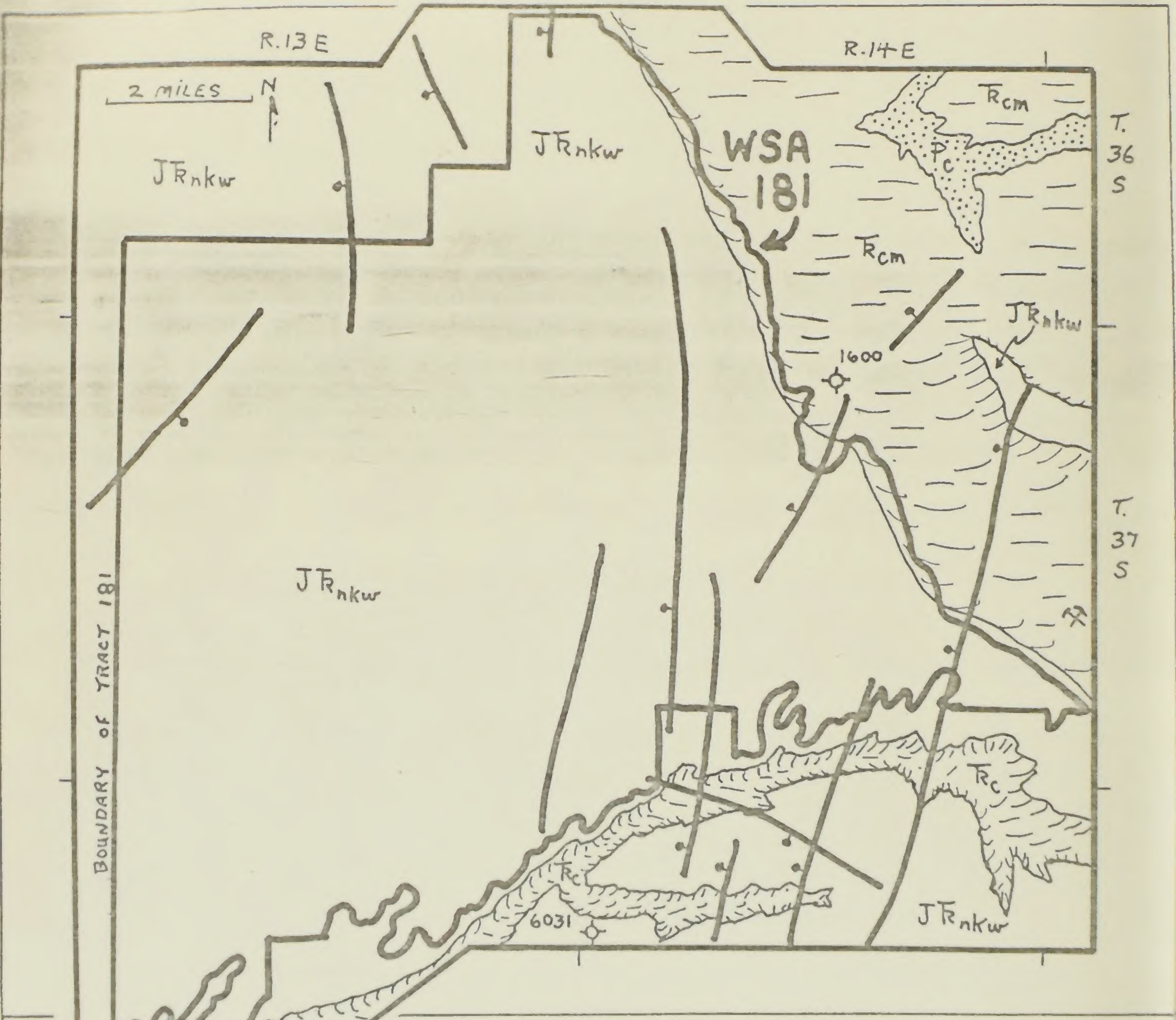
URANIUM IS THE ONLY COMMODITY EVALUATED FOR THIS TRACT TO BE ASSIGNED A FAVORABILITY OF F3 or GREATER.

ALL PARTS OF TRACT 181 ARE EQUALLY FAVORABLE FOR URANIUM.

SOURCE: BASE MAP FROM BLM (1980).

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 181, UTAH

SHOWING THE LOCATION OF MINES, PROSPECTS, OIL AND GAS WELLS, HOT SPRINGS, AND OTHER FEATURES RELATED TO THE MINERAL POTENTIAL OF THE TRACT.



EXPLANATION

JTRnkw - NAVAJO, KAYENTA, AND WINGATE FORMATIONS (TRIASSIC AND JURASSIC)

TRcm - CHINLE AND MOENKOPI FORMATIONS (TRIASSIC)

TRc - CHINLE FORMATION

Pc - CUTLER FORMATION (PERMIAN; ORGAN ROCK TONGUE).

- FAULT, BALL ON DOWN SIDE.

⚒ URANIUM MINE WITH PRODUCTION OF MORE THAN 100 TONS U_3O_8

6031 ⌖ OIL AND GAS EXPLORATORY WELL (DRY), SHOWING TOTAL DEPTH

SOURCE: HACKMAN AND WYANT (1973), AND HINTZE (1980)

OVERVIEW OF THE RATING SYSTEM

Each resource is assigned a dual rating (e.g. f3/c2). The first rating, "f3," estimates the "geologic favorability" (f) of the WSA for the resource. The second rating, "c2," is is an estimate of the "degree of certainty" (c), that the resource actually does, or does not, exist within the WSA. Favorability and certainty are rated on a scale of 1 to 4 and are defined in general terms in the two columns below. Specific criteria used to evaluate the favorability and certainty for the mineral resources evaluated in this study are contained in the appendix.

The "overall-importance rating" is a single-digit rating on a scale of 1 (low importance) to 4 (high importance). Shades of importance within each of the four categories are indicated by plus (+) and minus (-) superscripts. The overall-importance rating attempts to integrate the individual resource evaluations for a WSA, with other data such as gross economics or the proposed location of energy corridors, into a summary number that reflects the group's overall judgement of the resource-importance of the WSA. Specific criteria used to derive the overall-importance rating are contained in the appendix.

f1-The inferred past and/or current geologic processes operating in the area are believed to preclude the accumulation of the resource.

f2-The geologic environment of the area is considered favorable for the accumulation of (1) small deposits, (2) low-tonnage, low-grade, or low-volume resources, or (3) low-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f3-The geologic environment of the area is considered favorable for the accumulation of (1) medium-size (tonnage, volume) deposits, or (2) moderate-temperature geothermal resources. If these resources exist, they may or may not be economical to extract.

f4-The geologic environment of the area is considered favorable for the accumulation of (1) large-size (tonnage, volume) deposits, or (2) high-temperature geothermal resources. If the more conventional resources exist (oil, gas, coal, and uranium), they would probably be economical to extract.

c1-No direct data (such as mines, producing or abandoned wells, prospects, assays, bore holes, and so on) occur in the broad area surrounding the WSA to either support or refute the existence of the resource within the WSA.

c2-No direct data are available to support or refute the existence of the resource within or near the WSA. However, the WSA is fairly close to direct evidence of resource occurrence, and the past geologic conditions responsible for resource accumulation in this nearby area can be inferred, with a limited amount of confidence, to have existed in the WSA.

c3-At least "one piece" of direct evidence (an oil or gas seep, a coal-bed outcrop, a hot spring, a mine, and so on) is available from within or very near the WSA to support or refute the existence of the resource.

c4-Abundant direct evidence is available from within and/or very near the WSA to support or refute the existence of the resource. (When a c4 certainty is used with an f1 favorability, it indicates with a high degree of certainty that the resource does not exist in the WSA.)