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MINERAL-RESOURCE EVALUATION OF WILDERNESS STUDY AREAS

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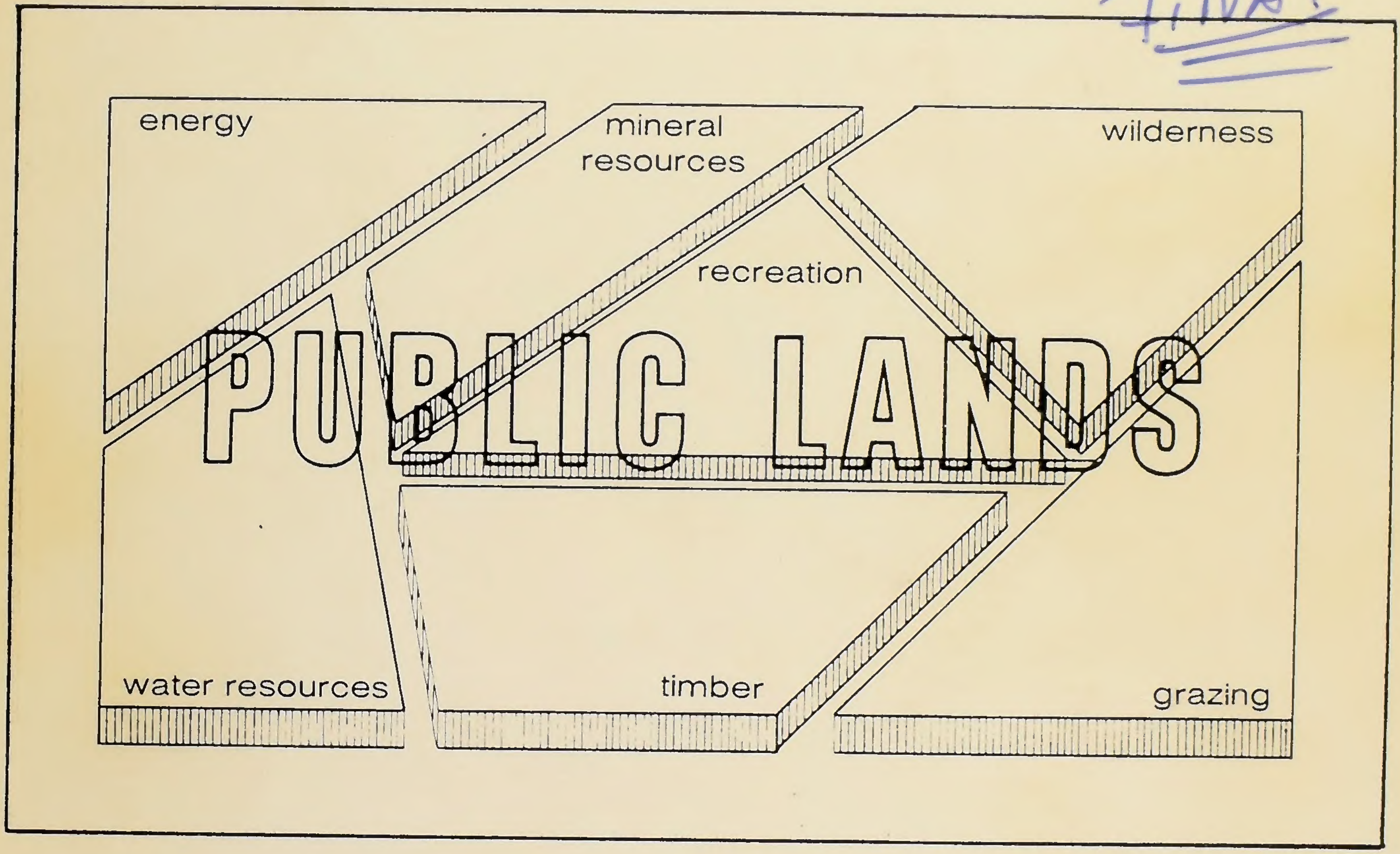

the
Bureau of Land Management's
Richfield District, Utah

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

the RICHFIELD DISTRICT, UTAH

October 1, 1982

prepared for:
The Bureau of Land Management
Salt Lake City, Utah

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NOTE:

The front section of this report containing the table of contents, introduction, statistical summary, and general resource description, is yet to be supplied. In addition, the rating criteria for non-energy minerals are complete but not edited. They will also be supplied.

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.

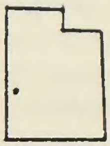
> Phase I- During Phase I (already completed), the BLM identified areas of 5,000 acres or more that possess wilderness characteristics based on general criteria established by Congress in the 1964 Wilderness Act. These areas are called Wilderness Study Areas (WSAs).
>
> Phase II- In Phase II, which is 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.**
>
> Phase III- 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.

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

TRACT NO: 035* **NAME:** Conger Range **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 22,863

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

*[NOTE: Tract 035 was identified as a WSA before the current Wilderness Planning Program. Tract 035 is illustrated on the map that accompanies BLM (1980), but descriptions of the tract are not contained in that report.]

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

Tract 035 lies within the Basin and Range physiographic province and encompasses part of the Confusion Range. Exposed bedrock consists chiefly of Mssissippian and Pennsylvanian age (Hintze, 1980).

The Confusion Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. High-angle faults and thrust faults are abundant and well-exposed throughout this area.

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:	f1/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 035 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 035 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 035 may lie on younger rocks in the subsurface. Thus, Tract 035 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 035 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the vicinity of Tract 035, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 035 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 035, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the Wah Wah Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 035 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

An 11,822-foot dry hole was drilled by Cities Services about a mile east of the tract. The well penetrated about 6,000 feet of Tertiary basin fill and bottomed in the Notch Peak Limestone of Cambrian age (pers. comm. with staff of Petroleum Investment Corporation, Salt Lake City, Utah)]. The few other wells that have been drilled in this region have also been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 035 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the northeast edge of Tract 035 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 035 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available pertaining to the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM <u>f1/c1</u>

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 035 lies 50 miles north of the Wah Wah Mountains uranium-producing district and about 35 miles southwest of the Topaz Mountain uranium area. According to Bromfield and others (1980), the Wah Wah Mountains district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age (Bromfield and others, 1980). At Topaz Mountain in the Thomas Range, several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspari pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 035 lies between (outside of) the mineral belts, and although small patches of favorable Tertiary volcanic rocks lie within the tract (see Geologic Sketch Map), their overall uranium potential is considered to be minimal (these mineral belts will be described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, Tract 035 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is low and has been assigned a value 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.

The Kolob field and the small Harmony field, both more than 80 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 035 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c1

Tract 035 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 035.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

Thermal springs are reported from the surrounding valleys and discharge at a temperature ranging from 22 to 31°C (NOAA, 1980). On the basis on the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 070 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

HYDROELECTRIC <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 Tract 035. On the basis of this information we have assigned Tract 035 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM <u>f2/c1</u>

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 035 lies about 35 miles southwest of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 077 lies in a region that is broadly favorable for beryllium although these deposits are not known to occur in or near the tract. Because of this regional favorability, we have assigned Tract 070 a beryllium favorability of f2 (based chiefly on the possibility of intrusive bodies at depth). The certainty that beryllium resources occur in the tract (or do not occur) is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest reported lead and zinc occurrences to Tract 035 are in the Saw Back district south of the tract. Significant production has not been recorded in this district, or for that matter, anywhere in Millard County (Kiilsgaard and Heyl, 1964).

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 035 and the Wah Wah-Tushar mineral belt to the south of Tract 035 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)]. Tract 035 lies within this intervening non-mineralized belt.

Although Tract 035 contains some carbonate host rocks that are favorable for lead and zinc, a nearby source for the metals such as an intrusion is not known not occur (except perhaps at depth). Despite the tract's location (between the two generally recognized mineral belts in this area), it is still within a broad area containing some favorable characteristics for lead and zinc. We have assigned Tract 035 a favorability of f2. The certainty that lead and zinc resources occur in the tract is low and is assigned a value of c1.

TUNGSTEN f1/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 035 (Everitt, 1961). The closest tungsten deposits to Tract 035 are at Notch Peak in the House Range about 10 miles to the west, where small bodies of scheelite-bearing tactite border a quartz monzonite stock (Lemmon, 1964).

Some favorable carbonate host rocks of chiefly Pennsylvanian age occur in the tract, igneous intrusive rocks are lacking (Hintze, 1980). Thus contact-metamorphic zones and/or vein deposits are unlikely (unless of course igneous intrusive rocks lie at depth). Moreover, the tract lies within a zone characterized by few igneous intrusive rocks [the mid-Utah gap of Jerome and Cook (1967)]. Nevertheless, we have assigned Tract 035 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten, and because the tract lies so close to an identified mineral belt. The certainty that tungsten deposits occur at depth in Tract 035 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING <u>2</u>

Tract 035 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 considered only marginally favorable for oil and gas and geothermal resources, and even less favorable for beryllium, lead, zinc, and tungsten.

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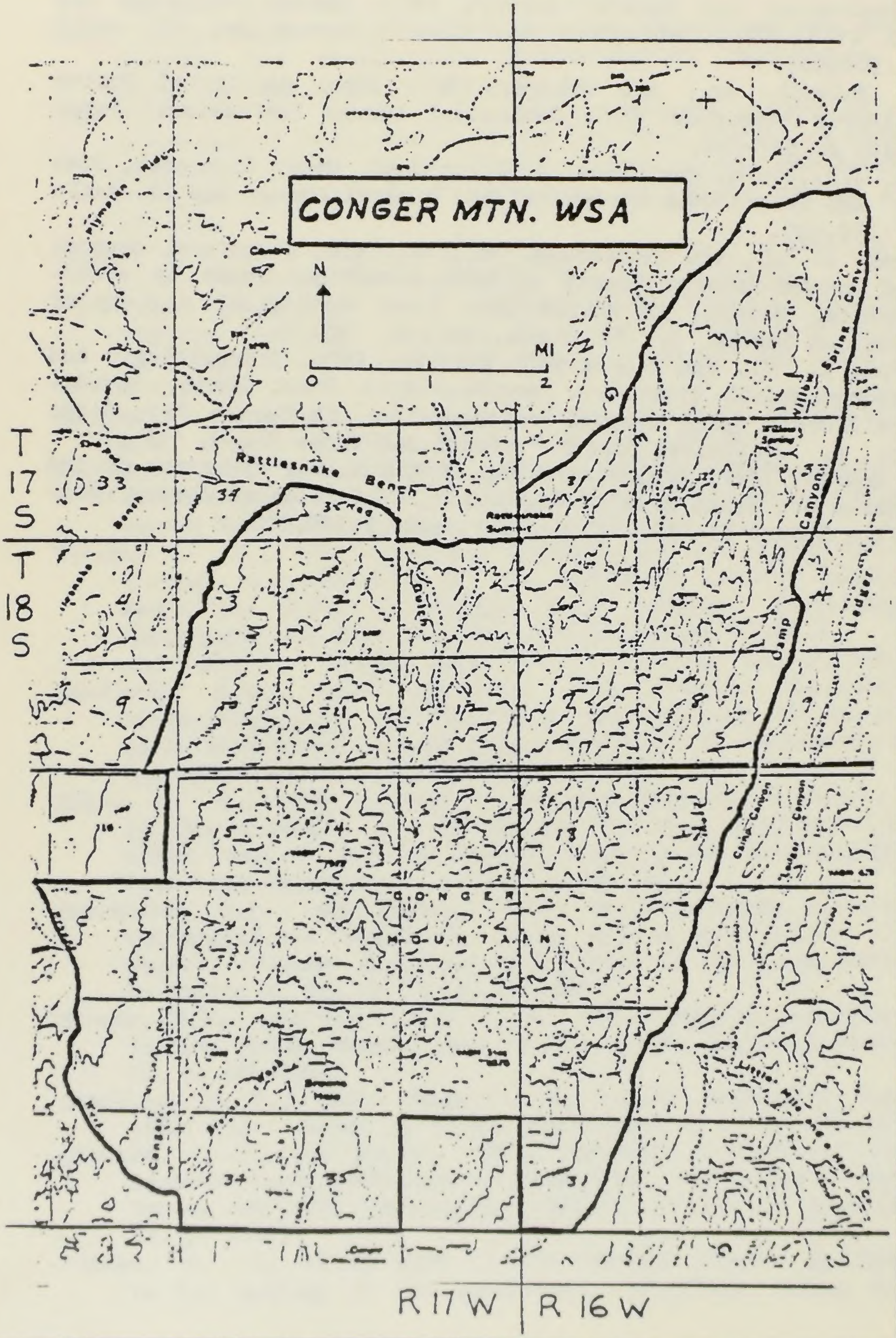
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 035 , UTAH

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



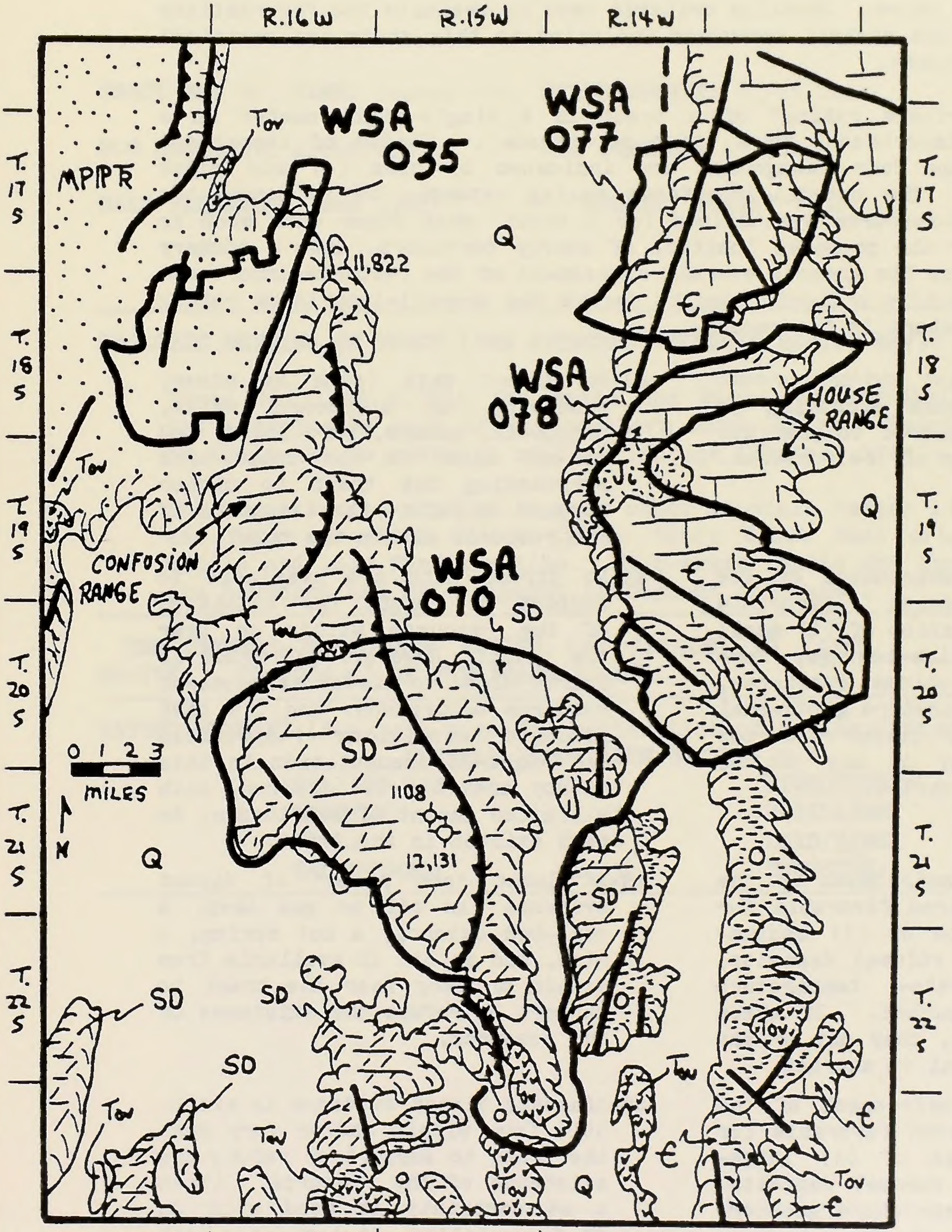
EXPLANATION

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

SOURCE: BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 035, 077, 078, 070

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



EXPLANATION

Q - QUATERNARY ALLUVIUM

MPIPTR - MISSISSIPPIAN THROUGH TRIASSIC ROCKS

SD - SILURIAN, DEVONIAN ROCKS

O - ORDOVICIAN ROCKS

Є - CAMBRIAN

Tov - VOLCANIC ROCKS (OLIGOCENE)

Ji - JURASSIC INTRUSIVE ROCKS.

THRUST FAULT

FAULT

12,131 OIL/GAS WELL (DRY), SHOWING TOTAL DEPTH

SOURCE:

MODIFIED 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: 061 **NAME:** Swasey Mtn. **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 49,500

DATE PREPARED: June 1982 **UPDATE:** August 1982

LOCATION

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

Tract 061 lies within the Basin and Range physiographic province and encompasses part of the northern House Range. Bedrock exposed in the tract is entirely of Cambrian age (Hintze, 1980).

The House Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. High-angle faults and thrust faults are abundant and well-exposed throughout this area.

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:	f1/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 061 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 061 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 061 may lie on younger rocks in the subsurface. Thus, Tract 061 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 061 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the Wah Wah Mountains south of Tract 061, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 061 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 061, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the House Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 061 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

The nearest exploratory wells have been drilled in the Confusion Range to the west, but all were dry (PIC, 1982). The few other wells that have been drilled in this region have also been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 061 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the west and east sides of Tract 061 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 061 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available regarding the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM f1/c1

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 061 lies 65 miles north of the Wah Wah Mountains uranium-producing district and about 10 miles southwest of the Topaz Mountain uranium area. According to Bromfield and others (1980), the Wah Wah Mountains district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age (Bromfield and others, 1980).

At Topaz Mountain in the Thomas Range, several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspari pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 061 lies between (outside of) these mineral belts (these mineral belts will be described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, Tract 061 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is low and has been assigned a value 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.

The Kolob field and the small Harmony field, both more than 80 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 061 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c1

Tract 061 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978).

In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 061.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

Thermal springs discharge west of the tract at Coyote, Tule, and South Tule Springs [28 to 31°C; NOAA (1980)]. On the basis of the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 061 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

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 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 061. On the basis of this information we have assigned Tract 061 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 061 lies about 10 miles southwest of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 061 lies in a region that is broadly favorable for beryllium although these deposits are not known to occur in or near the tract. Because of this regional favorability, we have assigned Tract 070 a beryllium favorability of f2, based chiefly on the possibility of intrusive bodies at depth. The certainty that beryllium resources occur in the tract (or do not occur) is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest lead and zinc deposits to the tract with recorded production are far to the south in Beaver County (Lemmon, 1964). Significant production has not been recorded in this district, or for that matter, anywhere in Millard County (Kiilsgaard and Heyl, 1964).

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 061 and the Wah Wah-Tushar mineral belt to the south of Tract 061 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)].

Tract 061 contains favorable carbonate host rocks for lead and zinc (the Cambrian Notch Peak Formation), but no obvious nearby metal source such as an intrusion (except perhaps at depth). Furthermore, Tract 061 lies between the two generally recognized mineral belts in this area, although still within a region that is broadly favorable for lead and zinc. On the basis of this discussion, we have therefore assigned Tract 061 a lead/zinc favorability of f2. The certainty that lead and zinc resources occur at depth in the tract is low and is assigned a value of c1.

TUNGSTEN <u>f1/c1</u>

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the

United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 061 (Everitt, 1961).

Many small bodies of scheelite-bearing tactite occur 15 miles south of the tract along the contact between granite and upper Cambrian limstones (Gehmans, 1958). According to Lemmon (1964), the ore bodies are mostly low grade and relatively small. Less than 7,000 tons containing about 5,000 units of WO_3 were reportedly shipped to mills from numerous properties around the intrusion (Everett, 1961).

We have assigned Tract 061 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten. The certainty that tungsten deposits occur at depth in Tract 070 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 2

Tract 061 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 considered only marginally favorable for oil and gas, geothermal, beryllium, lead, zinc, and tungsten.

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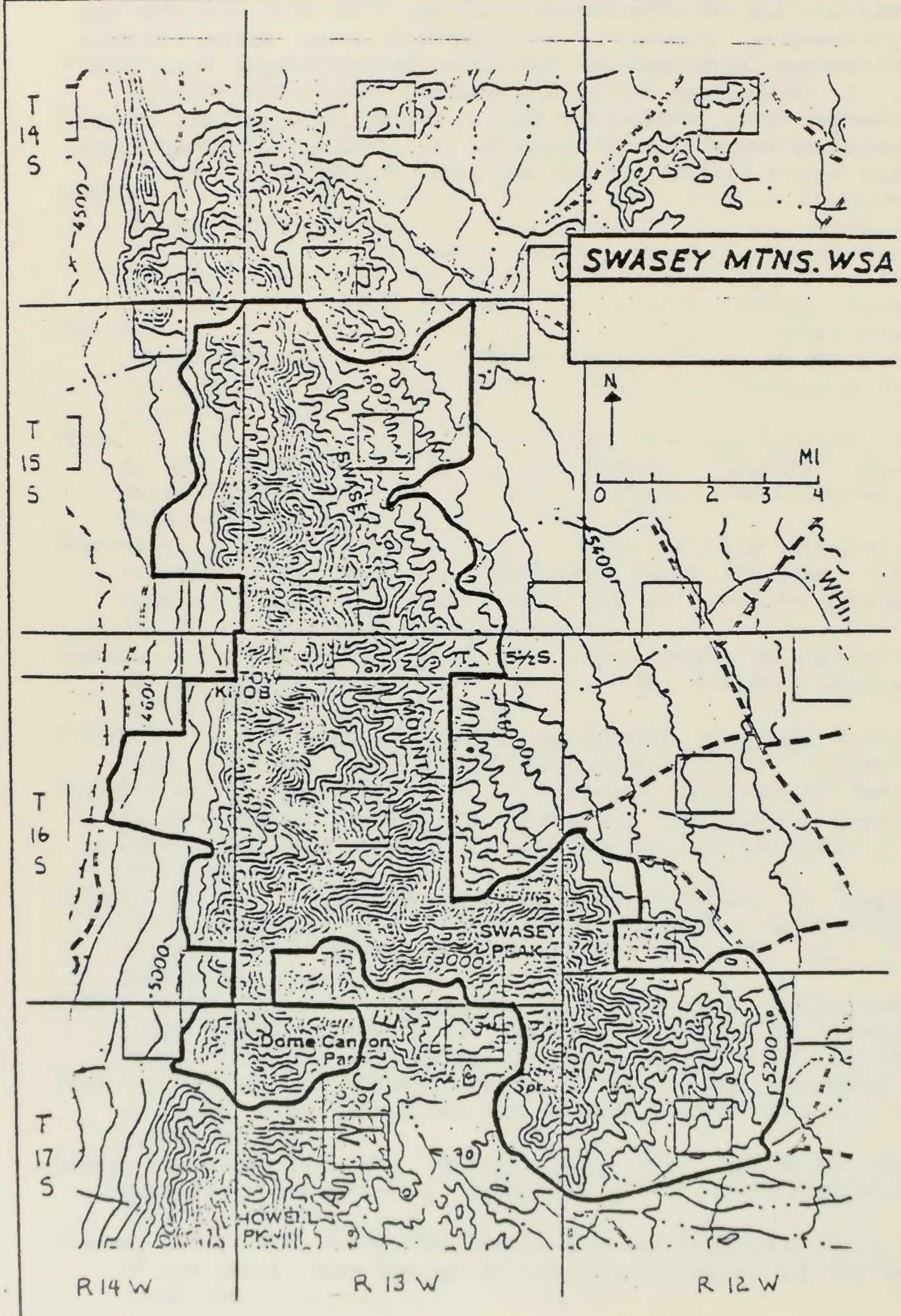
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 061, UTAH

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



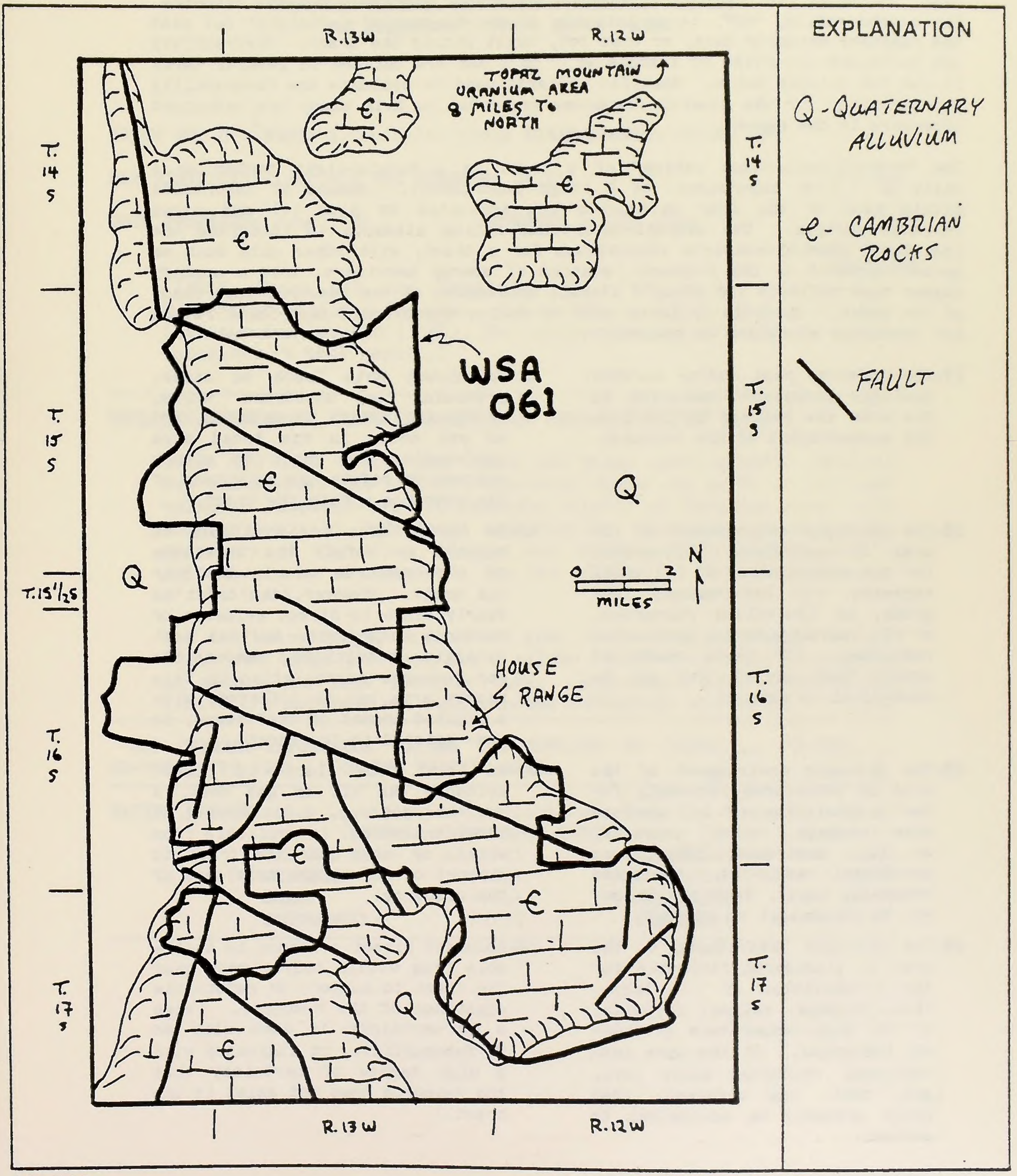
EXPLANATION

All resources evaluated for this tract were assigned a favorability of less than f3.

SOURCE: BLM, RICHFIELD, UTAH (MAP BASE)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 061, 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: MODIFIED 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.

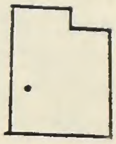
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 070* **NAME:** S.Confusion Range **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 84,771

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

*[NOTE: Tract 070 was identified as a WSA before the current Wilderness Planning Program. Tract 070 is illustrated on the map that accompanies BLM (1980), but descriptions of the tract are not contained in that report.]

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

Tract 070 lies within the Basin and Range physiographic province and encompasses the southern Confusion Range and parts of adjacent valleys. Exposed bedrock consists chiefly of Devonian rocks with smaller areas of Ordovician and Silurian rocks exposed along the periphery of the tract (Steven and others, 1978; Hintze, 1980). Volcanic rocks of Oligocene age are exposed in the southern part of the tract.

The Confusion Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. High-angle faults and thrust faults are abundant and well-exposed throughout this area.

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:	f1/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 070 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 070 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 070 may lie on younger rocks in the subsurface. Thus, Tract 070 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 070 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the vicinity of Tract 070, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 070 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 070, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the Wah Wah Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 070 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

Two exploratory wells have been drilled in the approximate center of Tract 070, about a mile west of an exposed thrust fault involving Devonian rocks (Hintze, 1980; PIC, 1982). Both wells reportedly were dry, and the deepest well went to total depth of 12,131 feet [PIC, 1982; no information was available for the deep well at the time of this writing (pers. comm. with staff of Petroleum Investment Corporation, Salt Lake City, Utah)]. The few other wells that have been drilled in this region have also been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 070 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the east and west edges of Tract 070 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 070 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available pertaining to the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM f1/c1

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

GEOTHERMAL f2/c1

Tract 070 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 070.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

No thermal springs exist near Tract 070 and no other evidence (certainty) is available to indicate that usable geothermal resources occur within or near the tract. On the basis on the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 070 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

Tract 070 lies 40 miles north of the Wah Wah Mountains uranium-producing district and about 35 miles south of the Topaz Mountain uranium area. According to Bromfield and others (1980), the Wah Wah Mountains district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age (Bromfield and others, 1980). At Topaz Mountain in the Thomas Range, several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspari pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 070 lies between (outside of) the mineral belts, and although small patches of favorable Tertiary volcanic rocks lie within the tract (see Geologic Sketch Map), their overall uranium potential is considered to be minimal (these mineral belts will be described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, Tract 070 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is low and has been assigned a value 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.

The Kolob field and the small Harmony field, both more than 80 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 070 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

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 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 070. On the basis of this information we have assigned Tract 070 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 070 lies about 45 miles south of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 070 contains a few small patches of Tertiary volcanic rocks of Oligocene age assigned to the Needles Range Formation (Rowley and others, 1979). The Needles Range Formation consists of a series of ash-flow sheets that covered a very large area in southwestern Utah and adjacent parts of Nevada. Near its cauldron source to the west of Tract 070, the various members of the formation total more than 1,500 feet thick, but they thin rapidly in all directions. The Needles Range Formation is not known to be beryllium-bearing anywhere in the region. No other volcanic rocks are exposed in Tract 070 (Rowley and others, 1979). The rocks that are exposed in the tract are not hydrothermally altered or significantly mineralized. In addition, igneous intrusive rocks, which host beryllium-bearing veins and pegmatites in other parts of west-central Utah, do not occur at the surface in Tract 070. Nevertheless, this region is generally favorable for beryllium, and on this basis we have assigned Tract 070 beryllium favorability of f2. The certainty that beryllium resources occur in the tract is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest reported lead and zinc occurrences to Tract 070 are in the Saw Back district south of the tract. Significant production has not been recorded in this district, or for that matter, anywhere in Millard County (Kiilsgaard and Heyl, 1964).

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 070 and the Wah Wah-Tushar mineral belt to the south of Tract 070 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)]. Tract 070 lies within this intervening non-mineralized belt.

Although the Tract 070 contains carbonate host rocks that are favorable for lead and zinc (for example, the Laketown, Sevy, and Simonson Dolomites), a nearby source for the metals such as an intrusion is not known not occur (except perhaps at depth). Despite the tract's location (between the two generally recognized mineral belts in this area), it is still within a broad area containing some favorable characteristics for lead and zinc. We have assigned Tract 070 a favorability of f2. The certainty that lead and zinc resources occur in the tract is low and is assigned a value of c1.

TUNGSTEN f1/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epidote, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 070 (Everitt, 1961). The closest tungsten deposits to Tract 070 are at Notch Peak in the House Range about 5 miles to the north, where small bodies of scheelite-bearing tactite border a quartz monzonite stock (Lemmon, 1964).

Favorable carbonate host rocks of Silurian and Devonian age occur throughout Tract 070 (Hintze, 1980). Igneous intrusive rocks, however, do not occur at the surface in Tract 070, thus contact-metamorphic zones and/or vein deposits are unlikely (unless of course igneous intrusive rocks lie at depth). Igneous intrusive rocks do not crop out in Tract 070, and the tract lies within a zone characterized by few igneous intrusive rocks [the mid-Utah gap of Jerome and Cook (1967)]. Nevertheless, we have assigned Tract 070 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten, and because the tract lies so close to an identified mineral belt. The certainty that tungsten deposits occur at depth in Tract 070 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 2

Tract 070 has been assigned an overall-importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Despite the fact that oil and gas, geothermal, beryllium, lead/zinc, and tungsten were each assigned a favorability of f2, these rating are not additive. In fact, if one assumes that the oil and gas favorability should be higher, the favorabilty for the other resources rated would necessarily be reduced (the converse is also true). This inverse relationship is due to the occurrence model used in the evaluation of Tract 070, which relates metal deposits and thermal waters to igneous intrusive rocks. If these intrusive rocks do in fact occur at relatively shallow depths in Tract 070, the oil and gas favorability is lower than the assigned rating of f2. Available information does not allow us to determine which of the resources is most likely to occur, so we have assigned each a favorability of f2. In any event, the overall mineral-resource potential of Tract 070 is considered to be low, despite its proximity to rather favorable mineralized areas to the north and to the south.

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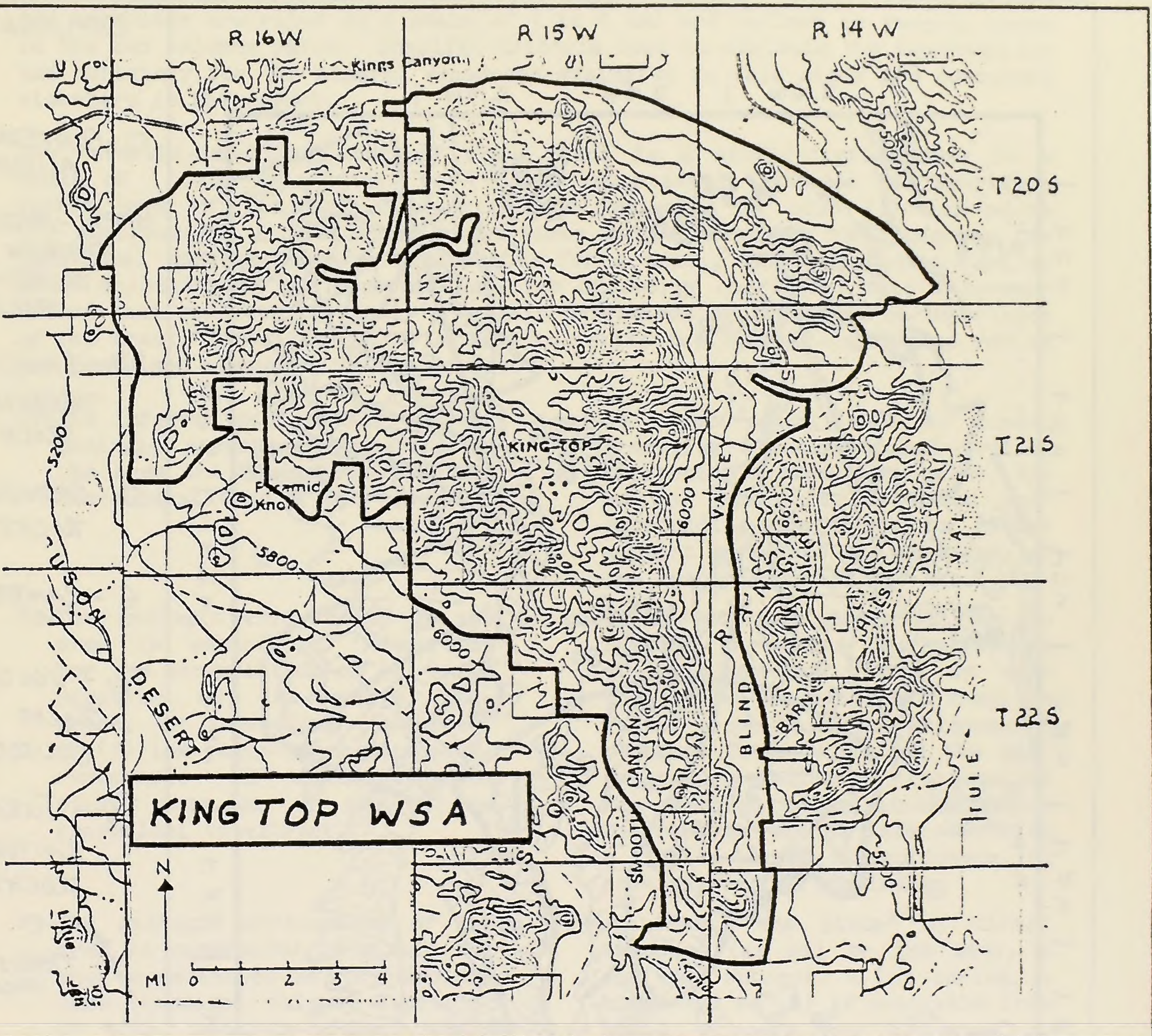
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 070, UTAH

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



EXPLANATION

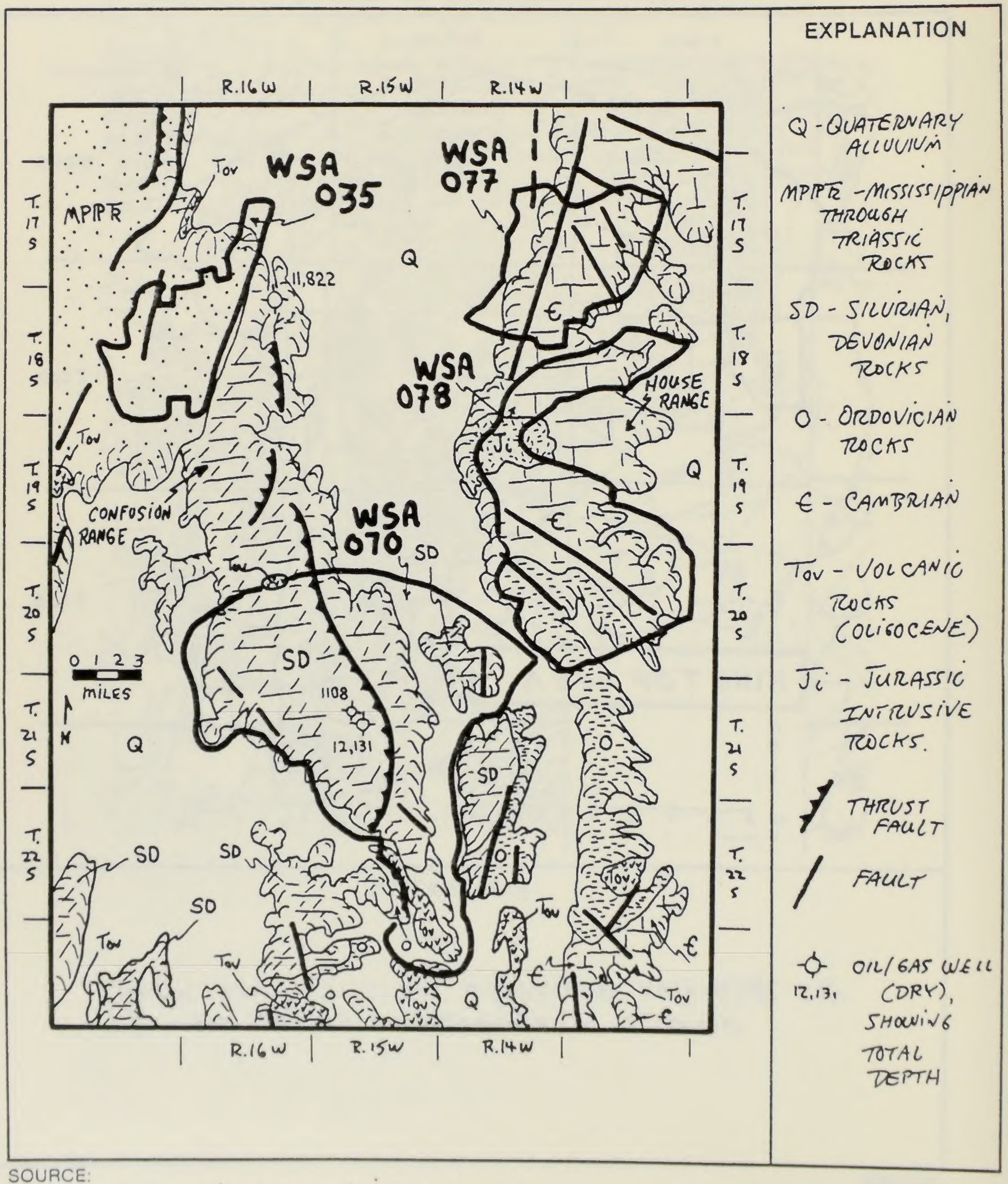
ALL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN 3.

SOURCE:

BASE MAP FROM BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 035, 077, 078, 070

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



SOURCE:

MODIFIED 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.

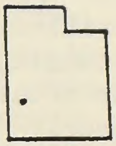
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 073 **NAME:** Wah Wah Range **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 35,000

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

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

Tract 073 lies within the Basin and Range physiographic province and encompasses the northern Wah Wah Mountains and parts of adjacent valleys. Exposed bedrock consists of gently-dipping Cambrian and Ordovician sedimentary rocks, and small patches of Tertiary volcanic rocks dated at approximately 30 million years old (Hintze, 1974). A short distance south of the tract, Tertiary diorite intrusive rocks have metamorphosed small areas of country rock.

The Wah Wah Mountains are an east-tilted fault block, and the visible structure of the range is not complex. Most tilting presumably occurred during middle and late Tertiary time, chiefly along a concealed fault that bounds the west flank of the range. Geologic relations farther south in the Wah Wah Mountains suggest that the Cambrian rocks exposed at the surface in Tract 073 are probably in thrust contact with Jurassic and Triassic rocks in the subsurface.

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:	f1/c2	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 073 is within an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "The thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuaton of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates and their width within the Sevier thrust belt in western Utah and eastern Nevada is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 073 lies a few tens of miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations a few miles south of Tract 073, the Cambrian rocks now exposed at the surface in Tact 073 probably lie in thrust contact at depth with Jurassic and Triassic sedimentary rocks (Miller, 1966). Thus, Tract 073 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 073 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the vicinity of Tract 073, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 073 lies slightly north of a region characterized by broad, east-west trending aeromagnetic highs that correspond closely with Tertiary intrusive rocks such as those exposed in the southern Wah Wah Mountains (Hintze, 1980). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits (the Wah Wah-Tushar mineral belt of Hilpert and Roberts, 1964). According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 073, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the Wah Wah Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 073 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet). Unfortunately, the Tertiary stratigraphy and lithology of the valley-fill adjoining Tract 073 are poorly known because few wells have been drilled. The wells that have been drilled in this general vicinity, however, have not reported any shows of oil or gas (Hansen and others, 1955; Heylmun and others, 1965; Reese, 1969; PIC, 1982).

The favorability of Tract 073 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the east and west edges of Tract 073 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 073 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available pertaining to the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM <u>f1/c2</u>

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 073 lies 20 miles north of the Wah Wah Mountains uranium-producing district. According to Bromfield and others (1980), the district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age. The uranium is believed to have been concentrated by hydrothermal processes and supergene enrichment (Lindsey and Osmonson, 1978; Bromfield and others, 1980). DOE (1979) estimates that about 1,000 tons of speculative uranium resources (at a $50/lb forward-cost category) are contained in the southern parts of both Wah Wah and Needles Mountains, presumably within the rhyolites and tuffs of Miocene age.

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 073 lies between (outside of) the mineral belts, and although small patches of favorable Tertiary volcanic rocks lie within the tract (see Geologic Sketch Map), their overall uranium potential is considered to be minimal by Bromfield and others (1980). Furthermore, Bromfield and others (1980, p. 70) state that on the basis of geochemical sampling and radiometric surveys, all other rocks in and near Tract 073 are unfavorable for uranium deposits. [The mineral belts are described further under the LEAD/ZINC section in this report.]

In view of the preceeding discussion, Tract 073 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is relatively low and has been assigned a value of c2.

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.

The Kolob field and the small Harmony field, both more than 70 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 073 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c1 ~~f1/c3~~

Tract 073 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 073.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly $5^{\circ}C$ to $10^{\circ}C/100$ meters (330 feet), and locally, gradients exceeding $60^{\circ}C/100$ meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only $1^{\circ}C$ to $10^{\circ}C/100$ meters (Whelan, 1976).

Other sources of geothermal energy in southwestern Utah include deep circulation and eventual discharge of hot water along steeply dipping faults that penetrate the crust to depths of a few miles. Although most high-temperature geothermal resources in Utah occur in areas of young silicic magmas as described previously, the Newcastle KGRA north of the Pine Valley Mountains is probably related to deep circulation along a fault.

No thermal springs exist near Tract 073 and no other evidence (certainty) is available to indicate that usable geothermal resources occur within or near the tract. On the basis on the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 073 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

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 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 073. On the basis of this information we have assigned Tract 073 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 073 lies about 70 miles south of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 073 contains only small patches of Tertiary volcanic rocks of Oligocene age assigned to the Needles Range Formation (Rowley and others, 1979). The Needles Range Formation consists of a series of ash-flow sheets that covered a very large area in southwestern Utah and adjacent parts of Nevada. Near its cauldron source to the west of Tract 073, the various members of the formation total more than 1,500 feet thick, but they thin rapidly in all directions. The Needles Range Formation is not known to be beryllium-bearing anywhere in the region. No other volcanic rocks are exposed in Tract 073 (Rowley and others, 1979). The rocks that are exposed in the tract are not hydrothermally altered or significantly mineralized. In addition, igneous intrusive rocks, which host beryllium-bearing veins and pegmatites in other parts of west-central Utah, do not occur at the surface in Tract 073. Nevertheless, this region is generally favorable for beryllium, and on this basis we have assigned Tract 073 beryllium favorability of f2. The certainty that beryllium resources occur in the tract is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest lead and zinc deposits to Tract 073 occur at the Horn Silver mine in the San Francisco Mountains about 15 miles to the southeast. Most lead and zinc production from this mine was prior to World War I from a replacement ore body localized along a fault at the contact between lower Paleozoic limestones and Tertiary volcanic rocks. Production from the Horn Silver mine, as well as from the entire San Francisco district, has been less than 1 million tons of lead and zinc ore. The San Francisco district contains the most productive lead and zinc deposits in southern and west-central Utah.

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 073 and the Wah Wah-Tushar mineral belt to the south of Tract 073 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)]. Tract 073 lies within this intervening non-mineralized belt, although a small diorite intrusive of Tertiary age crops out a few miles south of the tract's southern border (Hintze, 1974) and occurrences of lead, silver, and copper are reported from the area by Pera and others (1978).

Although the Tract 073 contains carbonate host rocks that are favorable for lead and zinc, a nearby source for the metals such as an intrusion is not known not occur (except perhaps at depth). Despite the tract's location (between the two generally recognized mineral belts in this area), it is still within a broad area containing some favorable characteristics for lead and zinc. We have assigned Tract 073 a favorability of f2. The certainty that lead and zinc resources occur in the tract is low and is assigned a value of c1.

TUNGSTEN f1/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains (Everitt, 1961).

Favorable carbonate host rocks of Cambrian and Ordovician age occur throughout Tract 073 (Hintze, 1974). Igneous intrusive rocks, however, do not occur at the surface in Tract 073, thus contact-metamorphic zones and/or vein deposits are unlikely (unless of course igneous intrusive rocks lie at depth). Hintze (1974) reports that a few miles south of Tract 073 diorite and quartz diorite have metamorphosed small areas of country rock. Altered carbonate rocks in this area are therefore favorable for tungsten deposits. In addition, Phelps Dodge Corporation discovered a molybdenum-porphyry deposit about 15 miles south of Tract 073 in the Wah Wah Mountains at Pine Grove (Wall Street Journal, January 6, 1978). Molybdenum-porphyry deposits are known to be tungsten-bearing in Colorado (Hobbs and Elliot, 1973); thus, the porphyry at Pine Groove is considered favorble for tungsten. Igneous intrusive rocks do not crop out in Tract 073, and the tract lies within a zone characterized by few igneous intrusive rocks [the mid-Utah gap of Jerome and Cook (1967)]. Nevertheless, we have assigned Tract 073 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten, and because the tract lies so close to an identified mineral belt. The certainty that tungsten deposits occur at depth in Tract 073 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 2

Tract 073 has been assigned an overall-importance rating (OIR) of 2 (on a 1 to 4 scale where 4 is equated with high mineral importance). Despite the fact that oil and gas, geothermal, beryllium, lead/zinc, and tungsten were each assigned a favorability of f2, these rating are not additive. In fact, if one assumes that the oil and gas favorability should be higher, the favorabilty for the other resources rated would necessarily be reduced (the converse is also true). This inverse relationship is due to the occurrence model used in the evaluation of Tract 073, which relates metal deposits and thermal waters to igneous intrusive rocks. If these intrusive rocks do in fact occur at relatively shallow depths in Tract 073, the oil and gas favorability is lower than the assigned rating of f2. Available information does not allow us to determine which of the resources is most likely to occur, so we have assigned each a favorability of f2. In any event, however, the overall mineral-resource potential of Tract 073 is considered to be low, despite its proximity to rather favorable areas to the south.

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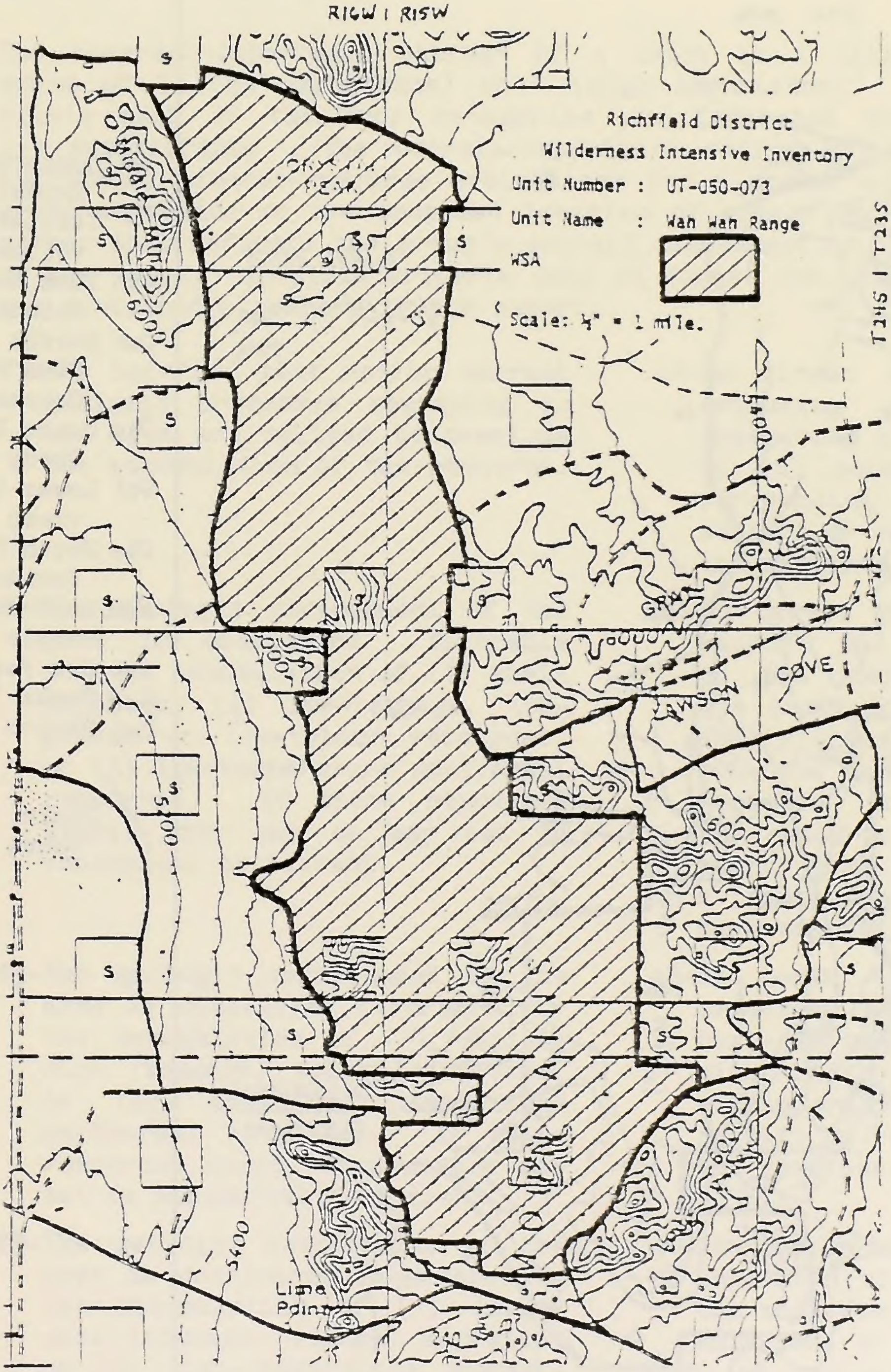
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 073 , UTAH

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



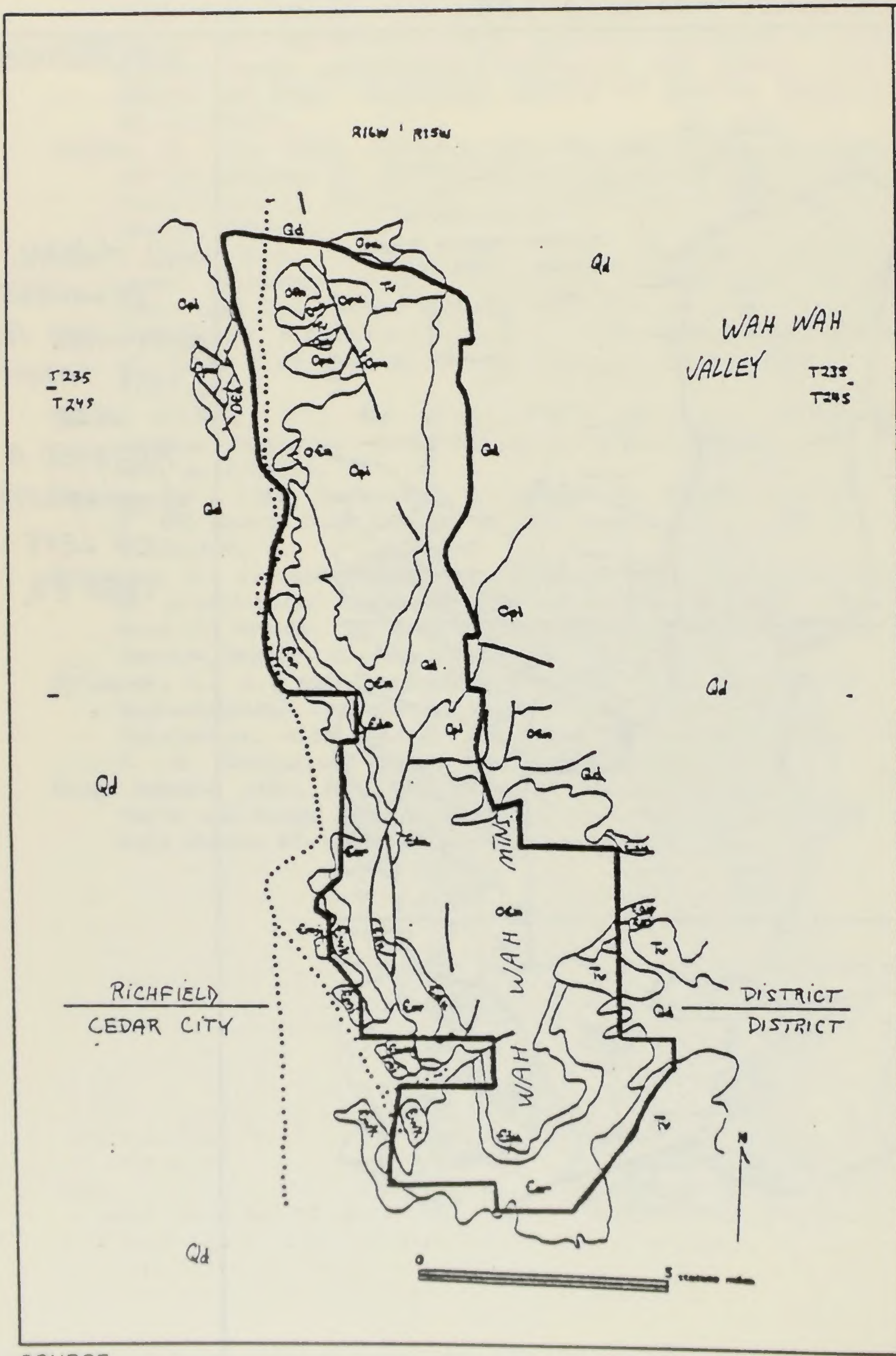
EXPLANATION

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

SOURCE: The April 1980 report by the Utah State Office of the BLM on "proposed" WSAs in Utah.

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 073 , 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

Qd	Quaternary deposits
Tv	Tertiary volcanics
Ofh	Fish Haven dolomite
Oes	Eureka and Swan Peak Quartzite
Opu	Upper Pogonip Group
Opl	Lower Pogonip Group
Oen	Notch Peak Formation
Edu	Dunderberg shale
Eor	Orr Formation
Cwk	Weeks limestone
Cmj	Marjum Formation

Fault, dotted where concealed

SOURCE: BASE MAP 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.

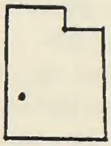
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource <u>does not</u> exist in the tract.)

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

TRACT NO: 077* **NAME:** Howell Peak **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 23,825

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

*[NOTE: Tract 077 was identified as a WSA before the current Wilderness Planning Program. Tract 077 is illustrated on the map that accompanies BLM (1980), but descriptions of the tract are not contained in that report.]

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

Tract 077 lies within the Basin and Range physiographic province and encompasses part of the House Range. Bedrock exposed in the tract is entirely of Cambrian age (Hintze, 1980).

The House Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. High-angle faults and thrust faults are abundant and well-exposed throughout this area.

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:	f1/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 077 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 077 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 077 may lie on younger rocks in the subsurface. Thus, Tract 077 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 077 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the Wah Wah Mountains south of Tract 077, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 077 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 077, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the House Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 077 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

The nearest exploratory wells have been drilled in the Confusion Range to the west, but all were dry (PIC, 1982). The few other wells that have been drilled in this region have also been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 077 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the west edge of Tract 077 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 077 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available regarding the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM <u>f1/c1</u>

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 077 lies 60 miles north of the Wah Wah Mountains uranium-producing district and about 30 miles south of the Topaz Mountain uranium area. According to Bromfield and others (1980), the Wah Wah Mountains district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age (Bromfield and others, 1980). At Topaz Mountain in the Thomas Range, several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspari pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 077 lies between (outside of) these mineral belts (these mineral belts will be described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, Tract 077 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is low and has been assigned a value 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.

The Kolob field and the small Harmony field, both more than 80 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 077 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c1

Tract 077 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 077.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

Thermal springs discharge in the valley west of the tract at Coyote, Tule, and South Tule Springs [28 to 31°C; NOAA (1980)]. On the basis of the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 077 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

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 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 077. On the basis of this information we have assigned Tract 077 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 077 lies about 35 miles south of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspari and uranium (from 1944 to 1952 about 75,000 tons of fluorspari were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 077 lies a few miles north of a intrusive body of Jurassic age [the Painter Spring Granite dated at 143 million years old (Armstrong and Suppe, 1973)]. It is possible that other intrusive bodies occur at depth in Tract 077, although this is pure conjecture.

Tract 077 lies in a region that is broadly favorable for beryllium although these deposits are not known to occur in or near the tract. Because of this regional favorability, we have assigned Tract 070 a beryllium favorability of f2, based chiefly on the possibility of intrusive bodies at depth. The certainty that beryllium resources occur in the tract (or do not occur) is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest lead and zinc deposits to the tract with recorded production are far to the south in Beaver County (Lemmon, 1964). Significant production has not been recorded in this district, or for that matter, anywhere in Millard County (Kiilsgaard and Heyl, 1964).

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 077 and the Wah Wah-Tushar mineral belt to the south of Tract 077 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)]. One of the rare intrusive bodies in the mid-Utah gap lies about 4 miles south (Hintze, 1980).

Tract 077 contains favorable carbonate host rocks for lead and zinc, plus a nearby intrusive source for the metals (the Notch Peak or Painter Spring granite to the south). Exploration in the area, however, indicates that significant lead and zinc mineralization has not occurred (Gehman, 1958). Furthermore, Tract 077 lies between the two generally recognized mineral belts in this area, although still within a region that is broadly favorable for lead and zinc. On the basis of this discussion, we have therefore assigned Tract 077 a lead/zinc favorability of f2. The certainty that lead and zinc resources occur at depth in the tract is low and is assigned a value of c1.

TUNGSTEN f1/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 077 (Everitt, 1961).

Many small bodies of scheelite-bearing tactite occur 4 miles south of the tract along the contact between granite and upper Cambrian limstones (Gehmans, 1958). According to Lemmon (1964), the ore bodies are mostly low grade and relatively small. Less than 7,000 tons containing about 5,000 units of WO_3 were reportedly shipped to mills from numerous properties around the intrusion (Everett, 1961).

We have assigned Tract 077 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten. The certainty that tungsten deposits occur at depth in Tract 070 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 2

Tract 077 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 considered only marginally favorable for oil and gas, geothermal, beryllium, lead, zinc, and tungsten.

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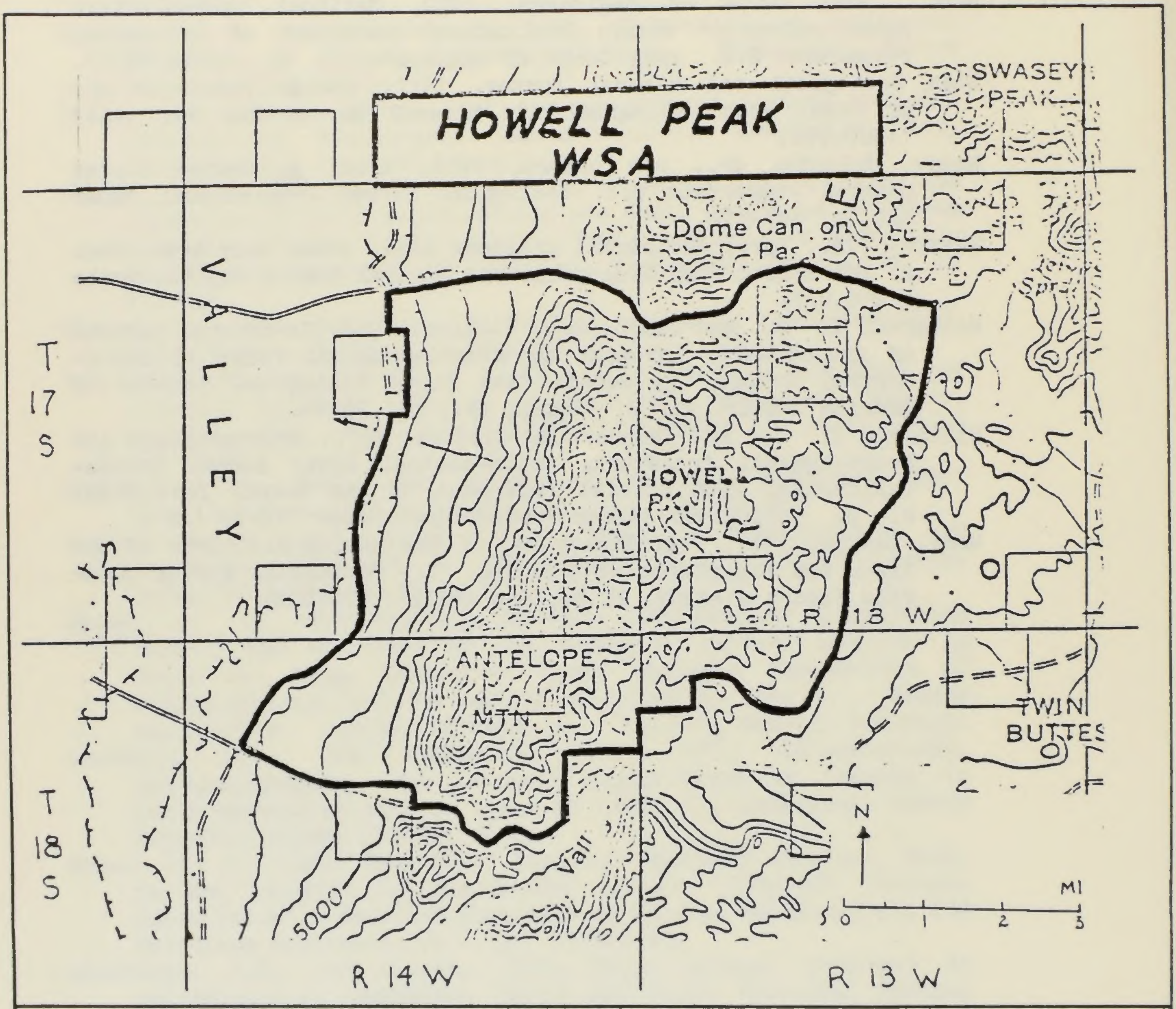
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 077, UTAH

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



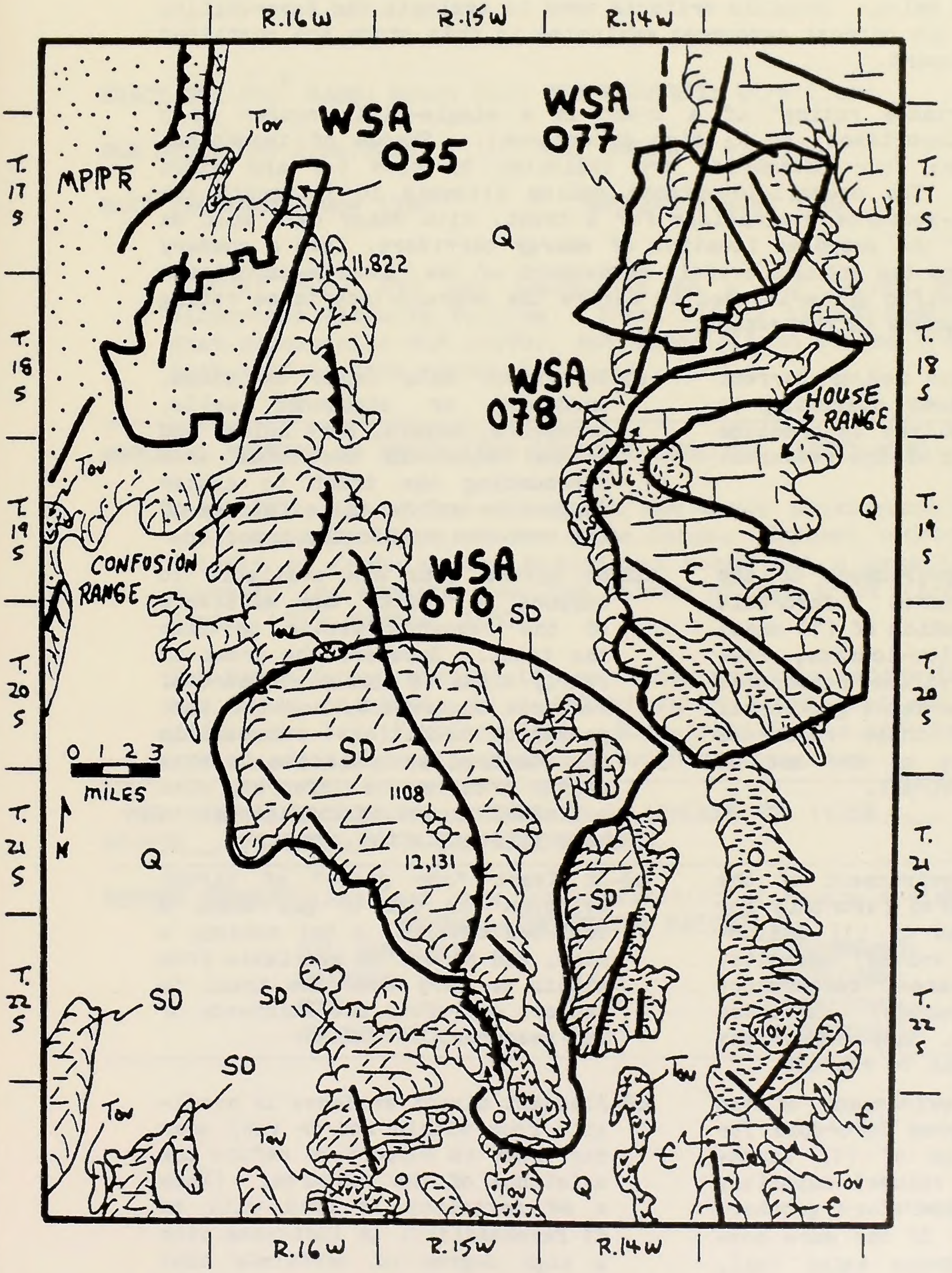
EXPLANATION

ALL RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN ~~f~~3.

SOURCE: BASE MAP FROM BLM, RICHFIELD, UTAH

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 035, 077, 078, 070

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



EXPLANATION

Q - QUATERNARY ALLUVIUM

MPIPTR - MISSISSIPPIAN THROUGH TRIASSIC ROCKS

SD - SILURIAN, DEVONIAN ROCKS

O - ORDOVICIAN ROCKS

Є - CAMBRIAN

Tov - VOLCANIC ROCKS (OLIGOCENE)

Ji - JURASSIC INTRUSIVE ROCKS.

THRUST FAULT

FAULT

12,131 OIL/GAS WELL (DRY), SHOWING TOTAL DEPTH

SOURCE:

MODIFIED 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.

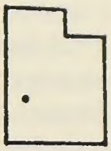
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource <u>does not</u> exist in the tract.)

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

TRACT NO: 078* **NAME:** Notch Peak **STATE/COUNTY:** UT/Millard

BLM DISTRICT: Richfield **WSA ACREAGE:** 51,130

DATE PREPARED: June 1982 **UPDATE:** August 1982


LOCATION

*[NOTE: Tract 078 was identified as a WSA before the current Wilderness Planning Program. Tract 078 is illustrated on the map that accompanies BLM (1980), but descriptions of the tract are not contained in that report.]

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

Tract 078 lies within the Basin and Range physiographic province and encompasses part of the House Range. Exposed bedrock consists chiefly of Cambrian and Ordovician rocks and a granitic mass of Jurassic age exposed near the center of the tract (Armstrong and Suppe, 1973; Hintze, 1980).

The House Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. High-angle faults and thrust faults are abundant and well-exposed throughout this area.

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:	f1/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f2/c1
GEOTHERMAL:	f2/c1	**TUNGSTEN:**	f2/c4

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 078 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 078 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 078 may lie on younger rocks in the subsurface. Thus, Tract 078 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 078 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the Wah Wah Mountains south of Tract 078, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 078 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 078, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the House Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 078 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

The nearest exploratory wells have been drilled in the Confusion Range to the west, but all were dry (PIC, 1982). The few other wells that have been drilled in this region have also been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 078 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the east edge of Tract 078 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 078 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available regarding the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM <u>f1/c1</u>

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 078 lies 50 miles north of the Wah Wah Mountains uranium-producing district and about 30 miles south of the Topaz Mountain uranium area. According to Bromfield and others (1980), the Wah Wah Mountains district has yielded about 5 tons of uranium oxide. The uranium occurs in close association with high-silica alkali rhyolites of Miocene age (Bromfield and others, 1980). At Topaz Mountain in the Thomas Range, several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspari pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 078 lies between (outside of) these mineral belts (these mineral belts will be described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, Tract 078 is assigned a uranium favorability of f1. The certainty that uranium resources do not exist in this tract is low and has been assigned a value 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.

The Kolob field and the small Harmony field, both more than 80 miles to the southeast, are the closest occurrences of potentially commercial coal. Coal-bearing rocks in each field are of Cretaceous age, and no other coal-bearing rocks with commercial potential are known from southwestern and central Utah (Doelling and Graham, 1972).

All bedrock of sedimentary origin in Tract 078 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c1

Tract 078 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Southwestern Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 25 miles east and south of Tract 078.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

Thermal springs discharge northwest of Tract 078 at Coyote, Tule, and South Tule Springs [28 to 31°C; NOAA (1980)]. On the basis of the area's igneous history, and on the structural setting of this region, low-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore assigned Tract 078 a geothermal favorability rating of f2, but a certainty of resource occurrence of only c1.

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 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 078. On the basis of this information we have assigned Tract 078 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 078 lies about 40 miles south of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 078 has been intruded by a granite of Jurassic age [the Painter Spring Granite dated at 143 million years old (Armstrong and Suppe, 1973)]. Mineralization of this intrusive body is chiefly in the form of tungsten (Gehman, 1958; see TUNGSTEN).

The granitic intrusion in Tract 078 is favorable for beryllium-bearing veins and pegmatites. On this basis, and because this region is broadly favorable for beryllium, we have assigned Tract 078 a beryllium favorability of f2. The certainty that beryllium resources occur in the tract is low and has been assigned a value of c1.

LEAD/ZINC f2/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

The closest reported lead and zinc occurrences to Tract 078 are in the Saw Back and Saw Tooth Mountain districts about 5 miles west of the tract. Significant production has not been recored in this district, or for that matter, anywhere in Millard County (Kiilsgaard and Heyl, 1964).

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt to the north of Tract 078 and the Wah Wah-Tushar mineral belt to the south of Tract 078 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)]. Tract 078 lies within this intervening non-mineralized belt, but it also encompasses one of the rare intrusive bodies.

Tract 078 contains favorable carbonate host rocks for lead and zinc (for example, the Notch Peak and House Limestones of Cambrian age), plus a nearby intrusive source for the metals (the Notch Peak or Painter Spring granite). Exploration in the area, however, indicates that significant lead and zinc mineralization has not occurred (Gehman, 1958). Furthermore, Tract 078 lies between the two generally recognized mineral belts in this area, although still within a region that is broadly favorable for lead and zinc. On the basis of this discussion, we have therefore assigned Tract 078 a lead/zinc favorability of f2. The certainty that lead and zinc resources occur at depth in the tract is low and is assigned a value of c1.

TUNGSTEN f1/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and

Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 078 (Everitt, 1961).

Many small bodies of scheelite-bearing tactite occur in the tract along the contact between granite and upper Cambrian limstones (Gehmans, 1958). According to Lemmon (1964), the ore bodies are mostly low grade and relatively small. Less than 7,000 tons containing about 5,000 units of WO_3 were reportedly shipped to mills from numerous properties around the intrusion (Everett, 1961).

On the basis of the discussion above, we have assigned Tract 078 a tungsten favorability of f2. The certainty that tungsten occurs in the tract is high and has been assigned a rating of c4. The relatively low favorability assigned to the tract is based on the likelihood that only small ore bodies exist at depth (Lemmons, 1964).

OVERALL-IMPORTANCE RATING 2+

Tract 078 has been assigned an overall-importance rating (OIR) of 2+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Tungstun, assigned an f2 favorability, is the chief reason for this rating. We increased the OIR from 2 to 2+ because of the high certainty that tungsten resources occur in the tract.

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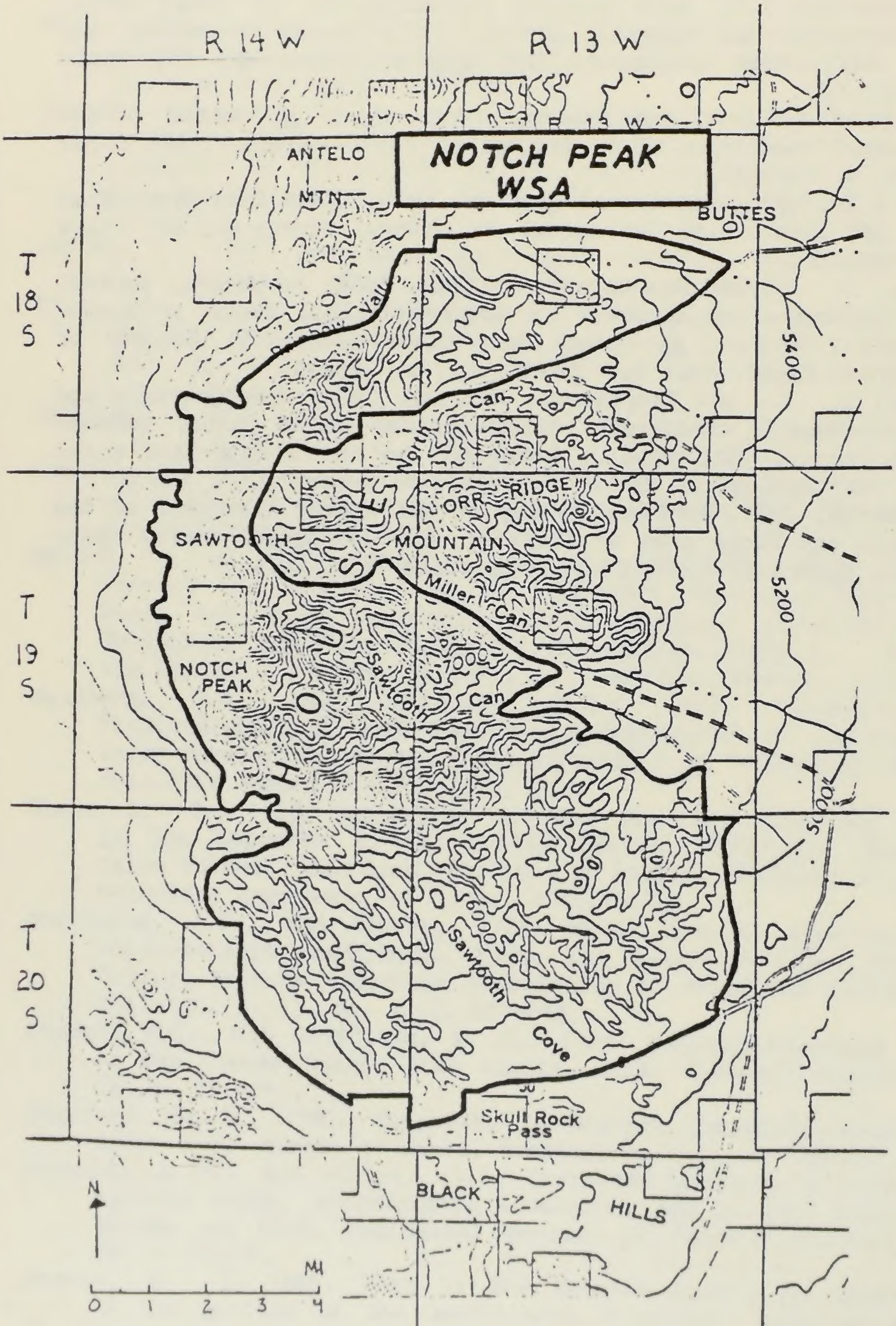
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 078, UTAH

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



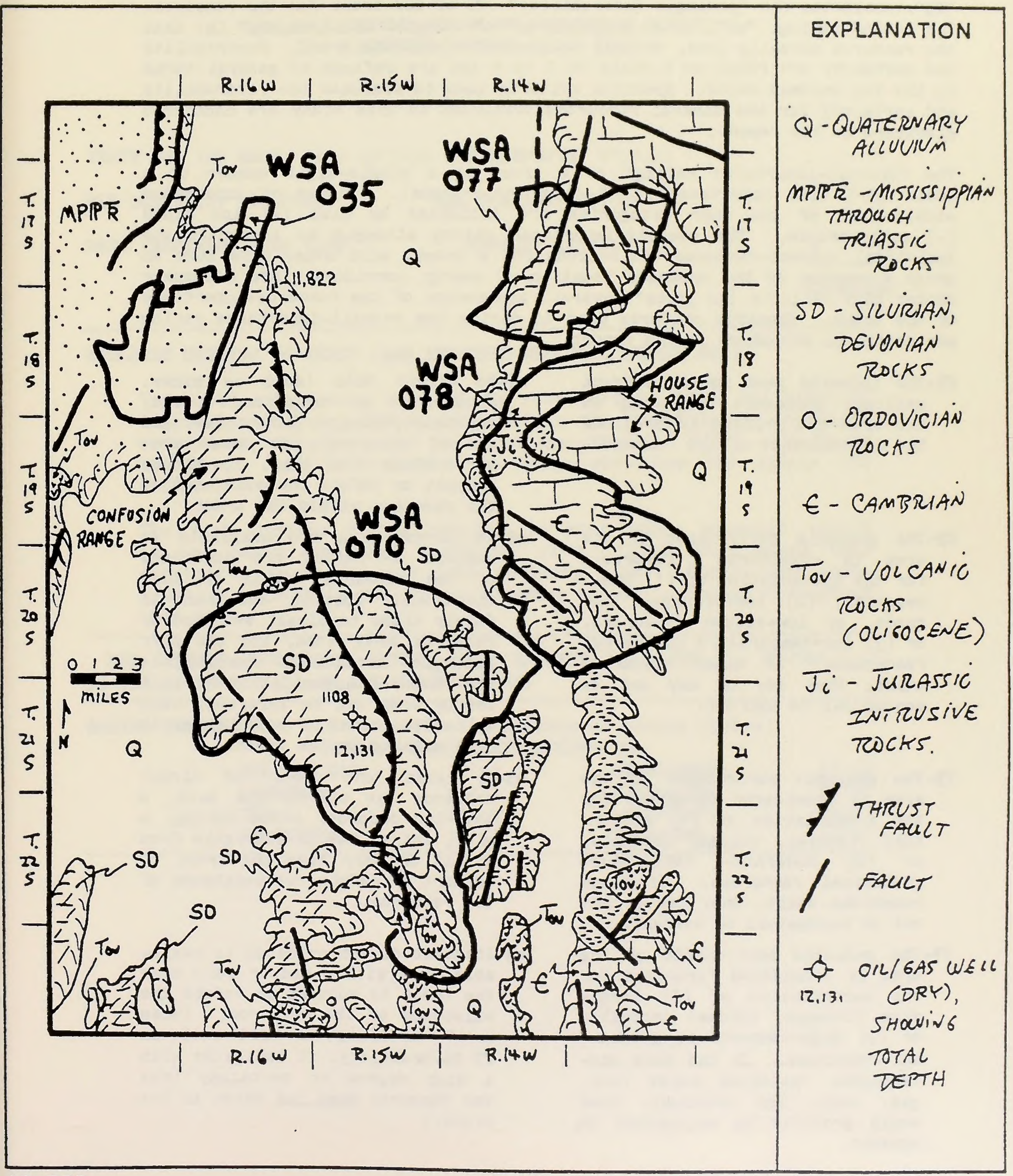
EXPLANATION

All resources evaluated for this tract were assigned a favorability of less than 3.

SOURCE: Base map from BLM (1980)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 035, 077, 078, 070

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



SOURCE:

MODIFIED 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: 127 **NAME:** Fish Springs **STATE/COUNTY:** UT/Juab

BLM DISTRICT: Richfield **WSA ACREAGE:** 52,500

DATE PREPARED: June 1982 **UPDATE:** August 1982


LOCATION

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

Tract 061 encompasses most of the Fish Springs Range and parts of adjacent valleys. Bedrock exposed in the tract is of Cambrian, Ordovician, Silurian, and Devonian age (Hintze, 1980). North of the tract, the Great Salt Lake basin stretches for almost 150 miles.

The Fish Springs Range, similar to most other mountain ranges in the Basin and Range province, is a tilted fault block that originated in middle and late Tertiary time. North- and west-trending high-angle faults are abundant and well-exposed throughout this area.

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: 3+

OIL AND GAS:	f2/c1	**HYDROPOWER:**	f1/c4
URANIUM:	f2/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f3/c1
GEOTHERMAL:	f3/c2	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 127 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuaton of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 127 lies many miles west of the leading edge of Sevier-age thrusts (Armstrong, 1968). On the basis of geologic relations throughout this area, it is possible that the Paleozoic rocks exposed at the surface in Tract 127 may lie on younger rocks in the subsurface. Thus, Tract 127 is considered here to be part of the "thrust belt," even though the age of the thrusts in this area may be considerably older than thrusts along the leading edge of the belt farther east.

The third development that affected the oil and gas potential of Tract 127 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured

bedrock and the Tertiary fill may be the rule rather than the excepton over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the Wah Wah Mountains south of Tract 127, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 127 lies between two west-trending areas characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Wah Wah-Tushar mineral belt to the south and the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 127, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the

damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks that fill the valleys adjoining the Fish Springs Range would seem to offer the best hope for oil and gas. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 127 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

No exploratory wells have been drilled in this area (PIC, 1982). The few wells that have been drilled in this region have been dry (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

The favorability of Tract 127 for oil and gas is considered to be low, and is assigned a value of f2. The boundary of the tract has been drawn by the BLM so that very little of the surrounding valley is included (see attached Mineral-Resource Potential Map). Nevertheless, the Tertiary sedimentary rocks underlying the west and east sides of Tract 127 are favorable for small oil accumulations in stratigraphic and structural traps that are similar to those at Eagle Springs and Trap Spring in east-central Nevada. Thus, even though the Tertiary stratigraphy in the vicinity of Tract 127 is not well known, the general structural and stratigraphic environment is considered marginally favorable for oil fields. No data are available regarding the certainty of resource occurrence and we have therefore assigned the tract a certainty rating of c1.

URANIUM f2/c1

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 127 lies about 10 miles west of the Topaz Mountain uranium area, where Several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspar pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 127 lies within the northern belt referred to as the Deep Creek-Tintic belt (Stewart and others, 1977; these mineral belts will be described in more detail under the section LEAD/ZINC).

Tract 127 is aligned along an east-west trend that contains abundant mineral deposits that are related chiefly to Tertiary igneous rocks. Although igneous rocks have not been mapped in the tract, these rocks may occur at relatively shallow depths. The thermal springs at the north end of the Fish Springs Range may be a manifestation of a Tertiary intrusion at depth.

In the basis of the preceeding discussion, we have assigned Tract 127 a uranium favorability of f2. The certainty that uranium resources exist in this tract is low and has been assigned a value 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.

All bedrock of sedimentary origin in Tract 127 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f3/c2

Tract 127 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Western Utah is a particularily favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources. All the known and potentially valuable geothermal resource areas identified by these agencies lie at least 20 miles east and south of Tract 127.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

A few thermal springs discharge at the northern and northeastern end of the Fish Springs Range (NOAA, 1980; Wilson Health Springs and Fish Springs). Water temperature (at the surface) ranges from 28 to 61°C. Furthermore, lead and zinc mineralization is reported along faults at the northern end of the Fish Springs Range (Lemmon, 1964). The mineralizing solutions presumably were derived from an igneous mass at depth.

On the basis on the area's igneous history, and on the structural setting of this region, low- and moderate-temperature resources probably occur at relatively shallow depths (less than 1,000 feet). We have therefore asssigned Tract 070 a geothermal favorability rating of f3. Low temperature thermal waters have been exploited commercially in this area, but the certainty that the resource occurs in the tract is moderately low and has been assigned a value of c2.

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 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 127. On the basis of this information we have assigned Tract 127 a hydropower favorability

rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chielfy to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 127 lies about 8 miles west of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspar and uranium (from 1944 to 1952 about 75,000 tons of fluorspar were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during depostion of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 127 lies in a region that is broadly favorable for beryllium although these deposits are not known to occur in the tract. Because of this regional favorability, we have assigned Tract 070 a beryllium favorability of f2, based chiefly on the possibility of intrusive bodies at depth. The certainty that beryllium resources occur in the tract (or do not occur) is low and has been assigned a value of c1.

LEAD/ZINC <u>f3/c1</u>

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porohyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertcal pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

Lead and silver are reported at the northern end of the Fish Springs Range in replacement bodies along faults that cut limestone (Butler and others, 1920; Lemmon, 1964). The Fish Springs district is characterized by Lemmon (1964) as a small or third order district; production plus reserves of lead and zinc are from 1,000 to 50,000 tons for lead and from 1,000 to 5,000 tons for zinc.

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt, in which Tract 127 lies, and the Wah Wah-Tushar mineral belt to the south of Tract 127 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)].

Tract 127 contains favorable carbonate host rocks for lead and zinc, as demonstrated by the occurrence of lead and zinc in limstones at the northern part of the range. Furthermore, Tract 127 lies [redacted] within the Deep Creek-Tintic mineral belt. On the basis of this discussion, we have assigned Tract 127 a lead/zinc favorability of f3. The certainty that lead and zinc resources occur at depth in the tract is low and is assigned a value of c1.

TUNGSTEN f2/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and

Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 127 (Everitt, 1961).

We have assigned Tract 127 a tungsten favorability of f2 because it lies within a recognized mineral belt [the Deep Creek-Tintic belt; see Stewart and others (1977)], and because there is some evidence to suggest that intrusive rocks underlie the tract (geophysical data, hot springs, and lead and zinc deposits). The certainty that tungsten deposits occur at depth in Tract 070 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 3+

Tract 127 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 tract is considered to be favorable for moderately large deposits of lead and zinc, and small deposits of beryllium, tungsten, and uranium. Oil and gas is considered to be marginally favorable, and only within the Tertiary rocks bordering the range on the east and west sides.

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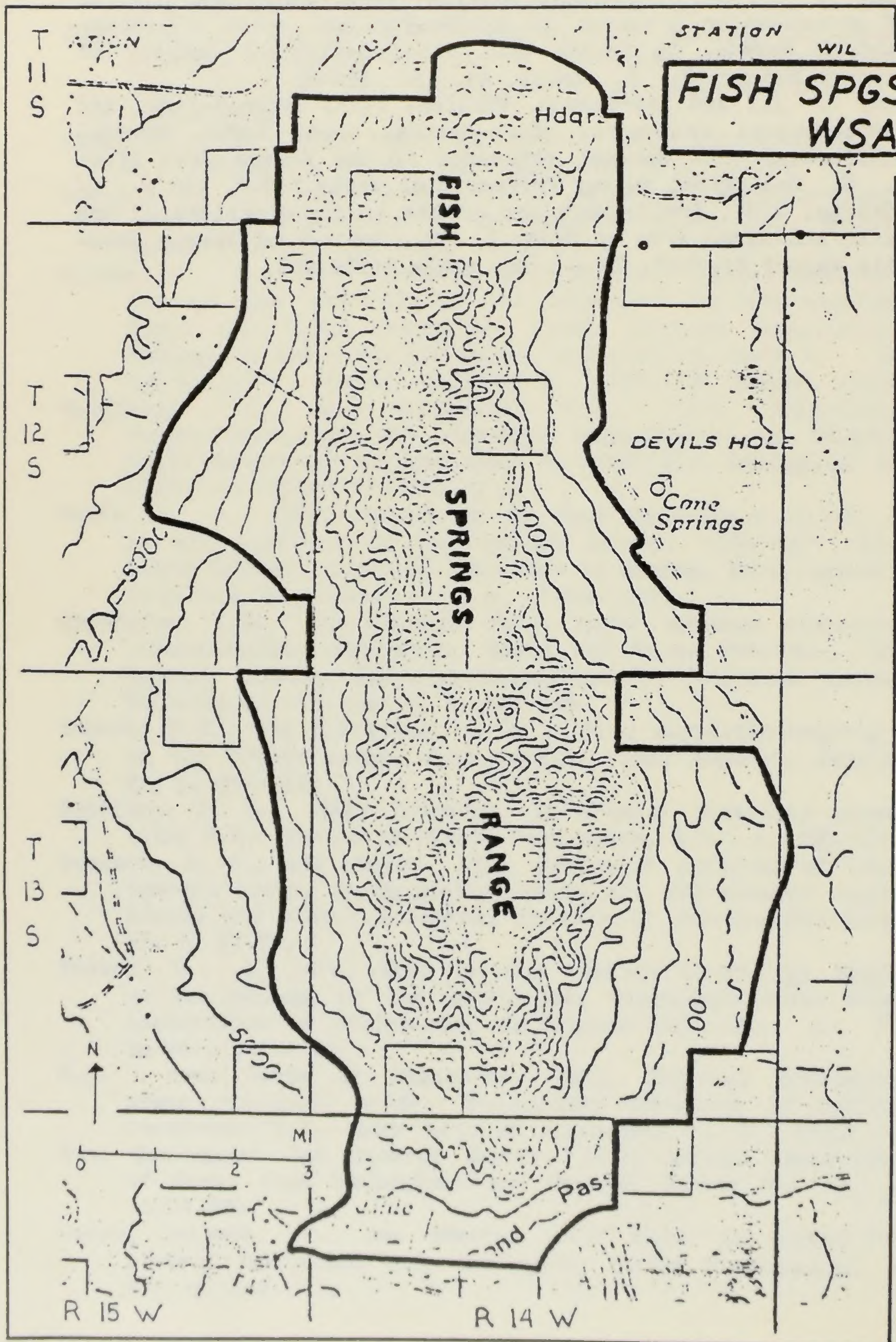
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 127, UTAH

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



EXPLANATION

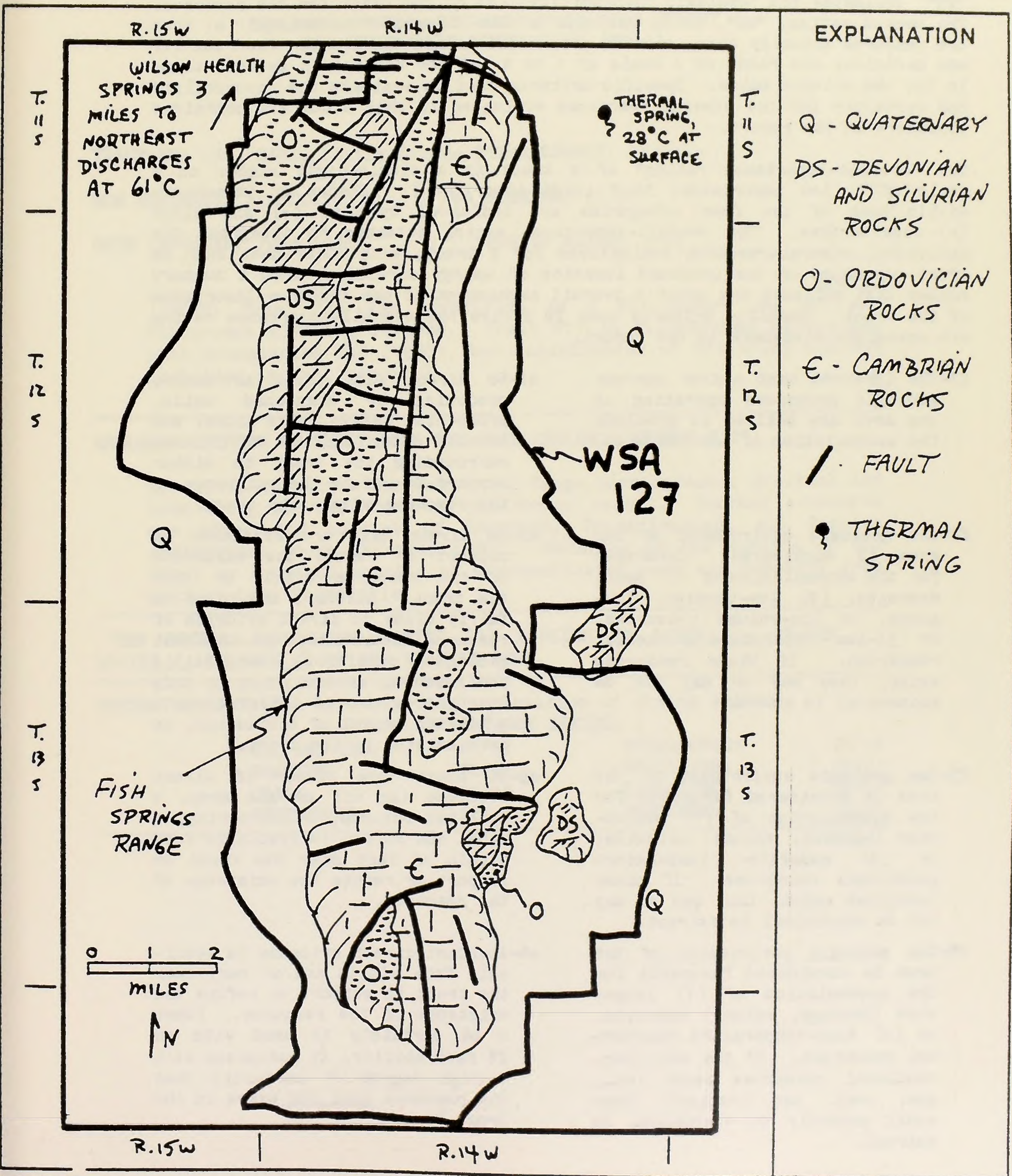
LEAD AND ZINC WERE ASSIGNED A FAVORABILITY OF S3, CHIEFLY FOR THE NORTHERN PART OF THE TRACT

GEOTHERMAL WAS ASSIGNED A FAVORABILITY OF S3, AND AGAIN CHIEFLY FOR THE NORTHERN PART OF THE TRACT.

SOURCE: BASE MAP FROM BLM, RICHFIELD DISTRICT

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 127 , 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: BASE MAP FROM HINTZE (1980), MODIFIED

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.

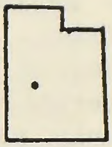
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 186* **NAME:** Little Sahara **STATE/COUNTY:** UT/Juab

BLM DISTRICT: Richfield **WSA ACREAGE:** 9,151

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

*[NOTE: Tract 186 was identified as a WSA before the current Wilderness Planning Program. Tract 077 is illustrated on the map that accompanies BLM (1980), but descriptions of the tract are not contained in that report.]

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

Tract 186 is within the Basin and Range physiographic province and lies along the east side of the Sevier desert. Bedrock exposures are minor and consist of Cambrian, Pennsylvanian, and Permian sedimentary rocks (Hintze, 1980). Material at the surface of the tract is composed chiefly of unconsolidated sand and deposits from ancient Lake Bonneville.

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/c1	**HYDROPOWER:**	f1/c4
URANIUM:	f2/c1	**BERYLLIUM:**	f2/c1
COAL:	f1/c4	**LEAD/ZINC:**	f4/c1
GEOTHERMAL:	f2/c2	**TUNGSTEN:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Most oil and gas production in Utah comes from the eastern side of the State, although the "thrust belt" in north-central Utah is rapidly becoming a region of major gas production (Brown and Ritzma, 1982). Historically, western Utah and the rest of the Basin and Range have never been considered to be a favorable region for petroleum by the oil companies; thus, few wells have been drilled. As described below, this pessimistic view is gradually changing as a result of oil discoveries in east-central Nevada. Nevertheless, the geology of the Basin and Range, although still poorly understood despite more than a century of investigation, suggests that large hydrocarbon accumulations probably do not exist.

Tract 186 lies in an area where the oil and gas favorability has been affected primarily by the development of three distinct depositional and/or tectonic settings. These settings, from oldest to youngest, include: (1) the Cordilleran miogeosyncline, (2) the Sevier thrust belt, and (3) the Basin and Range. The first two enhanced the oil and gas favorability of western Utah, and the latter reduced the favorability. As a result, a difference of opinion currently exists among some geologists regarding the overall oil and gas potential of this region. A brief discussion of each setting may help the reader to understand the reasons for these differences.

The Cordilleran geosyncline was part of a large, north-trending seaway that existed in the western United States from late Precambrian time, through the Paleozoic, and into early Mesozoic time. The deepest parts of the seaway lay west of the present meridian of central Nevada. Toward eastern Nevada and western Utah, the sea floor rose gradually and merged with a continental shelf in eastern Utah. The boundary between the continental shelf and the geosyncline has long been referred to by geologists as the Cordilleran "hingeline." In Utah, this hingeline trends to the northeast and coincides, in general, with the present-day boundary between the Colorado Plateau and the Basin and Range. As will be described below, this hingeline was also the zone along which major structural developments took place in more recent times. The history and significance of the hingeline has been reviewed by Stokes (1976), but for the purposes here, it is important only to point out that under suitable conditions, oil and gas generated in the strata deposited in the geosyncline would tend to migrate up-dip (eastward) and become trapped in reservoir rocks near the hingeline.

Development of the Sevier thrust belt during late Cretaceous to early Tertiary time (Armstrong, 1968) also enhanced the oil and gas favorability of western Utah. This belt marks the easternmost extent of thrust faults that place older geosynclinal rocks over

younger platform rocks; its exposed easternmost extent generally coincides with the hingeline described above. The Sevier thrust belt, however, is only a small part of a much larger system of thrust faults and folds that extend in a roughly continuous zone from Alaska, through western Canada, western Montana, eastern Idaho, western Wyoming, western Utah, and southern Nevada. Many geologists now believe that the thrust belt also continues across central Arizona, southwestern New Mexico, and on into Mexico, although its precise location is more obscure here than farther north. The leading or "eastern edge" of the entire thrust belt presumably originated near the close of Cretaceous time throughout all of North America. West of the leading edge, the thrust faults are older and there is considerable confusion, even among some geologists, in regard to the meaning of the expression "the thrust belt."

Thrust belts are considered favorable oil and gas targets because large structural traps are created during the thrusting process. In 1924, petroleum was discovered in the southern Canadian thrust belt, and about 50 years later large discoveries were made in the continuation of the thrust belt in northern Utah and western Wyoming (Hayes, 1976). These latest discoveries in Utah and Wyoming sparked the current wave of interest in the remainder of the thrust belt throughout the western United States, and even the thrust belt in the eastern United States.

The number of thrust plates, and their width within the Sevier thrust belt in western Utah and eastern Nevada, is poorly known. For the purposes of this analysis, however, it is important to note only that Tract 186 lies west of the leading edge of Sevier-age thrusts, but within the "thrust belt" (Armstrong, 1968).

The third development that affected the oil and gas potential of Tract 186 was widespread faulting and igneous activity during creation of the Basin and Range from mid-Cenozoic time to the present. The east-west extension that was responsible for development of the Basin and Range during this period may have destroyed any significant hydrocarbon accumulations that existed in the region after development of the Sevier thrust belt. In addition, regional flow of fresh ground water through the pervasively fractured, pre-Tertiary bedrock may have flushed even the small oil fields that survived the earlier effects of faulting and igneous activity (Osmond and Elias, 1971). Furthermore, as demonstrated by Mifflin (1968) and by Winograd and Thordarson (1968; 1975), ground water is not confined to the Tertiary structural basins, but moves through the bedrock ranges that separate these basins. Thus, fresh-water flushing of the fractured bedrock and the Tertiary fill may be the rule rather than the exception over large parts of the Basin and Range province. [An exception would be Railroad Valley in east-central Nevada where oil is produced from two small fields in fractured Tertiary rocks (Bortz and Murray, 1979; Duey, 1979).]

Mitchell (1979) considers the sub-thrust oil and gas potential in western Utah to be similar to the productive parts of the thrust belt in northern Utah and western Wyoming. Several factors, however, suggest that the thrust belt in western Utah is not nearly as favorable as the productive parts of the thrust belt farther north. First, the rich Cretaceous source rocks in northern Utah and western Wyoming do not occur in western Utah (for example, in the Wah Wah Mountains south of Tract 186, Cambrian rocks rest directly on Jurassic rocks). Second, the Sevier-age thrust slices in western Utah are far more fragmented due to development of the Basin and Range compared with the continuation of these thrusts in northern Utah, western Wyoming, and southeastern Idaho. And third, igneous intrusive rocks are abundant in western Utah, and generally post-date thrusting.

Tract 186 lies within a west-trending area characterized by aeromagnetic highs that correspond closely with Tertiary intrusive rocks (Stewart and others, 1977). This trend continues westward into Nevada and the entire zone is abundantly endowed with base-metal deposits [the Deep Creek-Tintic mineral belt to the north (Hilpert and Roberts, 1964; Stewart and others, 1977)]. According to Sandberg and Gutschick (1977), this and other mineral belts in Utah and Nevada may be related to slow movement of the North American plate over "hot spots" in the mantle. These authors speculate further that any organic matter or oil and gas that may have existed within these belts in the past, have since been destroyed by extreme heat, but that the areas between the belts do have some oil and gas potential. Furthermore, much evidence exists indicating that the heat flow throughout the present-day area of the Basin and Range has been high for the past 100 million years--long before development of the Basin and Range in middle and late Tertiary time (Eaton, 1979). Some of this evidence is in the form of hydrothermal mineral deposits and large masses of igneous rock that have periodically invaded the crust since Mesozoic time. Hydrocarbons trapped in Paleozoic and Mesozoic rocks may therefore have escaped to the surface in much the same way that hot springs discharge over large parts of the Basin and Range today. Furthermore, evidence from the thermal alteration of conodonts (the color alteration index of Epstein and others, 1977) suggests that thermal metamorphism in many parts of the Basin and Range (but not all parts) has destroyed the organic remains once contained in the rocks (Sandberg and Gutschick, 1977). Thus, if petroleum accumulations exist in the vicinity of Tract 186, they are probably small pools in Tertiary rocks (rather than in Paleozoic and Mesozoic rocks) that have been spared from the damaging affects of thermal metamorphism and flushing by fresh ground water.

On the basis of the discussion above, the Tertiary sedimentary rocks below Tract 186 are more favorable for oil and gas than is the underlying bedrock. The only oil fields in the entire Basin and Range--Eagle Springs and Trap Spring (and some heavy oil from the Great Salt Lake)--produce from Tertiary and Cretaceous rocks in Railroad Valley in east-central Nevada in a structural setting broadly similar to Tract 186 (Bortz and Murray, 1979; Duey, 1979). Ultimate recovery from the Eagle Springs field is estimated to be about 4 million barrels of oil; this field would therefore be characterized as 'small' in our classification (an f2--less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet).

The favorability of Tract 186 for oil and gas is considered to be low, and is assigned a value of f2, based chiefly on rocks of Tertairy age. No exploratory wells have been drilled in the area; thus the certainty that petroleum occurs in the tract is low and has been assigned a value of c1 (Hansen and others, 1955; Heylmun and others, 1965; PIC, 1982).

URANIUM f2/c1

The Basin and Range is not a major uranium-producing region, although recently, large uranium deposits have been reported from volcaniclastic rocks in west-central Arizona, and from volcanic rocks in the McDermitt caldera in northern Nevada (Sherborne and others, 1979; Chenoweth, 1979; Rytuba and others, 1979). Most other deposits in the Basin and Range are low-tonnage and occur in a wide variety of geologic environments. The most productive of these small deposits are related to veins in igneous rocks and mineralized volcanic sediments (DOE, 1979).

Tract 186 lies 50 miles west of the Topaz Mountain uranium area where several thousand tons of uranium ore were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962 (Shawe, 1968; Davis, 1979; Lindsey, 1979). In addition, the Thomas Range contains uranium-bearing fluorspar pipes that cut Paleozoic dolomites (Hilpert and Dasch, 1964).

Many of the base- and precious-metal deposits in western Utah (including uranium) are aligned along two west-trending belts that are characterized by igneous intrusive rocks of Tertiary age (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). Tract 186 lies within the northern belt, called the Deep Creek-Tintic mineral belt (described in more detail under the section LEAD/ZINC).

In view of the preceeding discussion, the bedrock underlying Tract 186 is considered favorable for uranium and is assigned a rating of f2. The certainty that uranium resources exist at depth in the tract is low and has been assigned a value 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.

All bedrock of sedimentary origin in Tract 186 is of pre-Cretaceous age. Because these rocks are not known to be coal-bearing anywhere in the region, we have assigned the tract a coal favorability of f1 with a certainty of c4 that the resource does not occur.

GEOTHERMAL f2/c2

Tract 186 lies within the Basin and Range physiographic province. Unlike the Colorado Plateau to the east, the Basin and Range contains many of the favorable characteristics that are normally associated with geothermal resources. These characteristics include crustal instability, high heat-flow, young igneous rocks, and widespread seismic activity.

Western Utah is a particularly favorable region for geothermal resources. Hot springs are abundant, and the U.S. Geological Survey has identified numerous "Known Geothermal Resource Areas" (KGRAs) as prime leasing prospects (Muffler and others, 1978). In addition, the Utah Geological and Mineral Survey (1977) has identified broad areas in western Utah that it considers potentially valuable for geothermal resources.

High-temperature geothermal resources in southwestern Utah are associated with young igneous rocks of silicic (rhyolite) composition. This is a common association throughout the western United States. Areas that contain only young basaltic rocks are considered less favorable for high-temperature resources because the basalt is presumed to rise rapidly from the earth's mantle to be extruded onto the surface where most of the heat is dispersed to the atmosphere. In contrast, the more viscous silicic magmas are presumably derived from partial melting of shallower crustal rocks. Unlike the deep basaltic magmas, silicic magmas can reside in the upper few miles of the crust for perhaps hundreds of thousands of years while heating the surrounding rock and water. As would be expected, geothermal gradients in parts of western Utah are steep, commonly 5°C to 10°C/100 meters (330 feet), and locally, gradients exceeding 60°C/100 meters have been reported (Whelan, 1976). In comparison, gradients on the nearby Colorado Plateau generally range from only 1°C to 10°C/100 meters (Whelan, 1976).

Tract 186 lies at the northern end of a large area that has been identified by NOAA (1980) as having a significant potential for low-temperature geothermal resources (springs west of the tract discharge at a temperature generally less than 30°C). On this basis, we have assigned Tract 061 a geothermal favorability rating of f2, and a certainty of resource occurrence of c2 (because of abundant and nearby springs).

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 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 186. On the basis of this information we have assigned Tract 186 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

BERYLLIUM f2/c1

Beryllium is used in a wide variety of products, but principally in nuclear reactors, in the aerospace industry, and as an alloy with copper in electrical equipment. U.S. consumption of beryllium metal, now more than 300 tons a year, is expected to increase at about 0.3 percent annually through 1990 (Petkof, 1982). In 1981, approximately 25 percent of our consumption was supplied by imports (Petkof, 1982), whereas the remainder was supplied largely by production at Spor Mountain in west-central Utah. Identified beryllium resources in known deposits in the United States are estimated at 80,000 tons of contained beryllium--sufficient to meet anticipated U.S. requirements for at least the next few decades (Petkof, 1982).

Beryllium deposits are generally divided into two broad categories; those in pegmatites and those derived from hydrothermal activity. The beryllium-bearing pegmatite deposits are confined chiefly to the eastern United States and to the Rocky Mountain States, but identified resources in these deposits are minor (Griffitts, 1973). The most important beryllium deposits and potential resources in the United States are those of hydrothermal origin that occur in areas of crustal instability and high heat-flow.

Tract 186 lies about 40 miles east of the Spor Mountain beryllium district where the world's largest known beryllium deposits occur (Shawe, 1968; Griffitts, 1964). Long before the beryllium deposits were discovered in 1959, the district produced fluorspari and uranium (from 1944 to 1952 about 75,000 tons of fluorspari were mined from mineralized pipes in Ordovician and Silurian rocks, and several thousand tons of uranium were mined from Tertiary lacustrine rocks at the Yellow Chief mine from 1956 to 1962; Shawe, 1968; Davis, 1979; Lindsey, 1979). Production of beryllium from Spor Mountain began almost 10 years after its discovery in 1959 (Davis, 1979). By 1979, more than a half-million tons of beryllium ore had been produced from three open-pit mines on the west side of Spor Mountain. Davis (1979) estimates reserves at several million tons of bertrandite-bearing beryllium ore with an average grade between 0.6 to 0.7 percent BeO. In addition, large amounts of lithium, fluorine, uranium, and zinc also occur with the beryllium.

The beryllium deposits at Spor Mountain are contained in bedded ryholite tuffs of Tertiary age. The most important beryllium mineral is finely disseminated, submicroscopic bertrandite. The ore bodies are nearly concordant to bedding and the largest are about 2.5 miles long, 1,000 feet wide (in a down-dip direction), and 6 feet thick (Shawe, 1968). The extensive fine-grained layers of tuff may be the result of air fall from rhyolitic eruptions that was then transported by water to the site of deposition; or at least reworked by water after deposition from the air (Shawe, 1968). Parts of the tuff contain abundant carbonate pebbles, mostly about one inch in diameter, derived from Paleozoic rocks that were exposed in the immediate vicinity during deposition of the tuff. Beryllium deposits are confined chiefly to tuff beds that contain these carbonate clasts. Furthermore, the largest beryllium deposits occur where the tuff unit is thickest, which is usually along fault-controlled paleo-valleys in which the tuff was deposited. According to Staatz and Griffitts (1961) and Shawe (1968), mineralization of the water-laid tuff was the result of hydrothermal solutions passing through and altering the highly permeable tuff (overlying and underlying rock units are much less permeable). Lindsey and others (1973) speculate that the metals and other materials concentrated in the tuff at Spor Mountain were deposited by fluorine-rich solutions that had been in contact with a buried granitic pluton.

The close association of the beryllium-tuff with carbonate clasts suggests that similar rhyolite tuffs deposited in areas with an abundant supply of carbonate clasts are as favorable for beryllium as Spor is Mountain. Other ore controls, however, include a chemically reactive and transmissive zone for hydrothermal solutions, as well as a suitable structural setting (some of the ore bodies are adjacent to fault zones; Shawe, 1968)

Beryllium minerals have been discovered in other parts of west-central Utah, particularly in Toole and Juab Counties, and in the Mineral Range in Beaver County. These deposits are much smaller than those at Spor Mountain, and they occur chiefly in beryl-bearing pegmatites, as beryl rosettes in granite, and in fine- and coarse-grained veins (Griffitts, 1964). According to Griffitts (1964) and Cohenour (1963), west-central Utah lies at the east end of a beryllium-rich province that extends as far west as central Nevada.

Tract 186 lies in a region that is broadly favorable for beryllium although these deposits are not known to occur in or near the tract. Because of this regional favorability, we have assigned Tract 070 a beryllium favorability of f2, based chiefly on the possibility of intrusive bodies at depth. The certainty that beryllium resources occur in the tract (or do not occur) is low and has been assigned a value of c1.

LEAD/ZINC f4/c1

In Utah, lead and zinc (and silver) occur in similar geologic environments and they are described together in the paragraphs below. James (1973) refers to the lead and zinc deposits in Utah and elsewhere in the western United States as "Cordilleran-group" deposits, in contrast to the "Mississippi Valley"-type deposits in the eastern United States. Regionally, however, lead and zinc occur in a wide variety of geologic environments, and much of our domestic production of these metals is derived from deposits containing only lead or zinc (see Morris and others, 1973, and Wedow and others, 1973).

About 65 percent of the lead consumed in this country is used in the transportation industry (batteries, gasoline additives, etc.), 30 percent is used in construction, paints, ammunition, and electrical use, and about 5 percent in ceramics, glass, and other uses (Rathjen, 1982). In 1981, 10 percent of our requirements for lead was supplied by imports (Rathjen, 1982). For zinc, about 40 percent is used in construction materials, 19 percent in transportation equipment, 18 percent for machinery and chemicals, and 12 percent in electrical equipment. About 67 percent of our 1981 requirements for zinc was supplied by imports (Cammarota, 1982).

For many years Utah produced large quantities of lead and zinc, but due to increased mining costs, mechanical problems, and competition from other domestic and foreign sources, the last lead-zinc mining operation in Utah closed in 1978 (Kennecott's Burgin mine near Eureka; McKinney and Stowe, 1979). In 1981, the leading lead- and zinc-producing states were Missouri and Tennessee (Rathjen, 1982; Cammarota, 1982).

Primary ores of lead and zinc commonly occur as the sulfide minerals galena (lead sulfide) and sphalerite (zinc sulfide), and the ores usually contain silver, some copper, and minor amounts of gold (Kiilsgaard and Heyl, 1964). The most important lead and zinc deposits in Utah, in terms of past production, are replacement deposits in carbonate rocks that have been intruded by igneous rocks of intermediate to acidic composition. The ore bodies are commonly localized by fractures and form veins. Small vein deposits also occur in Tertiary volcanic rocks, igneous intrusive rocks, and quartzites. Because lead and zinc react differently under oxidizing conditions (zinc is more soluble), oxidized bodies of lead and zinc usually do not occur together.

Lead and zinc have been mined from dozens of metal-mining districts throughout Utah, but almost all are in the western half of the state (Wong, 1981; Kiilsgaard and Heyl, 1964). Three districts--Bingham, Park City, and Tintic--in the vicinity of Salt Lake City, however, account for the bulk of the state's total output of lead and zinc. The Bingham mining district is known chiefly as a copper producer, but it was also the state's largest lead, zinc, and silver producer. Ore bodies in the district are grouped around a mineralized porphyry stock. The porphyry is enriched in copper and is surrounded by a zone that is enriched in lead and zinc. The lead and zinc deposits occur in veins and as replacement deposits in the Oquirrh Formation of Pennsylvanian age. The underground workings have averaged about 7 percent lead and 7 percent zinc.

In the Park City district, sedimentary rocks are intruded by diorite and diorite porphyry. The ore bodies occur along steeply-dipping, east- to northeast-trending fractures and along favorable beds that extend 100 to 200 feet from these fractures. The most productive ore bodies are in the Park City Formation of Permian age and the Thaynes Formation of Triassic age. (Kiilsgaard and Heyl, 1964).

The Tintic district, located only a few miles northeast of Tract 186, is commonly divided into the Main Tintic and East Tintic districts (Kiilsgaard and Heyl, 1964). The lead and zinc ores occur primarily as irregular replacement deposits in calcareous rocks of Paleozoic age that are folded, faulted, and intruded by monzonite and quartz monzonite. The ore bodies occur in linear zones that are laterally continuous across faults and across strata. At fault intersections the ore bodies are sometimes enlarged and form vertical pipes of high-grade ore. Lead and zinc ore bodies in the East Tintic district (such as at the Tintic Standard mine) occur as replacement bodies in shattered limestone at intersections of faults.

Base-metal deposits in western Utah are related chiefly to Tertiary igneous activity and associated hydrothermal alteration (Butler and others, 1920; Hilpert and Roberts, 1964; Stewart and others, 1977). The bulk of these deposits occur within two west-trending zones: the Deep Creek-Tintic mineral belt, in which Tract 186 lies, and the Wah Wah-Tushar mineral belt to the south of Tract 186 (Hilpert and Roberts, 1964; Jerome and Cook, 1967). That part of western Utah separating the two mineral belts contains only scattered and small mineral deposits and very few Tertiary igneous rocks [(referred to as the "mid-Utah gap" by Jerome and Cook (1967)].

Tract 186 contains favorable carbonate host rocks for lead and zinc (Cambrian), but occurrences are not reported from the tract's few exposures of bedrock. On the basis of the nearby large occurrences at Tintic, Tract 186 may contain favorable rocks for lead and zinc at depth. On this basis, we have assigned Tract 186 a lead/zinc favorability of f4. The certainty that lead and zinc resources occur at depth in the tract is low and is assigned a value of c1.

TUNGSTEN f2/c1

Tungsten is used chiefly in metal-working and construction machinery, transportation, lamps and lighting, and electrical applications (Stafford, 1982). In 1981, imports of tungsten supplied 52 percent of our consumption (Stafford, 1982).

Economic concentrations of tungsten occur in a wide variety of geologic environments, and except for placer deposits, all are related directly to magmatism. The chief source of tungsten in the United States is from tactite--a rock formed by the intrusion of igneous rock (usually granite) into carbonate rocks. The carbonate rocks are recrystallized and, where conditions are favorable, replaced with calcium tungstate in the form of the mineral scheelite ($CaWO_4$). Garnet, epdite, hornblende, and magnetite are usually deposited with the sheelite along the contact metamorphic zone, and the resulting rock is commonly much darker than the granite or the unaltered sedimentary host rocks. (The term "tactite" is generally synonomous with the Swedish term "skarn.") Other elements such as molybdenum, iron (in the form of magnetite), copper, zinc, and fluorine may also be abundant in tungsten-bearing tactites (Hobbs and Elliot, 1973). The geometry of tactite deposits is controlled chiefly by the lithology and structural configuration of the host sedimentary rocks. Tungsten-bearing tactite deposits range in size from a few tons to many millions of tons that average about 0.5 to 1.0 percent WO_3.

Other types of tungsten deposits include tungsten-bearing quartz veins, and veinlets in pervasively fractured and brecciated country rock (stockwork). The quartz-vein deposits are estimated to contain three-fourths of the world's tungsten reserves, the bulk of which are in mainland China (Hobbs and Elliot, 1973). The largest productive vein-deposits in the United States are in Arizona, California, Colorado, Idaho, and North Carolina. Cumulative production of tungsten from vein-type deposits in the United States has been small. In addition to these, tungsten is also found in hot-spring deposits, in placers, and in desert lakes in the southwest. Except for the desert lakes, the amount of tungsten in these deposits is very small. Technology to economically extract the huge amounts of tungsten from desert lakes is not available.

In 1973 the United States was estimated to contain 6 percent of the world's total tungsten reserves of 250 million units of WO_3 (one unit equals 1 percent per ton, or 20 pounds WO_3 containing 15.9 pounds of tungsten metal; Hobbs and Elliot, 1973). The bulk of these reserves are in tactite deposits in California, Nevada, and Montana, with smaller amounts in Utah, Arizona, Washington, and Idaho.

Tungsten production, reserves, and resources in Utah are comparatively small (Everett, 1961; Lemmon, 1964). Twenty-one deposits are reported in the State by Lemmon (1964), and all except one are in the western side of the State within the Basin and Range. Lemmon (1964) reports small amounts of production from 12 of these deposits during the periods 1914 to 1918, from 1940 to 1947, and from 1951 to 1956. Most of these deposits occur along the metamorphosed contact between granite and limestone, but tungsten-bearing quartz veins are reported from the Tushar Mountains south of Tract 186 (Everitt, 1961).

At the south end of the Sheeprock Mountains in the Tintic district, the Tintic Western mine (also known as the Desert Tungsten mine) produced 7,198 tons of ore containing 6,734 nits of WO_3 (Lemmon, 1964). Scheelite was disseminated in limonite veins that were confined to a pendant of limestone in monzonite (Lemmon, 1964).

We have assigned Tract 186 a tungsten favorability of f2 because it lies within a region that is broadly favorable for tungsten. The certainty that tungsten deposits occur at depth in Tract 186 is low and has been assigned a rating of c1.

OVERALL-IMPORTANCE RATING 1

Tract 186 has been assigned an overall-importance rating (OIR) of 1 (on a 1 to 4 scale where 4 is equated with high mineral importance). Despite the tract's estimated favorability for lead and zinc and other materials evaluated for this tract, very little bedrock is exposed. The costs associated with deep exploration in this area seem to us to outweigh the tract's importance as a potential target area for industry exploration in the future. In addition, Tract 186 is very small.

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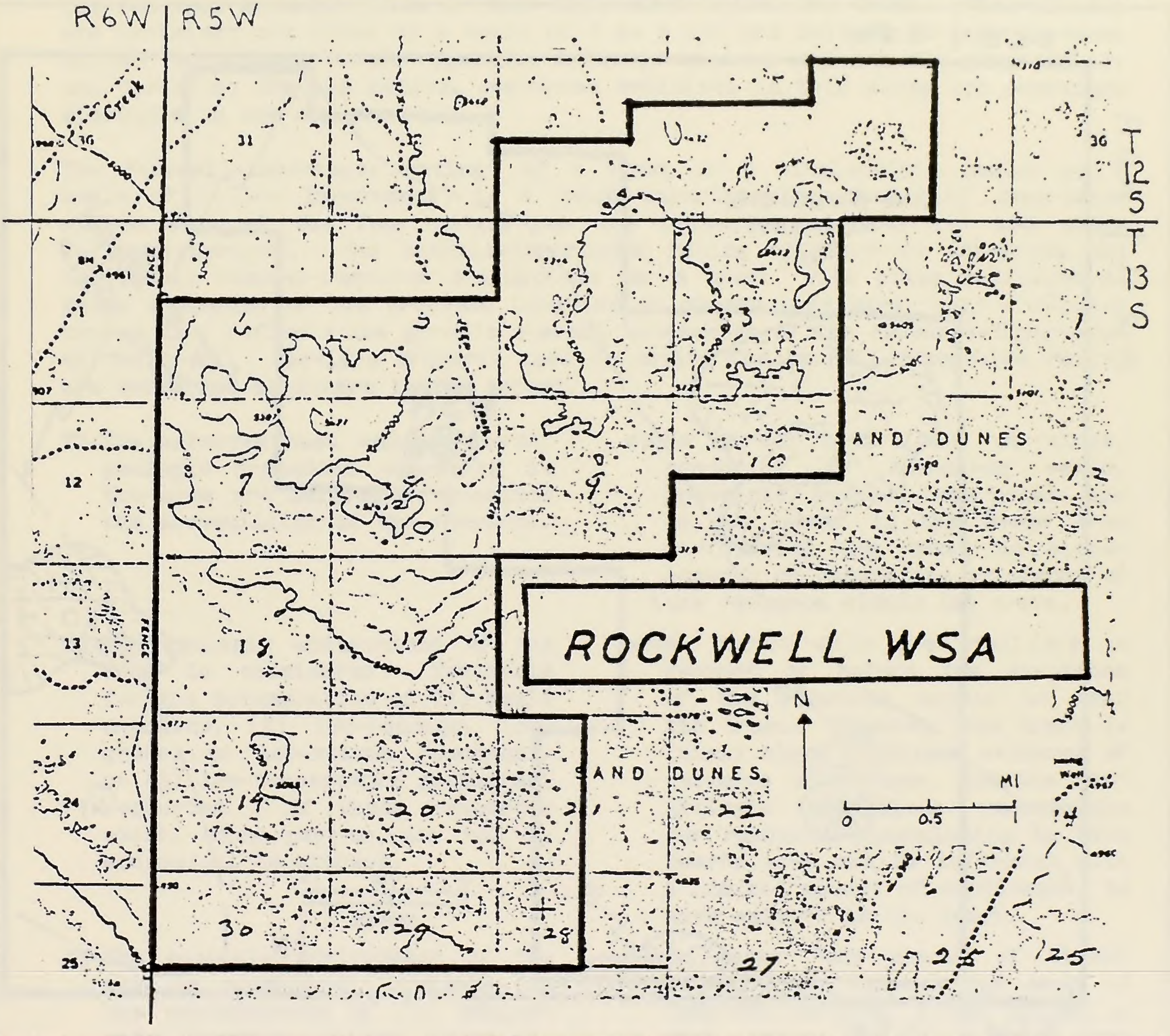
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 186, UTAH

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



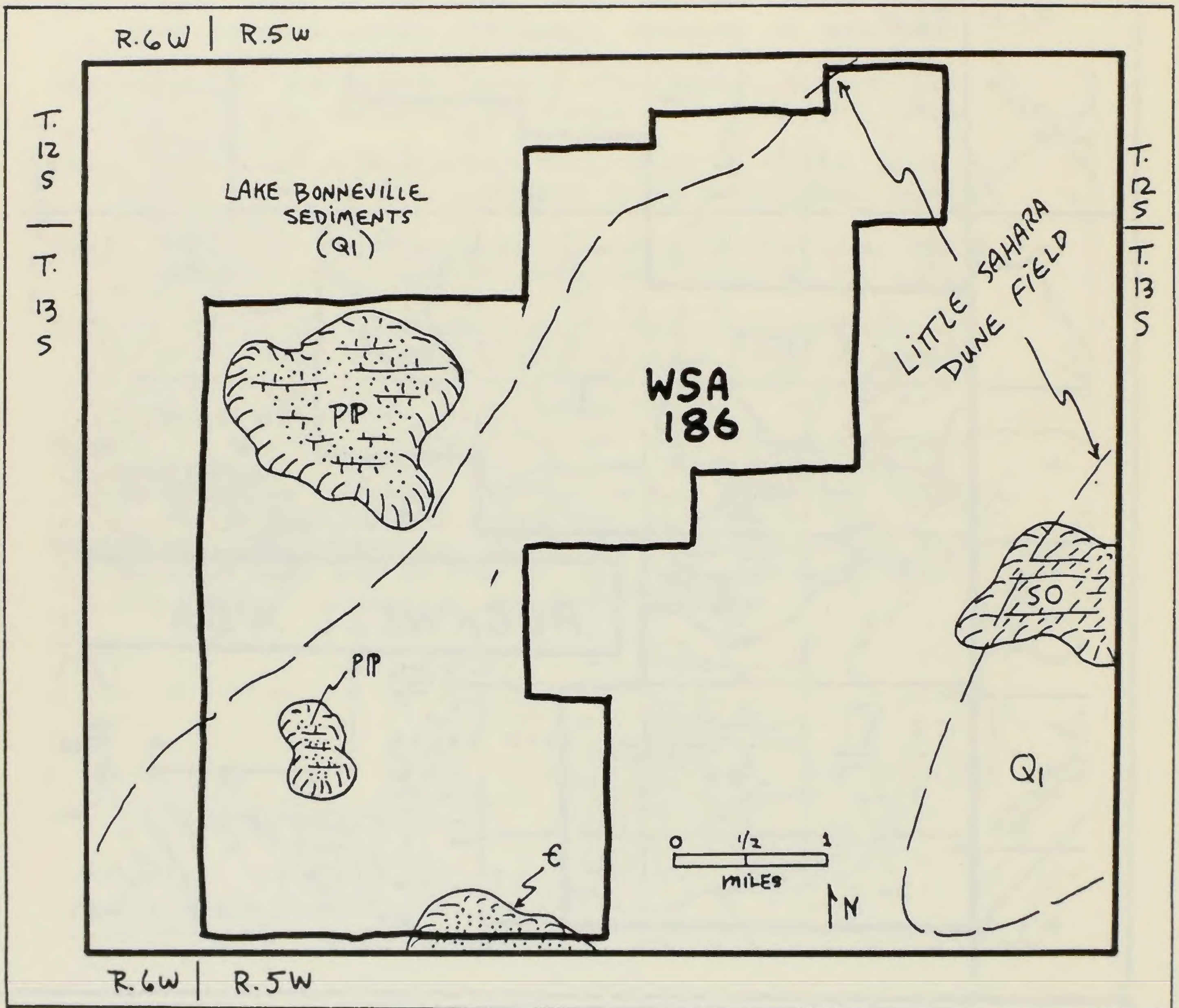
EXPLANATION

LEAD AND ZINC WERE ASSIGNED FAVORABILITIES OF F4 ON THE BASIS OF DEEP POTENTIAL (SEE TEXT).

SOURCE: BASE MAP FROM BLM, RICHFIELD, UTAH

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 186, 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

Q1 - SEDIMENTS OF LAKE BONNEVILLE

PIP - PENNSYLVANIAN AND PERMIAN ROCKS

€ - CAMBRIAN ROCKS

SOURCE: MODIFIED 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.

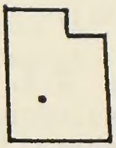
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a c4 certainty is used with an f1 favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 221 **NAME:** Fremont Gorge **STATE/COUNTY:** UT/Wayne

BLM DISTRICT: Richfield **WSA ACREAGE:** 2,540

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

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

Tract 221 lies near the structural crest of the Waterpocket fold--a large northwest-trending upwarp that forms the western border of the Henry Mountains Basin. The Marysvale volcanic field lies 10 miles to the west. Rocks at the surface of the tract consist exclusively of the Moenkopi Formation of Triassic age (Williams and Hackman, 1971). Small folds and numerous high-angle faults occur throughout the area.

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/c1	**GEOTHERMAL:**	f1/c~~3~~2
URANIUM:	f1/c1	**HYDROPOWER:**	f1/c4
COAL:	f1/c4	**COPPER:**	f1/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 221 lies along the crest of the Waterpocket fold, which is a structural extension of the Circle Cliffs uplift farther to the south. The closest gas production is from the Last Chance field about 25 miles to the northeast. The closest oil production is from the Upper Valley field 40 miles to the south (Brown and Ritzma, 1982).

The U.S. Geological Survey estimates that southeastern Utah (including the area of Tract 221) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, southeastern 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 that are related to the development in Pennsylvanian time of the Paradox Basin to the east of Tract 221 (Schneider and others, 1971).

Exploration in southern Utah for oil and gas has been centered chiefly in the Paradox Basin to the east--especially after the discovery of the Aneth and Lisbon fields in the late-1950s and early-1960s. In 1964, the Upper Valley field was discovered 40 miles south of Tract 221 along Upper Valley anticline. This discovery renewed interest in similar anticlinal structures in south-central Utah, but commercial depostis have not been found. Nevertheless, numerous oil shows (and oil-impregnated rocks) are reported from upper Paleozoic and lower Mesozoic rocks in this area (Veal, 1976; Heylmun and others, 1965; Campbell and Ritzma, 1979).;

The geology of Tract 221 is not overly favorable for oil and gas because Permian and younger strata are exposed along the Waterpocket fold a short distance southeast of the tract (Williams and Hackman, 1971). Where sufficiently buried, the Permian rocks probably have the greatest petroleum potential in this part of Utah (Welsh, 1976; Kiser, 1976; Schneider and others, 1971). Mississippian and Pennsylvanian rocks (represented by about 1,000 feet of the Redwall Limestone and almost 1,500 feet of the Hermosa Group) are also favorable in this general area (Gustafson, 1980), but wells drilled along the crest of the Waterpocket fold in the vicinity of Tract 221 have not been successful (Heylmun and others, 1965; PIC, 1980; see attached Geologic Sketch Map). Some of these wells penetrated the Cambrian section; the well drilled 6 miles southeast of the tract by Pure Oil in 1960 had oil shows in the Kaibab Formation at depths between 1,500 and 2,000 feet. Despite these less than encouraging results, numerous folds in this area and many have not been adequately tested (Thousand Lake anticline north of Tract 221 and Teasdale anticline to the south).

The discouraging results of exploration in this area suggest that the middle Paleozoic section is not overly petroliferous. It seems reasonable to believe, however, that the combination of favorable structures (folds) and a 2,000-foot thickness of middle Paleozoic rocks age should contain at least some small oil and gas accumulations (a small field in our classification contains less than 10 million barrels of recoverable oil or, if gas, less than 60 billion cubic feet). Tract 221 has therefore been assigned a favorability of f2. The certainty that oil and gas resources exist in the tract is very low and has been assigned a value of c1.

URANIUM 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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

A few uranium deposits are reported from the Chinle Formation along the upper flanks of the Waterpocket fold (Williams and Hackman, 1971; see attached Geologic Sketch Map). The Chinle Formation has been removed by erosion in Tract 221 and no other formations preserved in the tract are considered by Lupe and others (1980) to be favorable for uranium. We have therefore assigned Tract 221 a uranium favorability of f1. The certainty the uranium does not exist in this tract is low and has been assigned 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 of Tract 221 consists of sedimentary rocks of Permian age underlain by a thick section of Paleozoic rocks (Williams and Hackman, 1971). Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 221 a coal favorability of f1 (unfavorable), along with a high certainty (c4) that coal does not exist in this WSA.

GEOTHERMAL f1/c2

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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 221 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 area considering the probable great depth to the resource and the associated high drilling costs. The igneous rocks of the extensive Marysvale volcanic field to the west are close to Tract 221 and some of the rocks are as young as Quaternary. If ground water below the Waterpocket fold has and is still being heated by subsurface igneous masses, there are no manifestations of this heat source (such as hot springs) in the vicinity of Tract 221 (NOAA, 1980).

On the basis of the geologic characteristics of this part of the Colorado Plateau, we have assigned Tract 221 a geothermal favorabilty rating of f1. The certainty that geothermal resources do not exist in this area is low and has been assigned a rating of c2.

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 221. On the basis of this information we have assigned Tract 221 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.

The Chinle and other red-bed sandstones have been eroded from Tract 221. On this basis, and because pre-Triassic strata on the Colorado Plateau are not favorable for uranium, we have assigned Tract 221 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.

OVERALL-IMPORTANCE RATING 1

Tract 221 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. In addition, the tract is very small and is contiguous with Capitol Reef National Park.

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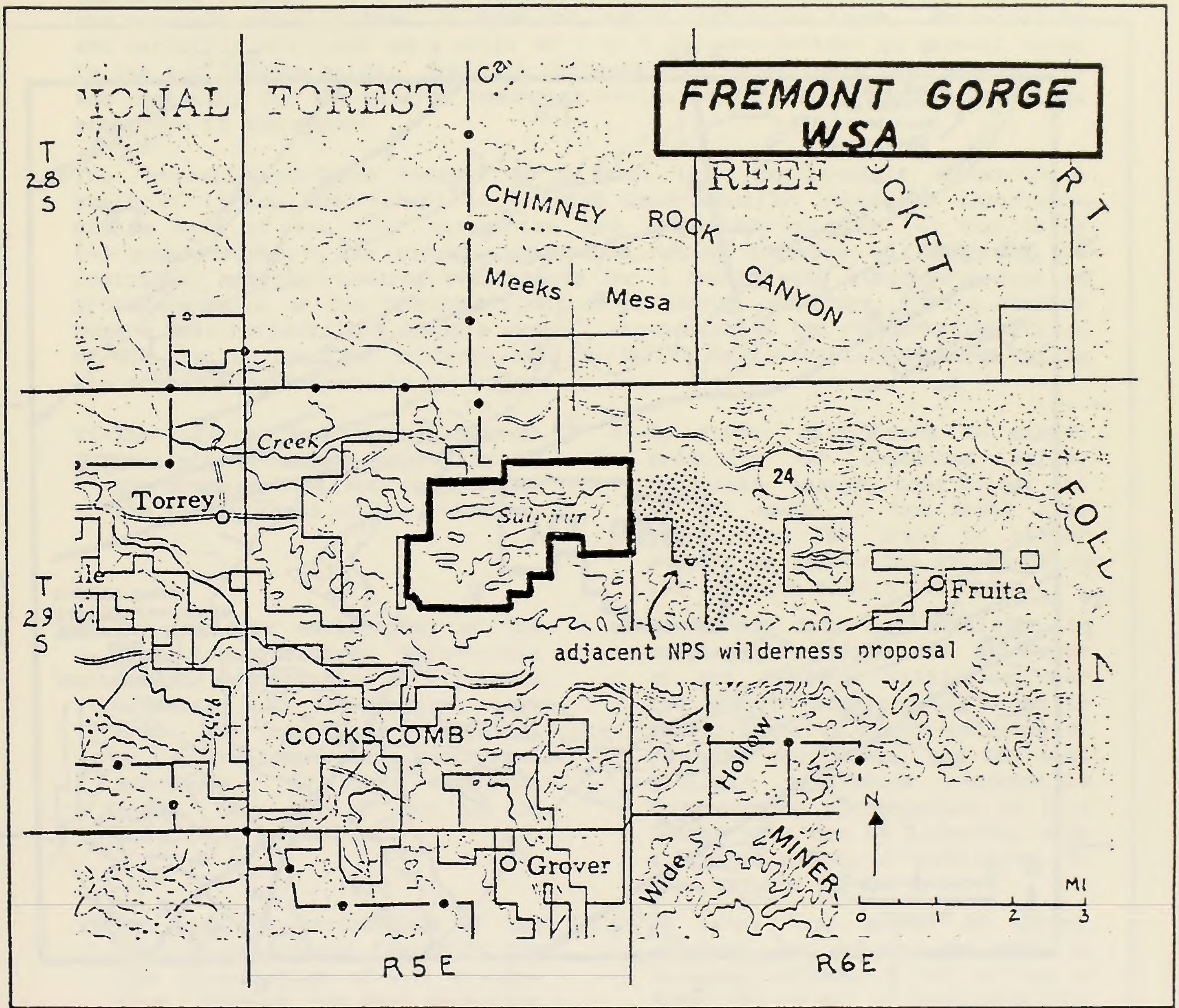
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 221, UTAH

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



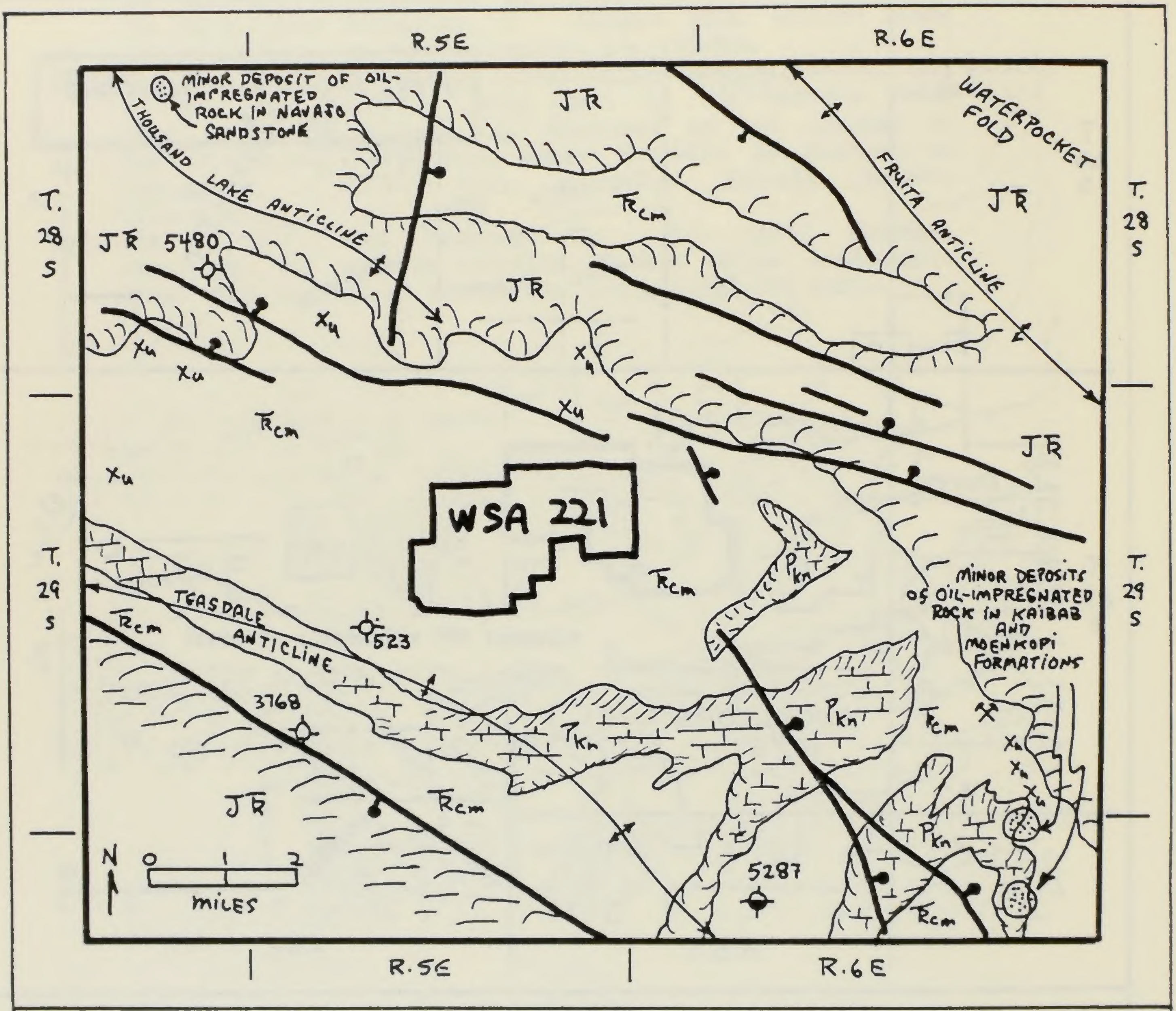
EXPLANATION

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

SOURCE: BASE MAP FROM BLM, RICHFIELD DISTRICT

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 221 , 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

JR - NAVAJO, KAYENTA, AND WINGATE (JURASSIC AND TRIASSIC)

Rcm - CHINLE AND MOENKOPI

Pkn - KAIBAB AND COCONINO

FAULT, BALL ON DOWNTHROWN SIDE

ANTICLINE

5237 OIL AND GAS EXPLORATORY WELL, SHOWING DEPTH (DRY)

SHOW OF OIL

URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION U_3O_8

Xu URANIUM PROSPECT

SOURCE: GEOLOGIC BASE FROM HINTZE (1980), MODIFIED

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: 236* **NAME:** Dirty Devil **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 86,000

DATE PREPARED: June 1982 **UPDATE:** August 1982

LOCATION

*[Tracts 236A and 236B were identified as WSAs before the current Wilderness Planning Program. The BLM has indicated that these tracks are to be evaluated as one unit, hereafter referred to as Tract 236.]

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

Tract 236 lies along the southern limb of a large structural trough that separates the San Rafael Swell to the northwest from the Monument Upwarp to the southeast. The moderately-deep Henry Mountains structural basin slopes to the southwest.

Rocks at the surface of the tract are of Permian, Triassic, and Jurassic age and belong to the following formations: the Moenkopi, Chinle, Wingate, Kayenta, Navajo, and Carmel (Williams and Hackman, 1971). The overall structure of the tract is a smooth, west-dipping homocline, disrupted slightly by a northwest-trending system of grabens that extends into the tract from the vicinity of the Needles fault zone 10 miles to the southeast.

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	**HYDROELECTRIC:**	f1/c4
OIL-IMPREGNATED ROCK:	f4/c4	**GOLD:**	f1/c3
URANIUM:	f2/c1	**SILVER:**	f1/c3
COAL:	f1/c4	**COPPER:**	f2/c1
GEOTHERMAL:	f1/c3		

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 236 lies along the northeast-flank of the Henry Mountains Basin and the west flank of the Monument Upwarp--two large structural feature on the Colorado Plateau that probably originated in late Cretaceous and early Tertiary time (Hunt, 1980; Kelley, 1955). The Monument Upwarp and the Henry Mountains Basin are not noted for petroleum production. In fact, the Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah and adjacent parts of Colorado (including the Henry Mountains Basin and the Monument Upwarp) contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin, discussed in more detail below (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Tar Sand Triangle, part of which trends through the southeast corner of the tract (see OIL-IMPREGNATED ROCKS in this report). Along the west side of the Monument Upwarp in the vicinity of Tract 236, oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heylmun and others, 1965; Weitz and Light, 1981).

The geology of Tract 236 is not very favorable for oil and gas, despite its projected position within the Paradox Basin--a large structural basin that developed in southeastern Utah in Pennsylvanian time. As indicated by Berghorn and Reid (1981), the area that now encompasses Tract 236 was probably near the west shore of the Paradox Basin (chiefly the penesaline facies). This same geologic environment is very favorable for petroleum in the Four Corners area (e.g., Aneth field). Nevertheless, 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, as pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon (10 miles southeast of the tract) and in other parts of the Monument Upwarp. Overlying, Permian, Triassic, and Jurassic strata are exposed progressively closer to the tract along the eroded northwest-flank of the Monument Upwarp (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

Exploratory drilling in the vicinity of Tract 237 has been discouraging. This fact has lead some geologists to conclude that the area is simply not petroliferous; or that most hydrocarbons have already migrated out of the surrounding basins (such as the Henry Mountains Basin) and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). For example, the "Tar Sand Triangle" on the east side of Tract 236 is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age.

Numerous exploratory wells have been drilled within and near Tract 236, and some oil shows were reported in Pennsylvanian rocks (Heylmun and others, 1965; PIC, 1981). Many of the wells penetrated Mississippian rocks at depths generally around 6,000 feet.

On the basis of the discussion above, and because of the discouraging results of nearby and relatively abundant exploratory wells, we have assigned Tract 236 an oil and gas favorability of only f2. If hydrocarbons exist in the tract, they would most likely be in small accumulations in pre-Laramide structural traps, or in stratigraphic traps in Pennsylvanian rocks. The certainty that oil and gas resources exist (or do not exist) in Tract 236 is very low and has been assigned a value of c1.

OIL-IMPREGNATED ROCKS f4/c4

As per the terms of this contract, oil-impregnated rocks are evaluated for those tracts in which these deposits are known to occur or have a high certainty of occurrence. We emphasize, however, that oil-impregnated rocks, along with other forms of solid and semi-solid hydrocarbons such as asphalt, tar, pitch, and gilsonite, are included within the definition of the term "petroleum" as used by most geologists.

Oil-impregnated rocks in Utah are estimated by Ritzma (1979) to contain 22 to 29 billion barrels of oil-in-place. Of the 50-plus identified deposits, more than 96 percent of the oil is contained in only six deposits (Campbell and Ritzma, 1979). A large part of the eastern side of Tract 236 lies within the boundary of the Tar Sands Triangle as drawn by Ritzma (1979). This deposit is the single largest group of deposits in Utah and is estimated to contain roughly 12.5 to 16 billion barrels of in-place-oil. Most of the oil occurs in the White Rim Sandstone of Permian age.

On the basis of rating criteria developed for this study (see appendix), we have assigned Tract 236 a favorability of f4 for oil-impregnated rock deposits (estimated to contain more than 500 million barrels of oil-in-place). This estimate was based on the large size of the deposits in the Tar Sands Triangle and the large area of these deposits that Tract 236 encompasses. certainty that these deposits exist in the tract is high and has been assigned a rating of c4.

URANIUM <u>f2/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 in the Colorado Plateau.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Tract 236 lies in an area containing relatively few uranium deposits (Williams and Hackman, 1971). A few uranium prospects occur near the southern and southeastern ends of the tract in the Chinle Formation (part of the Orange Cliffs area; Williams and Hackman, 1971; Utah Geological and Mineral Survey, 1977). According to Lupe and others (1980), Tract 236 is near the edge of a broadly favorable area for uranium deposits in the Chinle Formation. The Chinle in this area contains abundant sandstones that were deposited by streams flowing westward in Chinle time. Because the tract lies at the edge of the favorable area outlined by Lupe and others (1980), and because very little uranium has been discovered in this area, we have assigned the tract a favorability of only f2. The certainty that uranium occurs in the tract 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.

All bedrock of sedimentary origin in Tract 236 is of pre-Cretaceous age. Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 236 a coal favorability of f1 (unfavorable), along with a 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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau is therefore considered to be very low.

The only geothermal potential associated with Tract 236 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). 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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has lowered the depth to ground water over much of this region; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of this part of the Colorado Plateau, we have therefore assigned Tract 236 a geothermal favorability 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. 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 236. On the basis of this information we have assigned Tract 236 a hydropower favorability

rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c1

Besides the mineral fuels that have been produced from the region of the Henry Mountains/Monument Upwarp (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975).

Tract 236 has almost no potential for gold and silver, and we have therefore assigned the tract a favorability of f1 for each resource. The certainty that these commodities do not exist in the tract is relatively high and is assigned a rating of c3.

Copper, however, does have some potential within the tract because of its close association with uranium. Production of by-product copper from uranium/vanadium mining in this part of the Colorado Plateau has come chiefly from the area around Moab, Utah, the Big Indian/Lisbon Valley area, the White Canyon area, and 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 236) 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. We have therefore assigned Tract 236 a copper favorability of f2, but with a certainty of resource occurrence of only c1.

OVERALL-IMPORTANCE RATING 2+

Tract 236 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 resources, except oil-impregnated rocks, were assigned favorabilities less than f3. Although the tract was assigned an f4 for oil-impregnated rock deposits, this rating did not reflect the tract's assigned OIR of 2+ because potential development of these deposits is probably far in the future (if ever).

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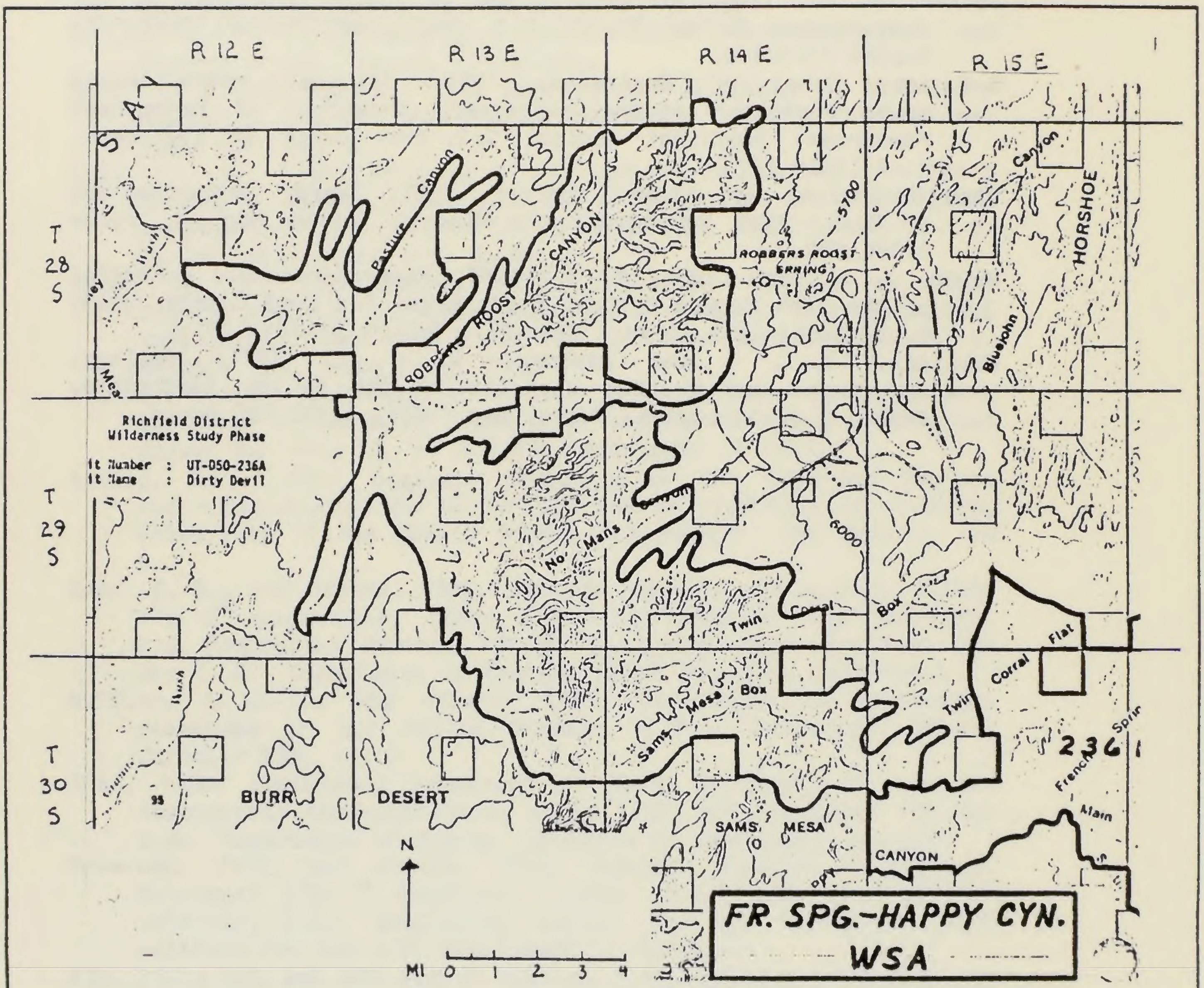
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 236A, UTAH

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



EXPLANATION

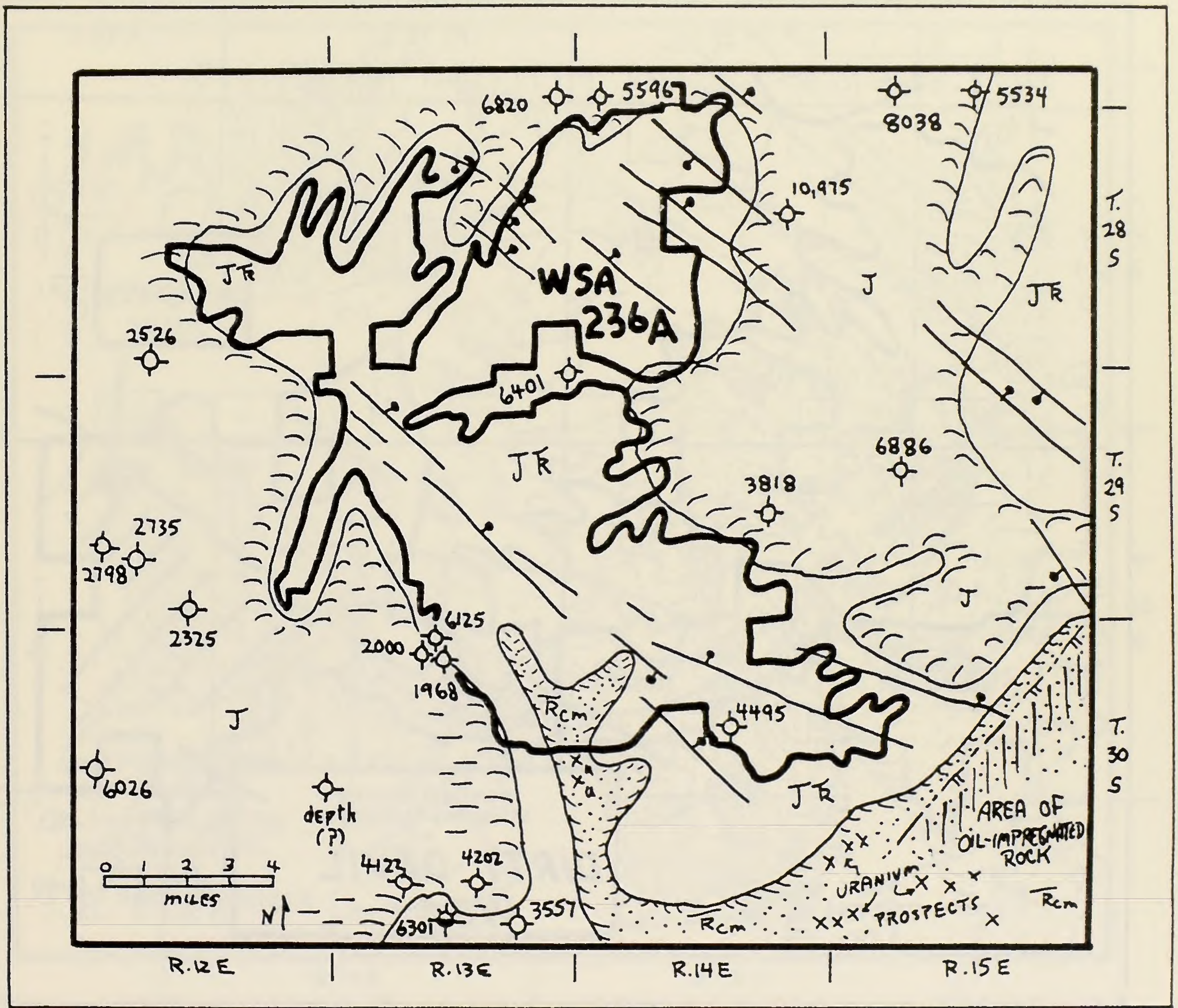
ALL RESOURCES EVALUATED FOR THIS HALF OF THE TRACT WERE ASSIGNED FAVORABILITIES OF LESS THAN f3

(SEE MAP FOR 236B)

SOURCE: BASE MAP FROM BLM, RICHFIELD

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 236A, 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

J - JURASSIC ROCKS

JR - JURASSIC / TRIASSIC ROCKS

Rcm - CHINLE AND MOENKOPI FORMATIONS

FAULT, BALL ON DOWNTHROWN SIDE

4211 OIL/GAS WELL (DRY), SHOWING TOTAL DEPTH

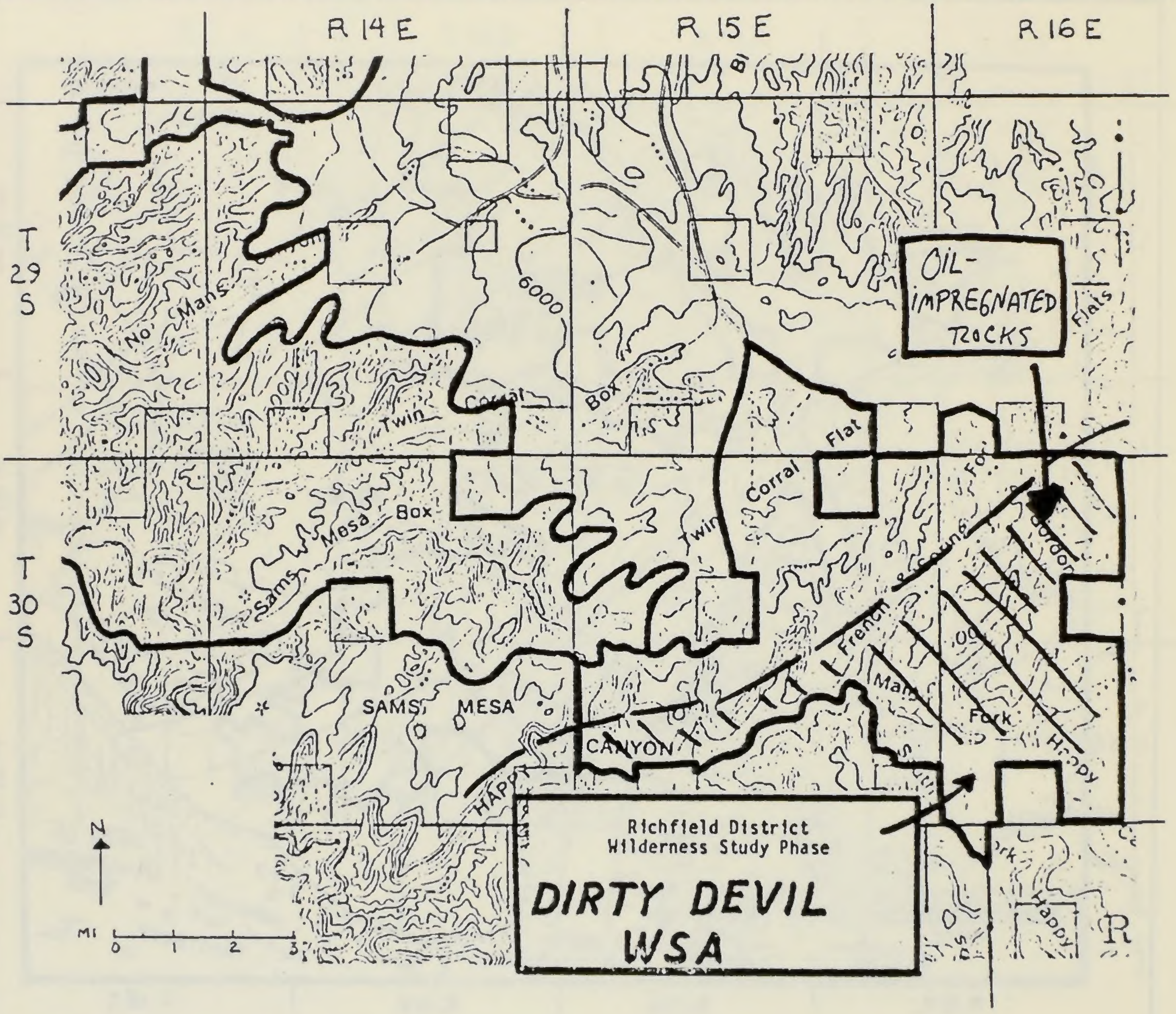
SHOW OF OIL AND GAS

Xu URANIUM PROSPECTS

SOURCE: GEOLOGIC MAP MODIFIED FROM HINTZE (1980)

MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 236B, UTAH

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



EXPLANATION

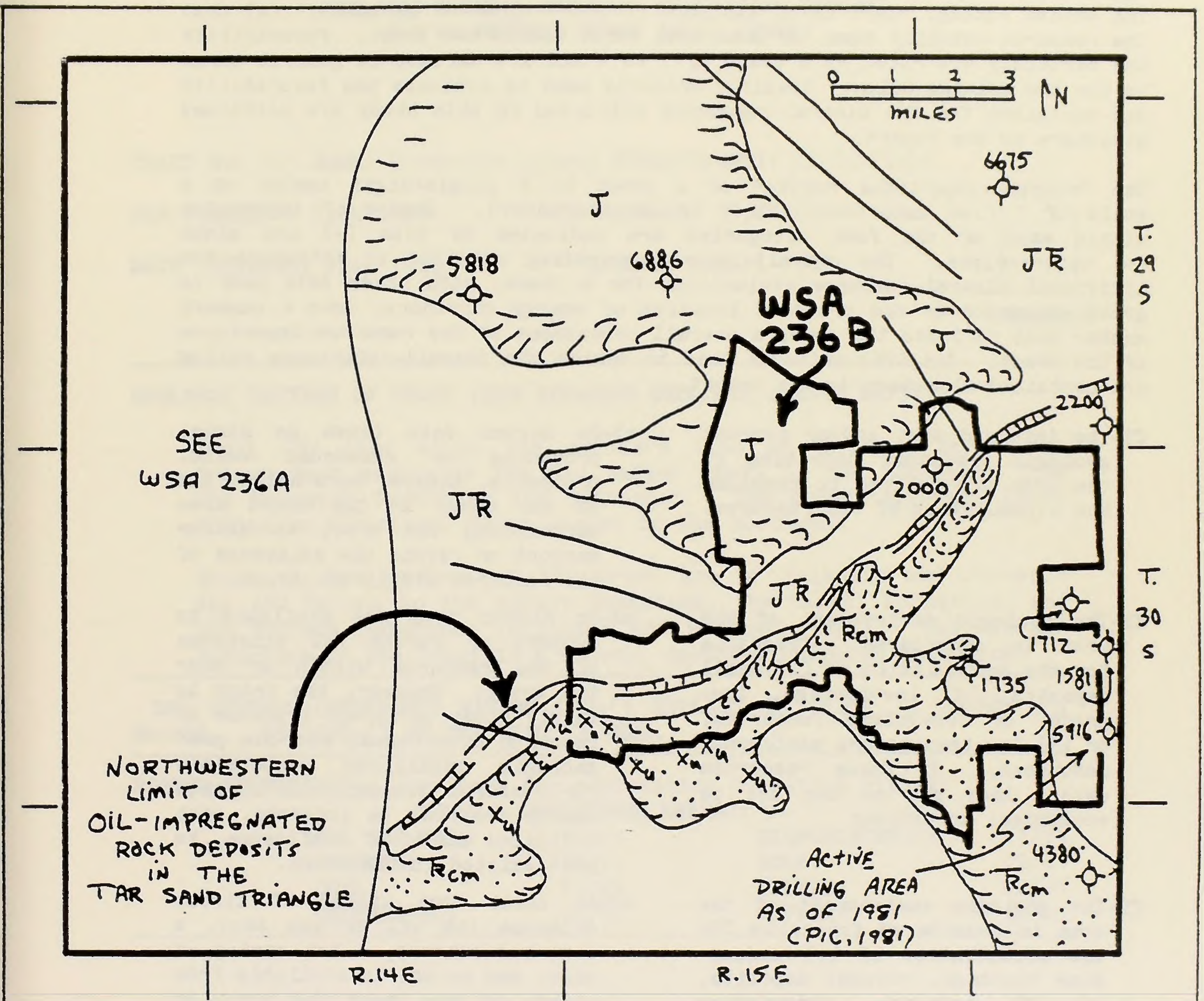
OIL-IMPREGNATED ROCKS WERE ASSIGNED A FAVORABILITY OF f4. THEIR GENERAL DISTRIBUTION IS SHOWN ABOVE.

(SEE MAP FOR 236A)

SOURCE: BASE MAP FROM BLM, RICHFIED, UTAH

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 236B, 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

J - JURASSIC ROCKS

JTR - JURASSIC/TRIASSIC ROCKS

TRcm - CHINLE AND MOENKOPI FORMATIONS (TRIASSIC)

FAULT

6811 OIL/GAS WELL (DRY), SHOWING TOTAL DEPTH

Xu URANIUM PROSPECTS

SOURCE: MODIFIED 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: 237 **NAME:** Horseshoe Canyon **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 38,800

DATE PREPARED: June 1982 **UPDATE:** August 1982

LOCATION

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

Tract 237 lies along the southern limb of a large structural trough that separates the San Rafael Swell to the northwest from the Monument Upwarp to the southeast. The moderately-deep Henry Mountains structural basin slopes to the southwest.

Rocks at the surface of the tract are of Triassic and Jurassic age and belong to the Navajo Sandstone, the Carmel Formation, and the Entrada Sandstone (Williams and Hackman, 1971). The overall structure of the tract is a smooth, northwest-dipping homocline.

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	**HYDROELECTRIC:**	f1/c4
URANIUM:	f3/c1	**GOLD:**	f2/c1
COAL:	f1/c4	**SILVER:**	f2/c1
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 237 lies along the structural saddle that separates the Monument Upwarp to the southeast from the San Rafael Swell to the northwest. Neither area is noted for the production of petroleum.

The U.S. Geological Survey estimates that 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 (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin, discussed in more detail below (Schneider and others, 1971).

Oil shows in exploratory wells in this region are reported from rocks of Mississippian, Pennsylvanian, Permian, and Triassic age the Redwall Limestone, the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Hansen and Scoville, 1955; Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980; Weitz and Light, 1981)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Tar Sand Triangle a few miles south of Tract 237 (Ritzma, 1979).

The geology of Tract 237 is not very favorable for oil and gas, despite its projected position within the Paradox Basin--a large structural basin that developed in southeastern Utah in Pennsylvanian time. As indicated by Berghorn and Reid (1981), the area that now encompasses Tract 237 was probably near the west shore of the Paradox Basin. This same geologic environment was very favorable for petroleum in the Four Corners area (e.g., Aneth field; especially the penesaline and marine shelf facies of the Paradox Formation). Nevertheless, 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, as pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon (about 25 miles southeast of the tract) and in other parts of the Monument Upwarp. Overlying, Permian, Triassic, Jurassic and Cretaceous strata are exposed progressively closer to the tract along the eroded northwest-flank of the Monument Upwarp (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in over a large part of this region may have little or no reservoir pressure.

Exploratory drilling in the vicinity of Tract 237 has been discouraging. About a half-dozen relatively deep (5,000 to 8,000 feet) dry wells have been drilled in the vicinity of Tract 237 (two were drilled in the tract; Heylmun and others, 1965; PIC, 1981). This fact has lead some geologists to conclude that the area is simply not petroliferous; or that most hydrocarbons have already migrated out of the surrounding basins (such as the Henry Mountains Basin) and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). For example, the "Tar Sand Triangle" a few miles southeast of Tract 237 is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age.

On the basis of the discussion above, we have assigned Tract 237 an oil and gas favorability of only f2. If hydrocarbons exist in the tract, they would most likely be in small accumulations in structural traps, or in stratigraphic traps in Pennsylvanian rocks. The certainty that oil and gas resources exist (or do not exist) in Tract 237 is very low and has been assigned a value of c1.

URANIUM f3/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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Tract 237 lies in an area containing relatively few uranium deposits (Williams and Hackman, 1971). According to Lupe and others (1980), Tract 237 is within a broadly favorable area for uranium deposits in the Chinle Formation. The Chinle in this area contains abundant sandstones that were deposited by streams flowing westward in Chinle time. On this basis, and because the favorable parts of the Chinle in this area are believed to be aligned along a mineral trend extending southeastward from the favorable parts of the San Rafael Swell (Lupe and others, 1980), we have assigned the tract a favorability of f3. The certainty that uranium occurs in the tract 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.

All bedrock of sedimentary origin in Tract 237 is of pre-Cretaceous age. Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 237 a coal favorability of f1 (unfavorable), along with a 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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau is therefore considered to be very low.

The only geothermal potential associated with Tract 237 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). 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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has lowered the depth to ground water over much of this region; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of this part of the Colorado Plateau, we have therefore assigned Tract 237 a geothermal favorability 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. 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 237. On the basis of this information we have assigned Tract 237 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c1

Besides the mineral fuels that have been produced from the region of the Henry Mountains/Monument Upwarp (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975).

Tract 237 has almost no potential for gold and silver, and we have therefore assigned the tract a favorability of f1 for each resource. The certainty that these commodities do not exist in the tract is relatively high and is assigned a rating of c3.

Copper, however, does have some potential within the tract because of its close association with uranium. Production of by-product copper from uranium/vanadium mining in this part of the Colorado Plateau has come chiefly from the area around Moab, Utah, the Big Indian/Lisbon Valley area, the White Canyon area, and 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 237) 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. We have therefore assigned Tract 237 a copper favorability of f2, but with a certainty of resource occurrence of only c1.

OVERALL-IMPORTANCE RATING 2±

Tract 237 has been assigned an overall importance rating (OIR) of 2+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Uranium was assigned a favorability rating of f3, but the depth to the favorable Chinle Formation is about 1,000 feet throughout much of the tract--a depth we thought to be excessive considering that the anticipated deposits are only between a 100 and a 1,000 tons of uranium oxide.

All other resources evaluated for Tract 237 were assigned favorabilities of f2 or less, and they did not contribute substantially to the assigned OIR.

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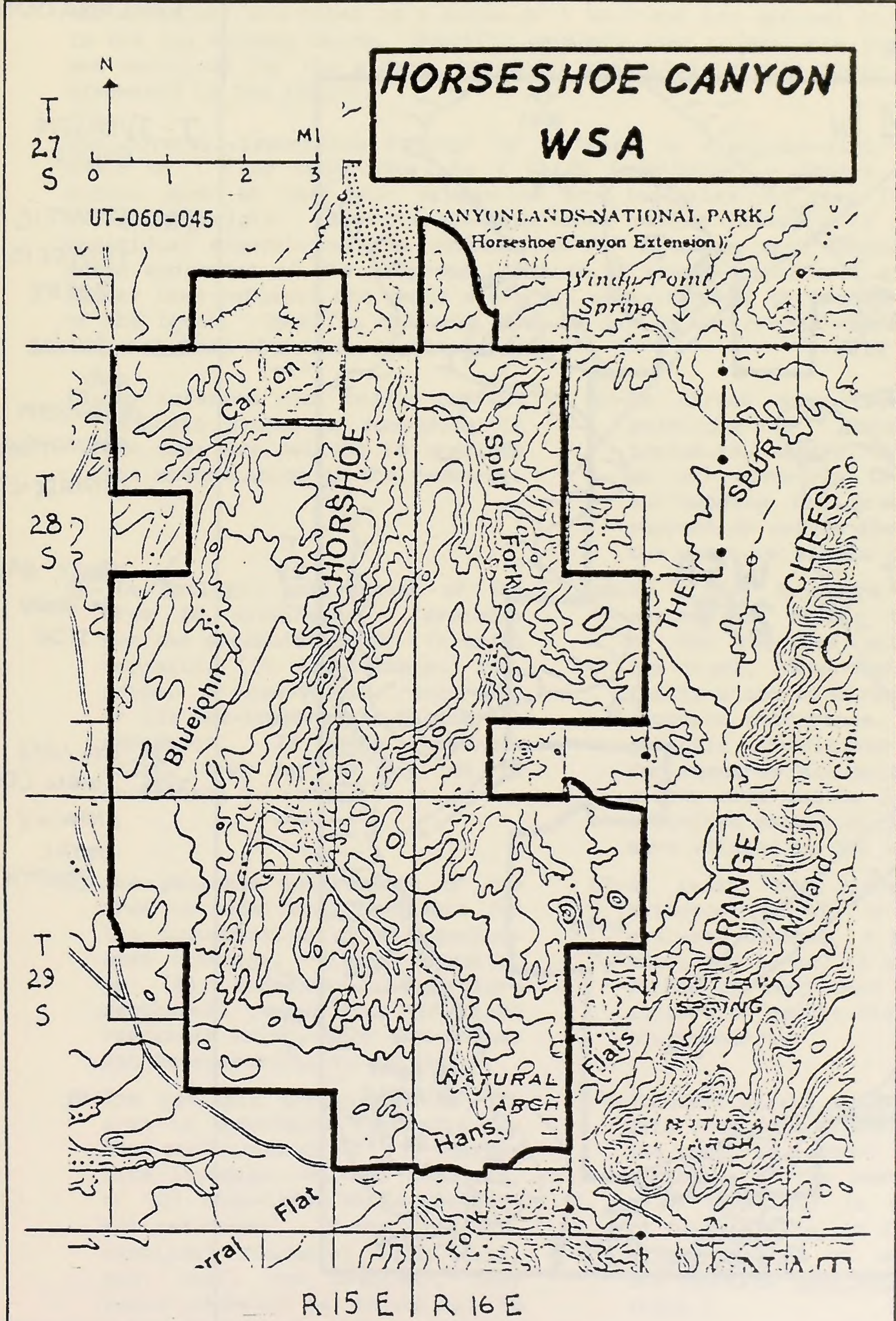
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 237 , UTAH

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



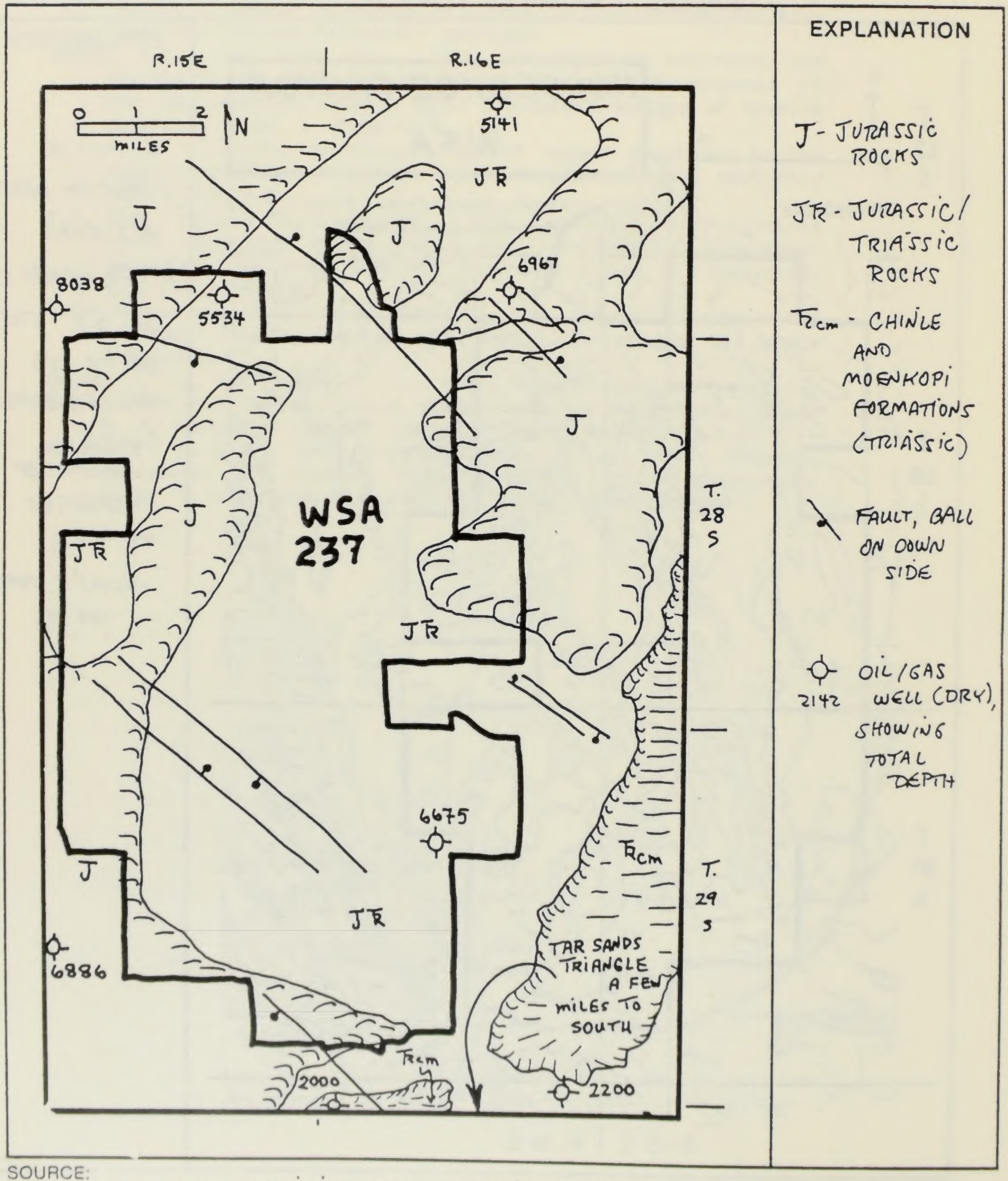
EXPLANATION

URANIUM WAS ASSIGNED A FAVORABILITY OF f3. THE DEPTH TO THE FAVORABLE CHINLE FORMATION INCREASES TO THE NORTH AND WEST.

SOURCE: BASE FROM BLM, RICHFIELD, UTAH

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 237, 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: BASE MAP MODIFIED 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.

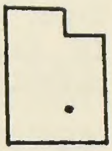
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 238 **NAME:** Mt. Ellen **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 58,480

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

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

Tract 238 lies in the Henry Mountains Basin--a large structural depression 100 miles long and 50 miles wide that probably developed in late Cretaceous to Eocene time (about 50 to 70 million years ago). During middle Tertiary time (about 45 million years years ago), large masses of igneous rock were injected into the overlying sedimentary strata along a north-trending belt on the east side of the basin. Subsequent erosion has since exposed many of these igneous masses, along with the sedimentary strata that were tilted sharply during intrusion. The five largest masses of exposed igneous rock now stand thousands of feet above the surrounding plateaus and are collectively referred to as the Henry Mountains. The southern part of Tract 238 encompasses part of one of these masses, called Mt. Ellen.

Rocks at the surface in Tract 238 consist of diorite porphyry at the south end and Cretaceous rocks throughout the remainder of the tract (Williams and Hackman, 1971). The axis of the Henry Mountains Basin trends northerly through the west side of the tract. At the south end, the tract is characterized by domes resulting from laccolithic intrusions that radiate outward from the Mt. Ellen stock.

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	**HYDROELECTRIC:**	f1/c4
URANIUM:	f1/c1	**GOLD:**	f2/c3
COAL:	f4/c4	**SILVER:**	f2/c3
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 238 lies along the east-flank of the Henry Mountains Basin--a moderately-large and moderately-deep structural depression that presumably developed in Cretaceous time (Hunt, 1980). The axis of the basin trends northerly, similar to most other large structural features on the Colorado Plateau, and lies about 10 miles west of Tract 238. The Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah (including the Henry Mountains Basin) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin east of the Henry Mountains (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Circle Cliffs area 20 miles to the southwest and in the Tar Sand Triangle 20 miles to the northeast (oil-impregnated sandstones; Campbell and Ritzma, 1979).

The geology of Tract 238 is not overly favorable for oil and gas. As pointed out by Irwin and others (1980), Pennsylvanian rocks are exposed in Cataract Canyon 40 miles to the east and in other parts of the Monument Upwarp. Furthermore, Permian, Triassic, Jurassic, and Cretaceous strata are exposed progressively closer to the tract along the eroded east-flank of the Henry Mountains Basin (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

In addition to the problems outlined above, the southern part of Tract 238 was intruded by a large mass of igneous rock in middle Tertiary time (a stock and subsidiary laccoliths; see Hunt and others, 1953). The sedimentary rocks into which this igneous mass was intruded now dip steeply away (northward) from the crest of Mt.

Ellen, suggesting forceful igneous intrusion (Hunt and others, 1953). The temperature of the intrusion near its contact with the surrounding country rock is estimated by Hunt (1980) to have been about 550°C. At a minimum, the intrusive rock pierced strata as young as Cretaceous age; thus, hydrocarbons and reservoirs that may have existed in older favorable sedimentary rocks near the intrusion were almost certainly destroyed by the heat. The volume of rock that may have been adversely affected by these intrusions is difficult to judge, but the central and northern parts of the tract probably affected only slightly.

Exploratory drilling in the Henry Mountains Basin has been very discouraging. This fact has lead some geologists to conclude that the basin is simply not petroliferous or that hydrocarbons have migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). For example, the "Tar Sand Triangle" on the east side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. It is not known with certainty if the oil now contained in these oil-impregnated rock deposits originated in the Henry Mountains Basin as outlined above, but we point out that Ritzma (1980) believes that the Circle Cliffs deposit formed essentially in place.

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (PIC, 1981). Of the half-dozen or so wells that have been drilled in the immediate vicinity of Tract 238, all reportedly were dry (Heylmun and others, 1965; PIC, 1981; see attached Geologic Sketch Map).

On the basis of the relatively unfavorable igneous history of the southern part of Tract 238, along with the discouraging results of nearby exploration, and the possibility that large volumes of oil have already migrated out of the basin, we have assigned the tract an oil and gas favorability of f2. If hydrocarbons exist in Tract 247, they would most likely be in small accumulations in pre-Laramide structural traps, and in stratigraphic traps in the northern half of the tract. The certainty that oil and gas resources exist (or do not exist) in Tract 238 is very low and has been assigned a value of c1.

URANIUM 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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Uranium deposits in the Henry Mountains Basin occur in the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). Most of the known deposits lie a few miles east of the Henry Mountains (and Tract 238) in a north-trending zone known as the Henry Mountains mineral belt. This mineral belt has accounted for 98 percent of the uranium produced in the Henry Mountains region (Chenoweth, 1980). Deposits that have been mined to date are small; according to Grundy [as reported in Cenoweth (1980, p. 299)], 80 tons of ore is the mean deposit size.

In the late-1970s, the discovery of three large uranium deposits in the southern part of the Henry Mountains mineral belt was announced by Plateau Resources (Chenoweth, 1980). Cumulative reserves for the three deposits is estimated to be about 2,900 tons of U_3O_8 at an ore grade ranging from 0.04 to 0.50 percent U_3O_8 (Peterson and others, 1980). These discoveries generated a surge of uranium exploration in the Henry Mountains area during the late-1970s that resulted in additional discoveries in the central and northern parts of the mineral belt.

The uranium resource potential of the Henry Mountains Basin is estimated to be relatively large [18,850 tons U_3O_8 of "probable" and "possible" resources according to DOE (1979)]. Most resource potential is assigned to the Salt Wash Member of the Morrison Formation within the Henry Mountains mineral belt east of Tract 238 (Peterson and others, 1980; Lupe and others, 1980).

In their evaluation of the uranium potential of the Salina 2-degree quadrangle, Lupe and others (1980) considered the area encompassed by Tract 238 to be unfavorable for uranium (this includes the igneous rocks comprising Mt. Ellen which the authors state are not a good source of uranium because of their relatively basic composition). Moreover, the Morrison Formation probably lies at depths exceeding 1,000 feet throughout most of the tract. We have therefore assigned the Tract 238 a uranium favorability of f1. The certainty the uranium does not exist in this tract is low and has been assigned rating of c1.

COAL f4/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.

The bulk of the coal in the Henry Mountains Basin lies west of the Henry Mountains. The most important coal beds are in the Mancos Shale (the Emery and Ferron Sandstone Members). Minor coal-bearing carbonaceous beds occur in the older Dakota Sandstone. All the coal is of Cretaceous age and it is best developed along the axis of the Henry Mountains Basin a short distance south of Tract 238 (Law, 1980).

Doelling and Graham (1972) estimate that only about 9,000 tons of coal have been produced from the Henry Mountains coal field. The coal was mined during the first half of the century, chiefly for local use; no mines are currently active (Law, 1979).

Tract 238 lies in the northern part of the Henry Mountains coal field (Utah Geological and Mineral Survey, 1977). The coal-bearing Emery Sandstone Member of the Mancos Shale has been eroded from the tract, and the non coal-bearing Blue Gate Shale Member is exposed throughout much of the northern two-thirds of the tract (Williams and Hackman, 1971). The up-turned edge of the underlying Ferron Sandstone Member crops out east of the tract and trends across the tract's mid-section a few miles north of Mt. Ellen (see attached Geologic Sketch Map). Coal beds in the Ferron Sandstone near the northern end of the tract are reported by Doelling and Graham (1972) to be thin and range up to only 3 feet thick. The thickest coal beds along this outcrop belt occur south of the tract near the Wayne-Garfield county line.

Except for the area near Mt. Ellen, Tract 238 is underlain completely by the coal-bearing Ferron Sandstone. Along the west side of the tract, the Ferron probably lies more than 1,500 feet below the surface. Overburden decreases to the east. On the basis of the relatively thick and continuous coal beds in the Ferron Sandstone throughout this area, we have assigned Tract 242 a coal favorability of f4. The certainty that coal occurs in Tract 238 is high and has been assigned a rating of c4.

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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 238 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant, they are much too old to be considered a present-day heat source. [Radiometric dates reported by Armstrong (1969) indicate an age of 44 to 48 million years old (Eocene) for the igneous rock in the Henry Mountains. Hunt (1980) considers this age to be excessive, and prefers an age of 20 to 25 million years on the basis of regional geologic relationships.] A few scattered warm springs at temperatures generally less than 30°C occur in region and 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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision has lowered the depth to ground water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau.

On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 238 a geothermal favorability 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. 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 238. On the basis of this information we have assigned Tract 238 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c4

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975). Hunt and others (1953) characterize the mineralized environments in the Henry's as follows: deposits within fissures in the intrusive rocks (the stocks), and within fissures in the overlying shattered sedimentary rocks; disseminated deposits in surrounding laccoliths; and placer deposits in the alluvial debris that surround the peaks. According to Doelling (1980), about 75 percent of the total value of production was derived from fissure deposits in Bromide Basin on Mt. Ellen--about 700 ounces of gold, 3,000 ounces of silver, and about 9 tons of copper. Bromide Basin is less than one-quarter mile south of Tract 238.

The history of mineral exploration and production in the Henry Mountains is colorful and worthy of a brief summary in this report. The account that follows is quoted directly from Doelling (1980, p. 290-291):

> "After gold was discovered in the placers along the Colorado River near Hite in 1883, prospectors eyed the Henry Mountains as the possible mother lode. This possibility was enhanced when the precious metal was found in the streams leading from them. After much painstaking prospecting, gold-bearing fissures were discovered in Bromide Basin in 1889 on the east side of Mt. Ellen above the 10,000-foot level. [Bromide Basin is located about 4 miles north of Tract 238.] Expectations ran high and a small town, known as Eagle City, was built 2 mi below the basin, complete with shops, saloon, and sheriff. The Bromide mine...came into production in 1891..." and "...$15,000 worth of ore was produced between 1891 and 1893....Soon thereafter the bubble burst, a rich chute of ore along the fissure was mined out, and no new economical ore had been blocked out. The mine was closed and Eagle City quickly became a ghost town."

Intermittent mining continued in the Bromide Basin area through about 1939. In 1913, the Bromide fissure was explored to depths of perhaps a few hundred feet below the previous workings, but economic deposits were not discovered (Butler, 1920). According to Doelling (1980), prospecting and assessment work have continued to the present, but that the small near-surface deposits along fissures in Bromide Basin are mined out.

In addition to the deposits described above, gold-bearing placers occur in the gravels along some creeks that drain the Henry Mountains. Production, however, is reported only from the northeast side of Mt. Ellen intermittently from the late-1800s to the 1940s (Doelling, 1980). No more than about 350 ounces of gold were recovered during this period, but with the recent increase in the price of gold, interest in placer gold in the Henry Mountains has also increased. Doelling (1980) states, however, that the gold particles in these placer deposits are very small (flour gold) and often float away during sluicing or panning. Furthermore, large quantities of water to work the gravel are not readily available.

In summary, the mineral potential of the Henry Mountains for gold, silver, and copper is apparently low. Although mineral exploration for these commodities will probably continue in the area, and small mining operations may begin as metal prices increase, the overall resource potential of the Henry Mountains for gold, silver, and/or copper is judged to be low. Tract 238 is therefore assigned a favorability of f2 for this group of minerals, but with a relatively high certainty (c3) that they exist in this area.

OVERALL-IMPORTANCE RATING 2+

Tract 238 has been assigned an overall importance rating (OIR) of 2+ (on a 1 to 4 scale where 4 is equated with high mineral importance). Although coal was assigned a favorability of f4 and a certainty of occurrence of c4, the depth to this coal through most of Tract 238 is considered to be excessive considering (1) the coal is fairly thin along the eastern side of the tract where the overburden is least, and (2) competition from nearby coal fields where there is thicker and more abundant coal.

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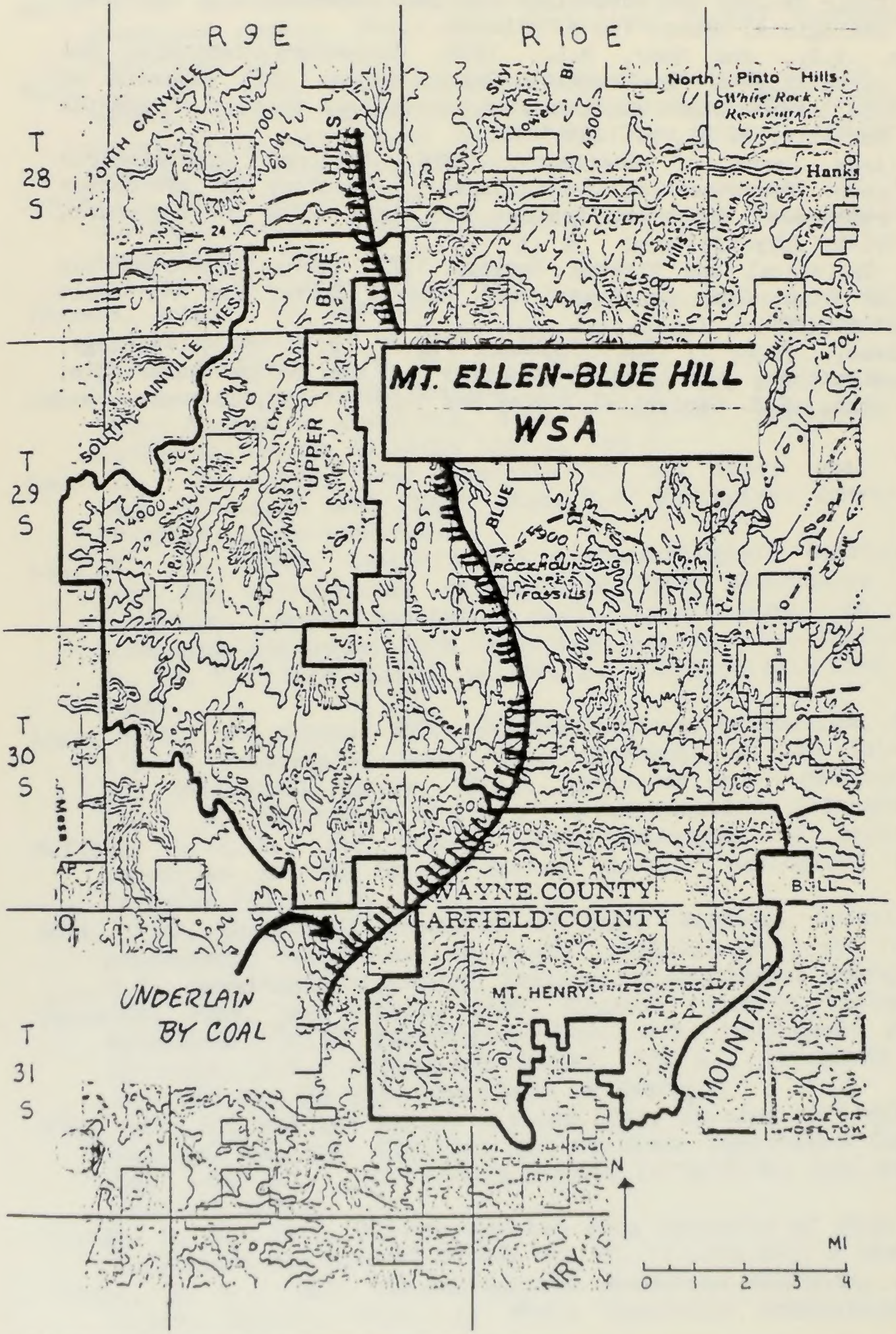
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 238 , UTAH

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



EXPLANATION

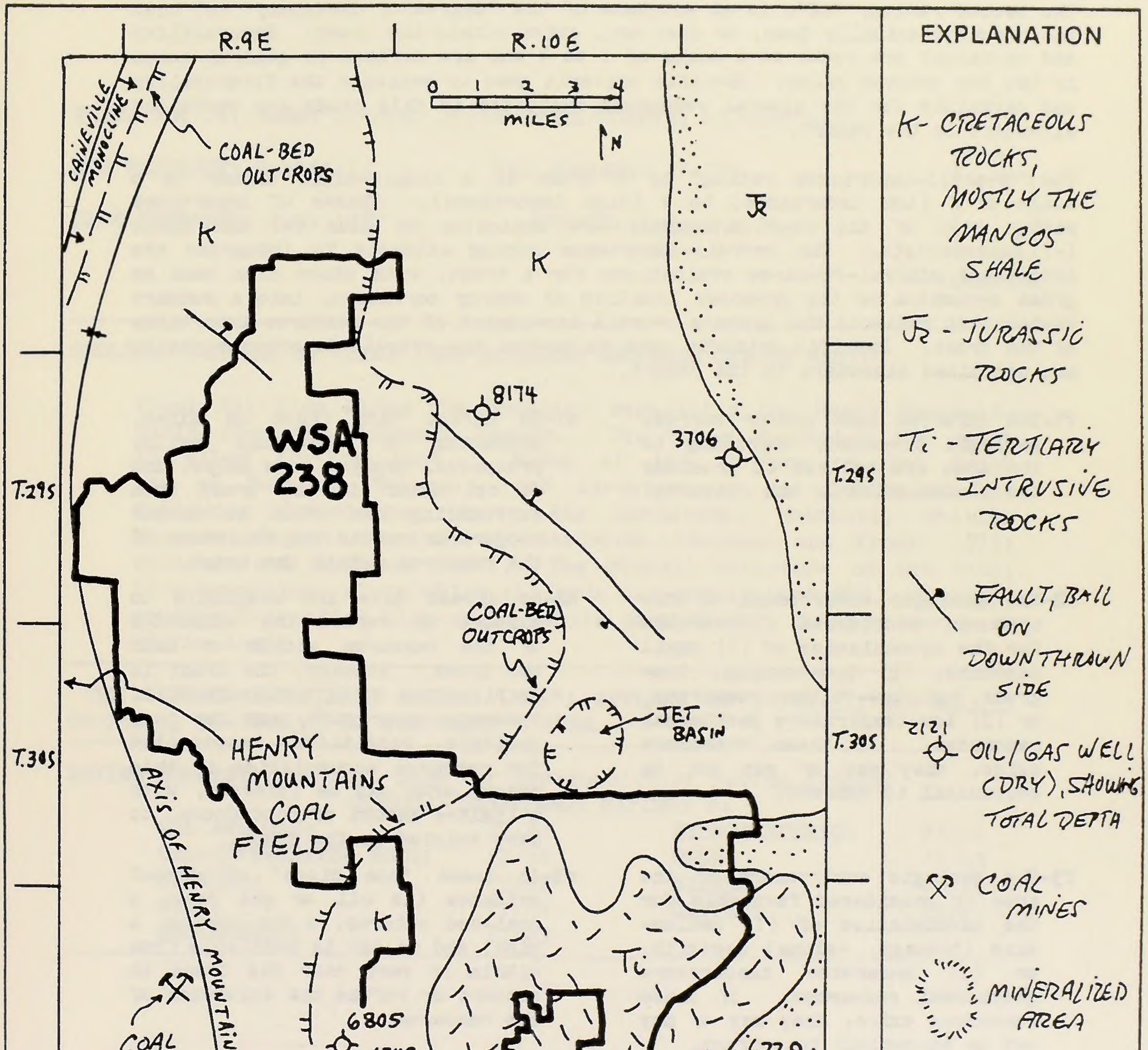
COAL WAS ASSIGNED A FAVORABILITY OF f4.

ALL OTHER RESOURCES EVALUATED FOR THIS TRACT WERE ASSIGNED A FAVORABILITY OF LESS THAN f3

SOURCE: BLM, RICHFIELD, UTAH

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 238, 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: BASE MAP MODIFIED 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.

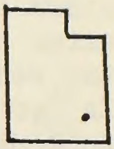
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a c4 certainty is used with an f1 favorability, it indicates with a high degree of certainty that the resource <u>does not</u> exist in the tract.)

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

TRACT NO: 241 **NAME:** Fiddler Butte **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 27,000

DATE PREPARED: June 1982 **UPDATE:** August 1982



LOCATION

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

Tract 241 lies along the boundary separating the Henry Mountains Basin from the Monument Upwarp. The Henry Mountains lie about 10 miles to the west. Rocks at the surface of the tract are of Permian, Triassic, and Jurassic age and belong to the following formations: White Rim Sandstone, Moenkopi, Chinle, Wingate, Kayenta, and Navajo Sandstone (Hackman and Wyant, 1972; Williams and Hackman, 1971). The overall structure of the tract is a homocline, along which all beds dip gently westward. Numerous northwest-trending high-angle faults pass through the southern part of the tract.

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	**HYDROELECTRIC:**	f1/c4
OIL-IMPREGNATED ROCK:	f2/c4	**GOLD:**	f1/c3
URANIUM:	f3/c2	**SILVER:**	f1/c3
COAL:	f1/c4	**COPPER:**	f2/c1
GEOTHERMAL:	f1/c3		

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 241 lies along the east-flank of the Henry Mountains Basin and the west flank of the Monument Upwarp--two large structural feature on the Colorado Plateau that probably originated in late Cretaceous and early Tertiary time (Hunt, 1980; Kelley, 1955). The axis of the basin and the upwarp trend northerly, similar to most other large structures in this region. Tract 241 lies about 25 miles from the axis of each structure. The Monument Upwarp and the Henry Mountains Basin are not noted for petroleum production. In fact, the Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah and adjacent parts of Colorado (including the Henry Mountains Basin and the Monument Upwarp) contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanain, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Tar Sand Triangle immediately east of the tract and in the Circle Cliffs area 40 miles to the west (see OIL-IMPREGNATED ROCKS in this report; Campbell and Ritzma, 1979). Along the west side of the Monument Upwarp in the vicinity of Tract 241, oil staining has been reported in Mississippian and Pennsylvanian rocks (Hansen and Scoville, 1955; Heymun and others, 1965; Weitz and Light, 1981).

The geology of Tract 241 is not very favorable for oil and gas, despite its projected position within the Paradox Basin--a large structural basin that developed in southeastern Utah in Pennsylvanian time. As indicated by Berghorn and Reid (1981), the area that now encompasses Tract 241 was probably near the west shore of the Paradox Basin (chiefly the marne shelf and penesaline facies). This same geologic environment is very favorable for petroleum in the Four Corners area (e.g., Aneth field). Nevertheless, 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, as pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon (15 miles east of the tract) and in other parts of the Monument Upwarp. Overlying, Permian, Triassic, and Jurassic strata are exposed progressively closer to the tract along the eroded northwest-flank of the Monument Upwarp (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanain and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

The geology of Tract 241 is not favorable for oil and gas. As pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon (15 miles east of the tract) and in other parts of the Monument Upwarp. Overlying, Permian, Triassic, and Jurassic strata are exposed progressively closer to the tract along the eroded east-flank of the Henry Mountains Basin (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanain and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

Exploratory drilling in the Henry Mountains Basin has been discouraging. This fact has lead some geologists to conclude that the Henry Mountains Basin is simply not petroliferous; or that most hydrocarbons have already migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). For example, the "Tar Sand Triangle" on the east of Tract 241 is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. [Ritzma (1980), in contrast, believes that the oil in the Circle Cliffs deposit did not migrate over great distances.]

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (Heylmun and others, 1965; PIC, 1981). Some wells have been drilled west of that tract, but all were dry.

On the basis of the discussion above, we have assigned Tract 241 an oil and gas favorability of f2. If hydrocarbons exist in the tract, they would most likely be in small accumulations in pre-Laramide structural traps, and in stratigraphic traps in the northern half of the tract. The certainty that oil and gas resources exist (or do not exist) in Tract 241 is very low and has been assigned a value of c1.

OIL-IMPREGNATED ROCKS f2/c4

As per the terms of this contract, oil-impregnated rocks are evaluated for those tracts in which these deposits are known to occur or have a high certainty of occurrence. We emphasize, however, that oil-impregnated rocks, along with other forms of solid and semi-solid hydrocarbons such as asphalt, tar, pitch, and gilsonite, are included within the definition of the term "petroleum" as used by most geologists.

Oil-impregnated rocks in Utah are estimated by Ritzma (1979) to contain 22 to 29 billion barrels of oil-in-place. Of the 50-plus identified deposits, more than 96 percent of the oil is contained in only six deposits (Campbell and Ritzma, 1979). Tract 241 lies adjacent to the single largest group of deposits, referred to as the Tar Sand Triangle, which is estimated by Ritzma (1979) to collectively contain 12.5 to 16 billion barrels of in-place-oil. Most of the oil occurs in the White Rim Sandstone of Permian age.

One minor oil-impregnated rock deposit occurs in the northern end of the tract and the estimated volume of in-place oil in this deposit is less than 0.5 million barrels (Ritzma, 1979). The Hatch Canyon deposit is contiguous with the northeast side of the tract, Poison Spring Canyon deposit lies a mile to the northwest, and a few scattered but minor deposits occur near the southeast side of the tract Ritzma (1979).

On the basis of rating criteria developed for this study (see appendix), we have assigned Tract 241 a favorability of f2 for oil-impregnated rock deposits (less than 10 million barrels of oil-in-place). The certainty that these deposits exist in the tract is high and has been assigned a rating of c4.

URANIUM 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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

The north-trending Henry Mountains mineral belt lies 6 miles west of the tract and it is the most significant uranium-producing district in the area. Production is derived from the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). The Morrison Formation has been eroded from Tract 241.

A few uranium mines and numerous prospects occur near the northern end of the tract in the Chinle Formation (the Orange Cliffs area; Williams and Hackman, 1971; Utah Geological and Mineral Survey, 1977). According to Lupe and others (1980), the broad area encompassing Tract 241 in favorable for uranium deposits in the Chinle Formation. The Chinle in this area contains abundant sandstones that were deposited by streams flowing westward in Chinle time. Although very little uranium has been produced from this area, we have assigned the tract a favorability of f3 based chiefly on the analysis by Lupe and others (1980). The certainty that uranium occurs in the tract is relatively low (despite the deposits near the northern end of the tract), and has been assigned a rating 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 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.

All bedrock of sedimentary origin in Tract 241 is of pre-Cretaceous age. Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 241 a coal favorability of f1 (unfavorable), along with a 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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau is therefore considered to be very low.

The only geothermal potential associated with Tract 241 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant to the west in the Henry Mountains, they are much too old to be considered a present-day heat source [44 to 48 million years old according to Armstrong (1969), and 20 to 25 million years according to Hunt (1980)]. A warm spring (26°C) in Red Canyon, about 20 miles southeast of Tract 241, is the only visible and naturally-occurring manifestation of geothermal energy in the entire region (NOAA, 1980). In addition, two thermal wells a few miles west of Mt. Ellsworth reportedly have surface water temperatures of 20°C and 21°C (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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has lowered the depth to groud water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 241 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. 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 241. On the basis of this information we have assigned Tract 241 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c1

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975).

Tract 241 has almost no potential for gold and silver, and we have therefore assigned the tract a favorability of f1 for each resource. The certainty that these commodities do not exist in the tract is relatively high and is assigned a rating of c3.

Copper, however, does have some potential within the tract because of its close association with uranium. Production of by-product copper from uranium/vanadium mining in this part of the Colorado

Plateau has come chiefly from the area around Moab, Utah, the Big Indian/Lisbon Valley area, the White Canyon area, and 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 241) 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 241 a copper favorability of f2, but with a certainty of resource occurrence of only c1.

OVERALL-IMPORTANCE RATING 2+

Tract 241 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 rating is based chiefly on the area's uranium potential [the tract lies along the west edge of a large favorable area identified by Lupe and others (1980) and by Peterson and others (1980)]. All other resources evaluated for Tract 241 were assigned favorabilities of f2 or less, and they did not contribute substantially to the assigned OIR.

The tract was assigned an OIR of 2+ rather than 3 because it is contiguous along its east side with Glen Canyon National Recreation Area.

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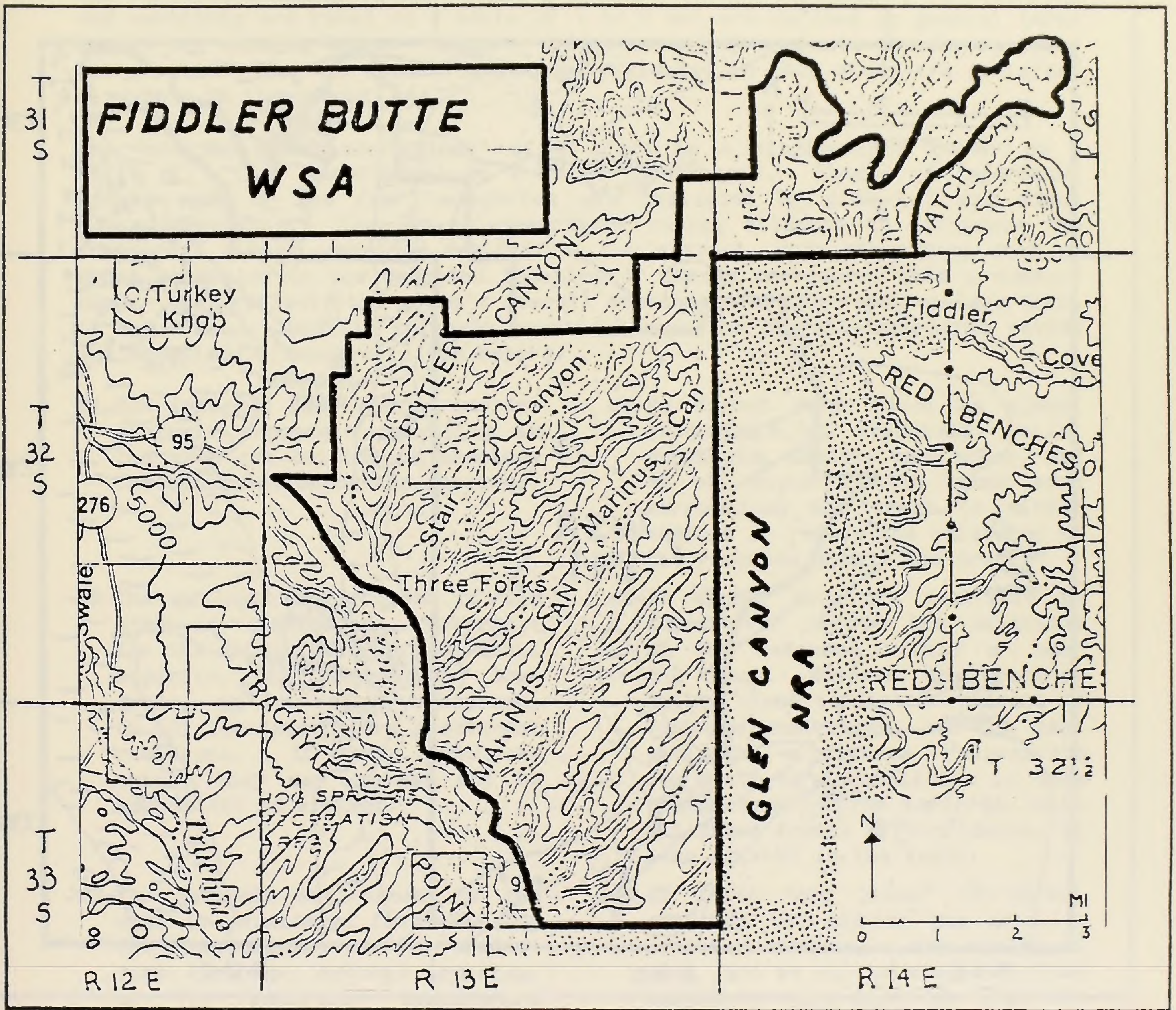
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 241 , UTAH

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



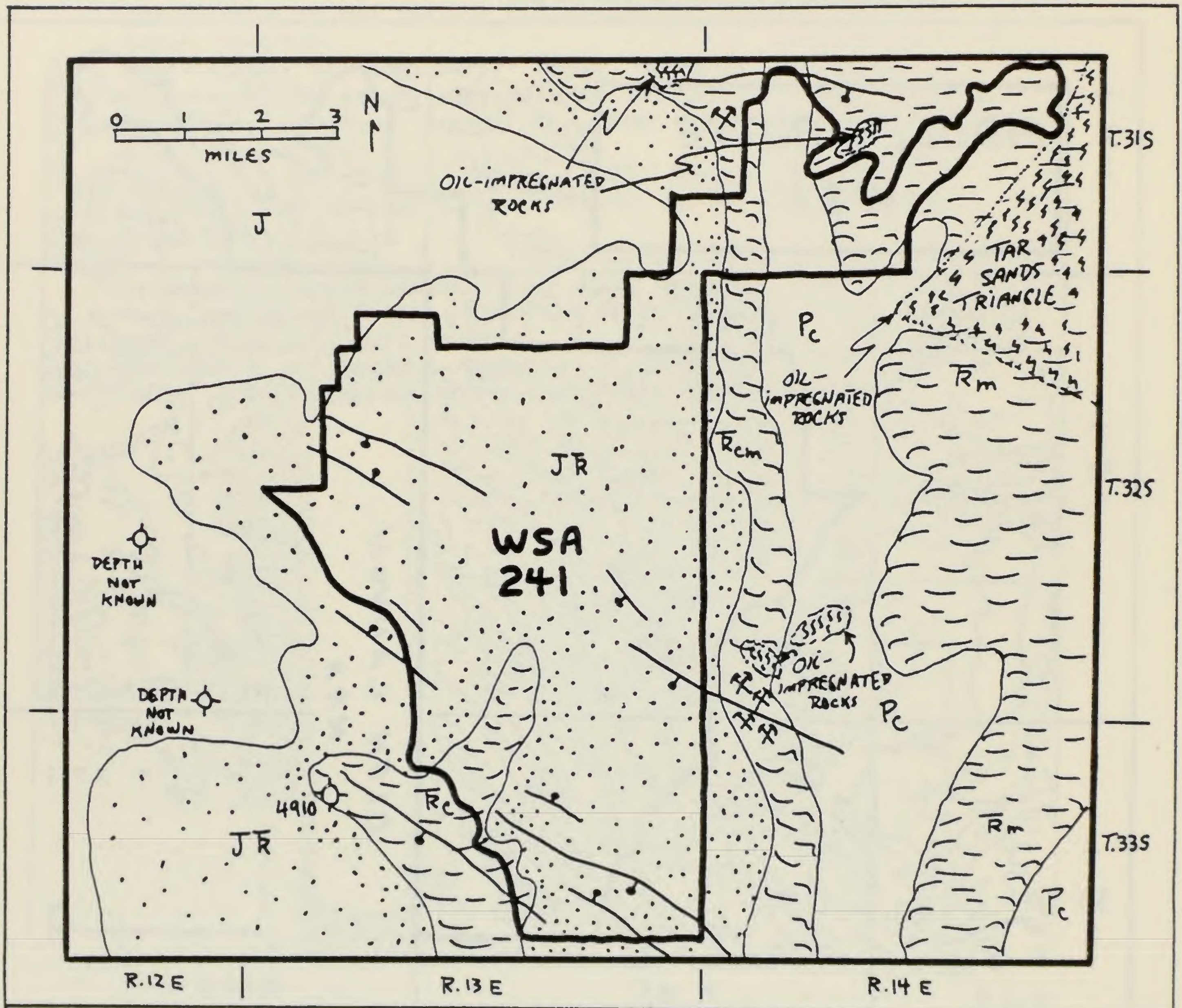
EXPLANATION

TRACT 241 WAS ASSIGNED A URANIUM FAVORABILITY OF f3. THE TRACT IS UNDERLAIN BY THE FAVORABLE CHINLE FORMATION, EXCEPT AT THE NORTHEAST END WHERE IT HAS BEEN ERODED. DEPTH TO CHINLE INCREASES TO NORTHWEST.

SOURCE: BLM, RICHFIELD, UTAH (BASE MAP)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 241, 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

J - JURASSIC ROCKS

JT̄R - JURASSIC/TRIASSIC ROCKS

T̄Rc - CHINLE FORMATION (TRIASSIC)

T̄Rcm - CHINLE/MOENKOPI

Pc - CUTLER (PERMIAN)

FAULT WITH BALL ON DOWNTHROWN SIDE

⚒ URANIUM DEPOSIT WITH LESS THAN 10 TONS PRODUCTION OF U_3O_8

⌖ 2113 OIL/GAS WELL (DRY). SHOWING TOTAL DEPTH

SOURCE:
BASE MODIFIED 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 ENERGY-RESOURCE EVALUATION REPORT
BLM WILDERNESS STUDY AREAS (WSAs)

TRACT NO: 242 **NAME:** Bull Mountain **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 11,800

DATE PREPARED: June 1982 **UPDATE:** August 1982

LOCATION

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

Tract 242 lies in the Henry Mountains Basin--a large structural depression 100 miles long and 50 miles wide that probably developed in late Cretaceous to Eocene time (about 50 to 70 million years ago). During middle Tertiary time (about 45 million years years ago), large masses of igneous rock were injected into the overlying sedimentary strata along a north-trending belt on the east side of the basin. Subsequent erosion has since exposed many of these igneous masses, along with the sedimentary strata that were tilted sharply during intrusion. The five largest masses of exposed igneous rock now stand thousands of feet above the surrounding plateaus and are collectively referred to as the Henry Mountains. Tract 242 encompasses the northeast flank of one of these masses, called Mt. Ellen.

Rocks at the surface in Tract 242 consist of diorite porphyry, surrounded by Mesozoic sedimentary rocks assigned to the Navajo Sandstone, the Carmel Formation, the Entrada Sandstone, the Curtis Formation, the Summerville Formation, the Morrison Formation, the Cedar Mountain Formation, the Dakota Sandstone, and the Mancos Shale (Williams and Hackman, 1971) The overall structure of the tract is a dome caused by laccolithic intrusions that radiate outward from the Mt. Ellen stock.

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	**HYDROELECTRIC:**	f1/c4
URANIUM:	f2/c1	**GOLD:**	f2/c3
COAL:	f1/c4	**SILVER:**	f2/c3
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c3

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 242 lies along the east-flank of the Henry Mountains Basin--a moderately-large and moderately-deep structural depression that presumably developed in Cretaceous time (Hunt, 1980). The axis of the basin trends northerly, similar to most other large structural features on the Colorado Plateau, and lies about 10 miles west of Tract 242. The Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah (including the Henry Mountains Basin) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin east of the Henry Mountains (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Circle Cliffs area 20 miles to the southwest and in the Tar Sand Triangle 15 miles to the northeast (oil-impregnated sandstones; Campbell and Ritzma, 1979).

The geology of Tract 242 is not favorable for oil and gas. As pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon 30 miles to the east and in other parts of the Monument Upwarp. Furthermore, Permian, Triassic, Jurassic, and Cretaceous strata are exposed progressively closer to the tract along the eroded east-flank of the Henry Mountains Basin (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

In addition to the problems outlined above, Tract 242 was intruded by a large mass of igneous rock in middle Tertiary time (a stock and subsidiary laccoliths; see Hunt and others, 1953). The sedimentary rocks into which this igneous mass was intruded now dip steeply away (northward) from the crest of Mt. Ellen, suggesting forceful igneous intrusion (Hunt and others, 1953). The temperature of the intrusion near its contact with the surrounding country rock is estimated by Hunt (1980) to have been about 550°C. At a minimum, the intrusive rock pierced strata as young as Cretaceous age; thus, hydrocarbons and reservoirs that may have existed in older favorable sedimentary rocks near the intrusion were almost certainly destroyed by the heat. The volume of rock that may have been adversely affected by these intrusions is difficult to judge. Metamorphism (and brecciation) of the country rock surrounding Mt. Ellen is generally slight (Hunt and others, 1953), so it seems reasonable to speculate that petroleum accumulations that had existed a "safe" distance from the intrusions may still exist. Moreover, post-intrusive migration and entrapment of hydrocarbons may have occurred along the sedimentary flanks of the dome caused by these intrusions. Nevertheless, exploratory drilling in the basin has been very discouraging. This fact has lead some geologists to conclude that the Henry Mountains Basin is simply not petroliferous; or that most hydrocarbons have already migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). [The "Tar Sand Triangle" on the east side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. Ritzma (1980), in contrast to part of the discussion above, believes that the oil in the Circle Cliffs deposit did not migrate over great distances.]

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (PIC, 1981). About a half dozen wells have been drilled in the immediate vicinity of Tract 242 to depths between 6,000 and 7,000 (to Mississippian rocks), but all the wells were were reportedly dry (Heylmun and others, 1965; PIC, 1981).

On the basis of the relatively unfavorable igneous history of Tract 242, along with the discouraging results of nearby exploration, we have assigned the tract an oil and gas favorability of f2. The certainty that oil and gas resources exist (or do not exist) in Tract 242 is very low and has been assigned a value of c1.

URANIUM f2/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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of

Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Uranium deposits in the Henry Mountains Basin occur in the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). Most of the known deposits lie a few miles east of the Henry Mountains in a north-trending zone known as the Henry Mountains mineral belt. This mineral belt has accounted for 98 percent of the uranium produced in the Henry Mountains region (Chenoweth, 1980). Deposits that have been mined to date are small; according to Grundy [as reported in Cenoweth (1980, p. 299)], 80 tons of ore is the mean deposit size.

Similar to many of the uranium mining districts on the Colorado Plateau, the Henry Mountains area went through three periods of development--an early period for radium, a middle period for vanadium, and the latest period of uranium exploration and development (Chenoweth, 1980). During the first five decades of this century, very little radium and vanadium were produced from the Henry Mountains area. From 1948 through 1978, the time of maximum uranium/vanadium production, approximately 240 tons of U_3O_8, and 850 tons of V_2O_5, were produced from deposits within the Henry Mountains mineral belt (Chenoweth, 1980).

In the late-1970s, the discovery of three large uranium deposits in the southern part of the Henry Mountains mineral belt was announced by Plateau Resources (Chenoweth, 1980). Cumulative reserves for the three deposits is estimated to be about 2,900 tons of U_3O_8 at an ore grade ranging from 0.04 to 0.50 percent U_3O_8 (Peterson and others, 1980). These discoveries generated a surge of uranium exploration in the Henry Mountains area during the late-1970s that resulted in additional discoveries in the central and northern parts of the mineral belt.

The uranium resource potential of the Henry Mountains Basin is estimated to be relatively large [18,850 tons U_3O_8 of "probable" and "possible" resources according to DOE (1979)]. Most resource potential is assigned to the Salt Wash Member of the Morrison Formation within the Henry Mountains mineral belt east of Tract 242 (Peterson and others, 1980; Lupe and others, 1980).

The Henry Mountains mineral belt lies a few miles east of Tract 242 (Williams and Hackman, 1971), and the Salt Wash Member crops out along the northeast side of the tract. In their evaluation of the uranium potential of the Salina 2-degree quadrangle, Lupe and others (1980) considered the area encompassed by Tract 242 not to be favorable for uranium (this includes the Morrison Formation which they consider to be unfavorable in this area, as well as the igneous rocks comprising Mt. Ellen which the authors state are not a good source of uranium because of their relatively basic composition). Nevertheless, the recent discoveries of large uranium deposits in the southern part of the mineral belt (discussed above) suggest that the Morrison Formation throughout this area should be considered at least marginally favorable for uranium. We have therefore assigned the tract a uranium favorability of f2. Because the tract lies outside the generally-recognized boundary of the Henry Mountains mineral belt (Chenoweth, 1980), the certainty that uranium resources occur in the tract is low and has been assigned a rating of c1.

COAL f4/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.

The bulk of the coal in the Henry Mountains Basin lies west of the Henry Mountains. The most important coal beds are in the Mancos Shale (the Emery and Ferron Sandstone Members). Minor coal-bearing carbonaceous beds occur in the older Dakota Sandstone. All the coal is of Cretaceous age and it is best developed along the synclinal axis of the Henry Mountains Basin to the west of Tract 242 (Law, 1980).

Doelling and Graham (1972) estimate that only about 9,000 tons of coal have been produced from the Henry Mountains coal field. The coal was mined during the first half of the century, chiefly for local use; no mines are currently active (Law, 1979).

A band of the Mancos Shale extends into the east-central section of of the tract (Williams and Hackman, 1971). Coal is not reported ot occur in this area by Doelling and Graham (1972) All other rocks of sedimentary origin in the tract are pre-Cretaceous age.

On the basis of the foregoing discussion, we have assigned Tract 242 a coal favorability of f1 and a certainty of c4 that coal resources do not occur 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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the

Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 242 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant, they are much too old to be considered a present-day heat source. [Radiometric dates reported by Armstrong (1969) indicate an age of 44 to 48 million years old (Eocene) for the igneous rock in the Henry Mountains. Hunt (1980) considers this age to be excessive, and prefers an age of 20 to 25 million years on the basis of regional geologic relationships.] A few scattered warm springs at temperatures generally less than 30°C occur in region and 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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision has lowered the depth Furthermore, deep stream-incision has lowered the depth to ground water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau.

On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 242 a geothermal favorability 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. 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 242. On the basis of this information we have assigned Tract 242 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c4

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975). Hunt and others (1953) characterize the mineralized environments in the Henry's as follows: deposits within fissures in the intrusive rocks (the stocks), and within fissures in the overlying shattered sedimentary rocks; disseminated deposits in surrounding laccoliths; and placer deposits in the alluvial debris that surround the peaks. According to Doelling (1980), about 75 percent of the total value of production was derived from fissure deposits in Bromide Basin on Mt. Ellen--about 700 ounces of gold, 3,000 ounces of silver, and about 9 tons of copper. Bromide Basin is less than one-quarter mile southwest of Tract 242.

The history of mineral exploration and production in the Henry Mountains is colorful and worthy of a brief summary in this report. The account that follows is quoted directly from Doelling (1980, p. 290-291):

> "After gold was discovered in the placers along the Colorado River near Hite in 1883, prospectors eyed the Henry Mountains as the possible mother lode. This possibility was enhanced when the precious metal was found in the streams leading from them. After much painstaking prospecting, gold-bearing fissures were discovered in Bromide Basin in 1889 on the east side of Mt. Ellen above the 10,000-foot level. [Bromide Basin is located about 4 miles north of Tract 242.] Expectations ran high and a small town, known as Eagle City, was built 2 mi below the basin, complete with shops, saloon, and sheriff. The Bromide mine...came into production in 1891..." and "...$15,000 worth of ore was produced between 1891 and 1893....Soon thereafter the bubble burst, a rich chute of ore along the fissure was mined out, and no new economical ore had been blocked out. The mine was closed and Eagle City quickly became a ghost town."

Intermittent mining continued in the Bromide Basin area through about 1939. In 1913, the Bromide fissure was explored to depths of perhaps a few hundred feet below the previous workings, but economic deposits were not discovered (Butler, 1920). According to Doelling (1980), prospecting and assessment work have continued to the present, but that the small near-surface deposits along fissures in Bromide Basin are mined out.

In addition to the deposits described above, gold-bearing placers occur in the gravels along some creeks that drain the Henry Mountains. Production, however, is reported only from the vicinity of Tract 242 on the northeast side of Mt. Ellen intermittently from the late-1800s to the 1940s (Doelling, 1980). No more than about 350 ounces of gold were recovered during this period, but with the recent increase in the price of gold, interest in placer gold in the Henry Mountains has also increased. Doelling (1980) states, however, that the gold particles in these placer deposits are very small (flour gold) and often float away during sluicing or panning. Furthermore, large quantities of water to work the gravel are not readily available.

In summary, the mineral potential of the Henry Mountains for gold, silver, and copper is apparently low. Although mineral exploration for these commodities will probably continue in the area, and small mining operations may begin as metal prices increase, the overall resource potential of the Henry Mountains for gold, silver, and/or copper is judged to be low. Tract 242 is therefore assigned a favorability of f2 for this group of minerals, but with a relatively high certainty (c3) that they exist in this area.

OVERALL-IMPORTANCE RATING 2

Tract 242 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 the resources evaluated for this tract were assigned favorabilities of f2 or less.

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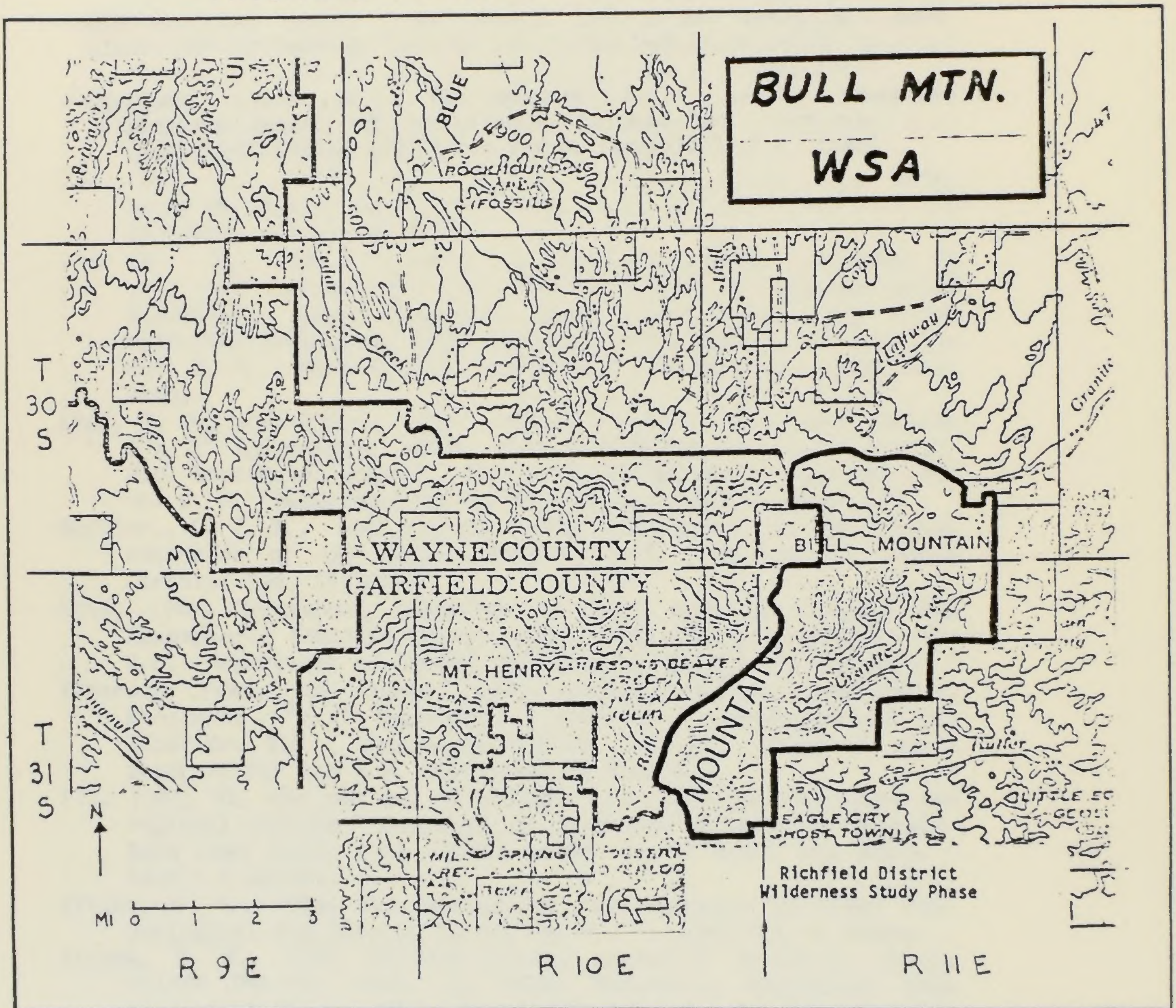
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 242 , UTAH

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



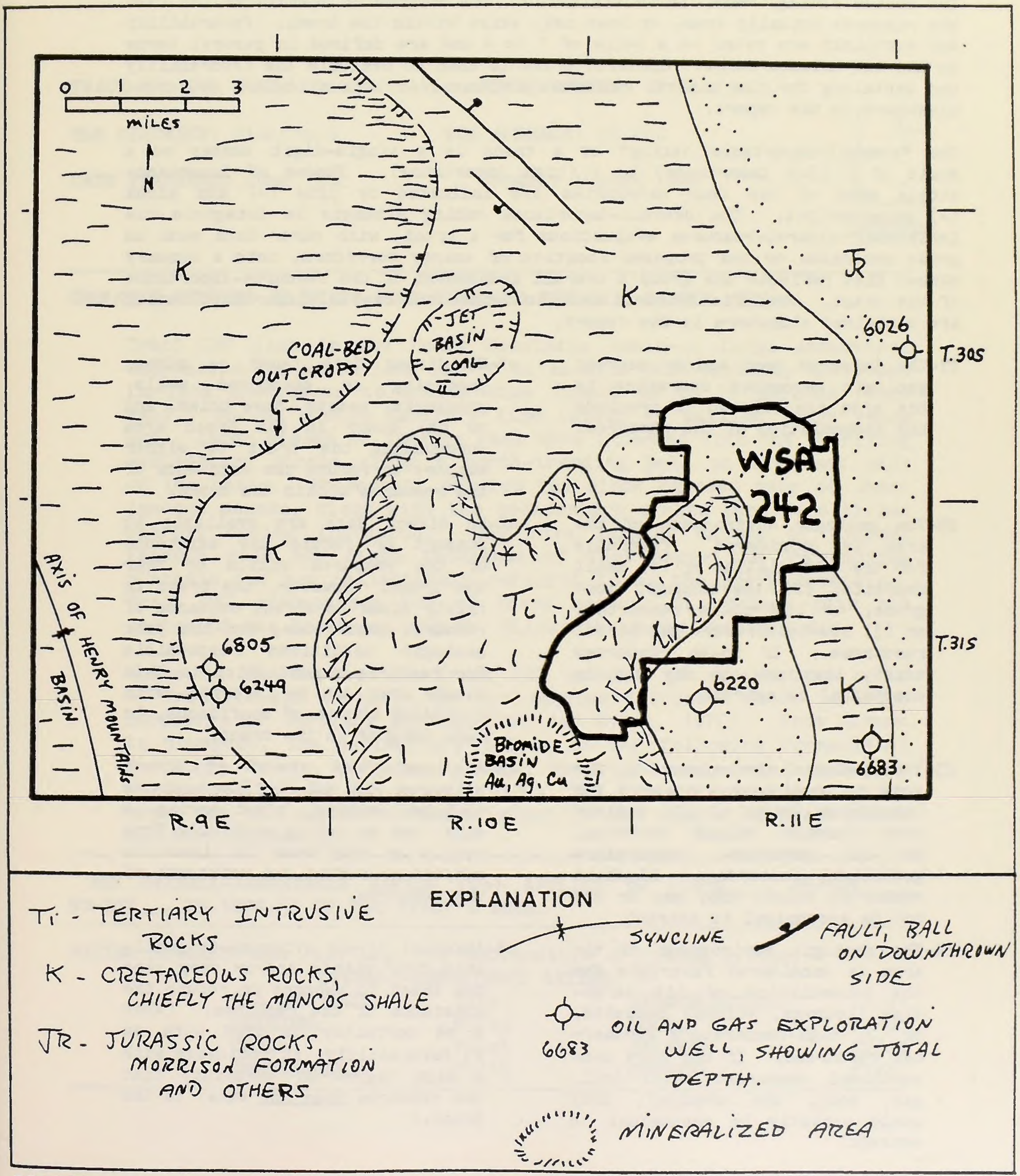
EXPLANATION

ALL RESOURCES EVALUATED FOR THIS TRACT HAVE BEEN ASSIGNED A FAVORABILITY OF LESS THAN ≤3

SOURCE: BASE MAP FROM BLM, RICHFIELD DISTRICT

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 242, 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), MODIFIED

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: 247 **NAME:** Little Rockies **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 38,700

DATE PREPARED: June 1982 **UPDATE:** August 1982

LOCATION

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

Tract 247 lies in the Henry Mountains Basin--a large structural depression 100 miles long and 50 miles wide that probably developed in late Cretaceous to Eocene time (about 50 to 70 million years ago). During middle Tertiary time (about 45 million years years ago), large masses of igneous rock were injected into the overlying sedimentary strata along a north-trending belt on the east side of the basin. Subsequent erosion has since exposed many of these igneous masses, along with the sedimentary strata that were tilted sharply during intrusion. The five largest masses of exposed igneous rock now stand thousands of feet above the surrounding plateaus and are collectively referred to as the Henry Mountains. Tract 247 encompasses two of these masses; Mt. Holmes near the center of the tract and and Mt. Ellsworth at the southern end.

Rocks at the surface in Tract 247 consist of sedimentary rocks of Triassic and Jurassic age and igneous intrusive rocks (diorite porphyry) of Tertiary age (Hackman and Wyant, 1972). From oldest to youngest, the sedimentary belong to the following formations: Moenkopi, Chinle, Wingate, Kayenta, Navajo, Carmel, and the Entrada Sandstone (Hackman and Wyant, 1973). The largest structures in the tract are the symmetric domes caused by the stocks at Mt. Holmes and Mt. Ellsworth.

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	**HYDROELECTRIC:**	f1/c4
URANIUM:	f3/c3	**GOLD:**	f2/c1
COAL:	f1/c4	**SILVER:**	f2/c1
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c1

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 247 lies along the east-flank of the Henry Mountains Basin--a moderately-large and moderately-deep structural depression that presumably developed in Cretaceous time (Hunt, 1980). The axis of the basin trends northerly, similar to most other large structural features on the Colorado Plateau, and lies about 10 miles west of Tract 247. The Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah (including the Henry Mountains Basin) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin east of the Henry Mountains (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Circle Cliffs area 30 miles to the west and in the Tar Sand Triangle 15 miles to the northeast (oil-impregnated sandstones; Campbell and Ritzma, 1979).

The geology of Tract 247 is not very favorable for oil and gas, despite its projected position within the Paradox Basin--a large structural basin that developed in southeastern Utah in Pennsylvanian time. As indicated by Berghorn and Reid (1981), the area that now encompasses Tract 247 was probably near the west shore of the Paradox Basin (chiefly the penesaline and marine-shelf facies). This same geologic environment, and the strata that eventually formed in it, is very favorable for petroleum in the Four Corners area (e.g., Aneth field). Nevertheless, 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, as pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon to the east and in other parts of the Monument Upwarp. Overlying, Permian, Triassic, and Jurassic strata are exposed progressively closer to the tract along the eroded northwest-flank of the Monument Upwarp (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

In addition to the problems outlined above, Tract 247 was intruded by two large masses of igneous rock in middle Tertiary time (a stock and subsidiary laccoliths; see Hunt and others, 1953). The sedimentary rocks into which this igneous mass was intruded now dip steeply away from the crest of Mt. Hillers, suggesting forceful igneous intrusion (Hunt and others, 1953). The temperature of the intrusion near its contact with the surrounding country rock is estimated by Hunt (1980) to have been about 550°C. At a minimum, the intrusive rock pierced strata as young as Cretaceous age; thus, hydrocarbons and reservoirs that may have existed in older favorable sedimentary rocks near the intrusion were almost certainly destroyed by the heat. The volume of rock that may have been adversely affected by these intrusions is difficult to judge. Metamorphism (and brecciation) of the country rock surrounding the stocks is slight (Hunt and others, 1953), so it seems reasonable to speculate that petroleum accumulations that had existed a "safe" distance from the intrusions may still exist. Moreover, post-intrusive migration and entrapment of hydrocarbons may have occurred along the sedimentary flanks of the dome caused by these intrusions. Nevertheless, exploratory drilling in the basin has been very discouraging. This fact has lead some geologists to conclude that the Henry Mountains Basin is simply not petroliferous; or that most hydrocarbons have already migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). [The "Tar Sand Triangle" on the east side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. Ritzma (1980), in contrast to part of the discussion above, believes that the oil in the Circle Cliffs deposit did not migrate over great distances.]

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (Heylmun and others, 1965; PIC, 1981). Some wells have been drilled north of Tract 247, but all were dry (PIC, 1981; the nearest well is a 4,910-foot dry hole drilled by Southland Oil).

On the basis of the relatively unfavorable igneous history of Tract 247, the discouraging results of nearby exploration, and deep erosion a short distance to the east, we have assigned the tract an oil and gas favorability of f2. If hydrocarbons exist in Tract 247, they would most likely be in small accumulations in pre-Laramide structural traps, and in stratigraphic traps in the northern half of the tract. The certainty that oil and gas resources exist (or do not exist) in Tract 247 is very low and has been assigned a value of c1.

URANIUM f3/c3

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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley in northeastern Arizona, and White Canyon located about 10 miles east of Tract 247 (Fischer, 1968).

Uranium deposits in the Henry Mountains Basin occur in the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). Most of the known deposits lie a few miles east of the Henry Mountains in a north-trending zone known as the Henry Mountains mineral belt. This mineral belt has accounted for 98 percent of the uranium produced in the Henry Mountains region (Chenoweth, 1980). Deposits that have been mined to date are small; according to Grundy [as reported in Cenoweth (1980, p. 299)], 80 tons of ore is the mean deposit size.

Similar to many of the uranium mining districts on the Colorado Plateau, the Henry Mountains area went through three periods of development--an early period for radium, a middle period for vanadium, and the latest period of uranium exploration and development (Chenoweth, 1980). During the first five decades of this century, very little radium and vanadium were produced from the Henry Mountains area. From 1948 through 1978, the time of maximum uranium/vanadium production, approximately 240 tons of U_3O_8, and 850 tons of V_2O_5, were produced from deposits within the Henry Mountains mineral belt (Chenoweth, 1980).

In the late-1970s, the discovery of three large uranium deposits in the southern part of the Henry Mountains mineral belt was announced by Plateau Resources (Chenoweth, 1980). Cumulative reserves for the three deposits is estimated to be about 2,900 tons of U_3O_8 at an ore grade ranging from 0.04 to 0.50 percent U_3O_8 (Peterson and others, 1980). These discoveries generated a surge of uranium exploration in the Henry Mountains area during the late-1970s that resulted in additional discoveries in the central and northern parts of the mineral belt.

The uranium resource potential of the Henry Mountains Basin is estimated to be relatively large [18,850 tons U_3O_8 of "probable" and "possible" resources according to DOE (1979)]. Most of the potential is assigned to the Salt Wash Member of the Morrison Formation within the Henry Mountains mineral belt (Peterson and others, 1980). The mineral belt (and the Morrison Formation) lies west of the tract had no influence on the tract's uranium favorability. The only other rock unit in the area considered favorable by Peterson and others (1980) is the Chinle Formation, which is exposed in the tract and is the host unit for uranium in the White Canyon uranium mining district 10 miles to the east.

The uranium deposits in the White Canyon 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 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).

A few prospects are reported from the Moss Back Member of the Chinle Formation in North Wash Canyon about one mile east of the tract and a few tons of uranium oxide have been produced from the Monitor Butte Member along the Colorado River about 5 miles east of the tract (Hackman and Wyant, 1973). Petterson and others (1980) consider the entire area of Tract 247 (and areas to the east) to be favorable for uranium deposits in the lower part of the Chinle Formation.

On the basis of the discussion above, we have assigned Tract 247 a uranium favorability of f3 (favorable for deposits containing up to 1,000 tons of uraium oxide). Because uranium deposits and prospects occur in nearby, and stratigraphically-equivalent, rocks we have the tract a certainty of resource occurrence of c3.

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.

The bulk of the coal in the Henry Mountains Basin lies west of the Henry Mountains. The most important coal beds are in the Mancos Shale (the Emery and Ferron Sandstone Members). Minor coal-bearing carbonaceous beds occur in the older Dakota Sandstone. All the coal is of Cretaceous age and it is best developed along the synclinal axis of the Henry Mountains Basin to the west of Tract 247 (Law, 1980).

All bedrock of sedimentary origin in Tract 247 is of pre-Cretaceous age. Because these rocks are not known to be favorable for coal anywhere in the region, we have assigned Tract 247 a coal favorability of f1 (unfavorable), along with a 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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 247 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant, they are much too old to be considered a present-day heat source. [Radiometric dates reported by Armstrong (1969) indicate an age of 44 to 48 million years old (Eocene) for the igneous rock in the Henry Mountains. Hunt (1980) considers this age to be excessive, and prefers an age of 20 to 25 million years on the basis of regional geologic relationships.] A warm spring (26°C) in Red Canyon, about 6 miles southeast of Tract 247, is the only visible and naturally-occurring manifestation of geothermal energy in the entire region (NOAA, 1980). In addition, two thermal wells a few miles west of Mt. Ellsworth reportedly have surface water temperatures of 20°C and 21°C (NOAA, 1980; one well is about 470 feet deep, the other is about 840 feet deep). 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 this part of the Richfield district considering the probable great depth to the resource and the associated high drilling costs. Furthermore, deep stream-incision of the Colorado Plateau has lowered the depth to ground water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 247 a geothermal favorability 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. 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 247. On the basis of this information we have assigned Tract 247 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c1

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975). Hunt and others (1953) characterize the mineralized environments in the Henry's as follows: deposits within fissures in the intrusive rocks (the stocks), and within fissures in the overlying shattered sedimentary rocks; disseminated deposits in surrounding laccoliths; and placer deposits in the alluvial debris that surround the peaks. According to Doelling (1980), about 75 percent of the total value of production was derived from fissure deposits in Bromide Basin on Mt. Ellen--about 700 ounces of gold, 3,000 ounces of silver, and about 9 tons of copper.

The history of mineral exploration and production in the Henry Mountains is colorful and worthy of a brief summary in this report. The account that follows is quoted directly from Doelling (1980, p. 290-291):

> "After gold was discovered in the placers along the Colorado River near Hite in 1883, prospectors eyed the Henry Mountains as the possible mother lode. This possibility was enhanced when the precious metal was found in the streams leading from them. After much painstaking prospecting, gold-bearing fissures were discovered in Bromide Basin in 1889 on the east side of Mt. Ellen above the 10,000-foot level. [Bromide Basin is located about 4 miles north of Tract 247.] Expectations ran high and a small town, known as Eagle City, was built 2 mi below the basin, complete with shops, saloon, and sheriff. The Bromide mine...came into production in 1891..." and "...$15,000 worth of ore was produced between 1891 and 1893....Soon thereafter the bubble burst, a rich chute of ore along the fissure was mined out, and no new economical ore had been blocked out. The mine was closed and Eagle City quickly became a ghost town."

Intermittent mining continued in the Bromide Basin area through about 1939. In 1913, the Bromide fissure was explored to depths of perhaps a few hundred feet below the previous workings, but economic deposits were not discovered (Butler, 1920). According to Doelling (1980), prospecting and assessment work have continued to the present, but that the small near-surface deposits along fissures in Bromide Basin are mined out.

There are no deposits of gold, silver, or copper reported from the area of Tract 247 (Doelling, 1980). It seems likely that at least some mineralization occurs in viens and along zones of brecciated rock, similar to those at Mt. Pennell and in the Bromide Basin north of Mt. Pennell. Nevertheless, the mineral potential of the Henry Mountains for gold, silver, and copper is apparently low. Although mineral exploration for these commodities will probably continue in the area, and small mining operations may begin as metal prices increase, the overall resource potential of the Henry Mountains for gold, silver, and/or copper is judged to be low. Tract 247 is therefore assigned a favorability of f2 for this group of minerals, with a certainty of only c1 that these resources exist in the tract.

OVERALL-IMPORTANCE RATING 2+

Tract 247 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 rating is based chiefly on the area's uranium potential [the tract lies along the west edge of a large favorable area identified by Peterson and others (1980)]. All other resources evaluated for Tract 247 were assigned favorabilities of f2 or less, and they did not contribute substantially to the assigned OIR.

The tract was assigned an OIR of 2+ rather than 3 because it is contiguous along its entire east side with Glen Canyon National Recreation Area.

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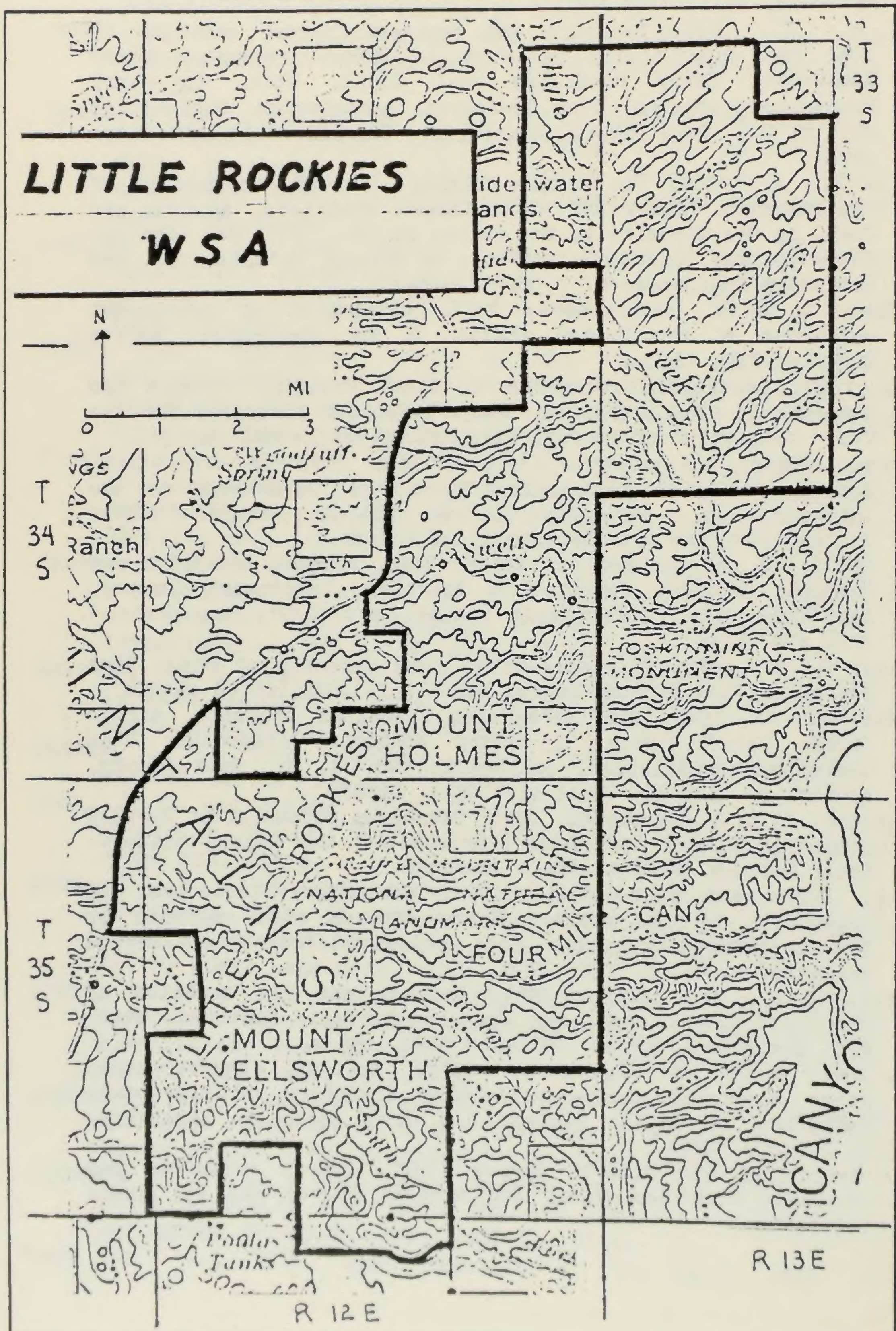
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 247 , UTAH

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



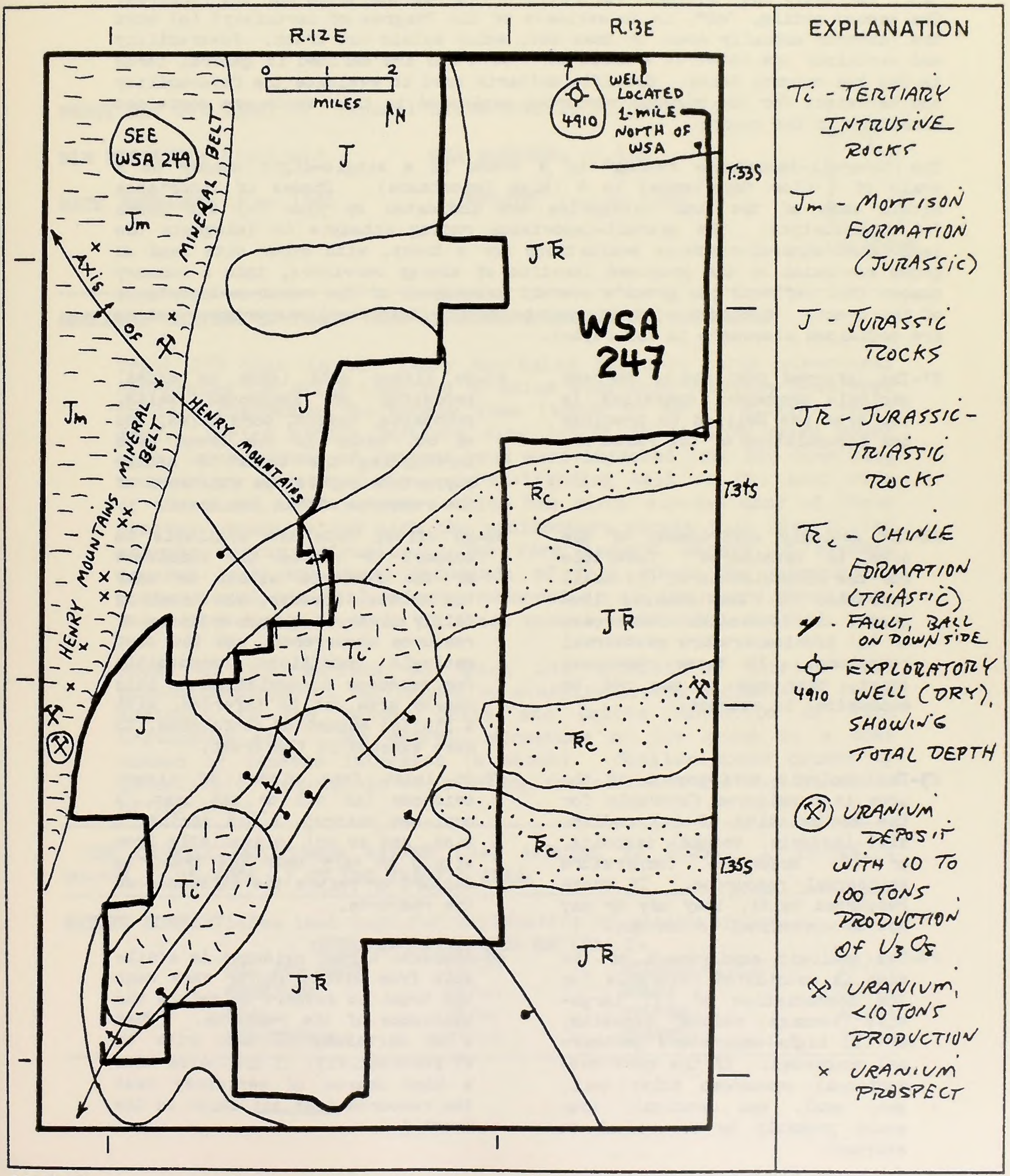
EXPLANATION

URANIUM WAS ASSIGNED A FAVORABILITY OF f3, AND THIS RATING APPLIES TO THE ENTIRE TRACT, ALTHOUGH THE DEPTH TO THE FAVORABLE CHINLE FORMATION INCREASES TO THE WEST.

SOURCE: FROM BLM, RICHFIELD, UTAH (BASE MAP)

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 247, 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: MODIFIED 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.

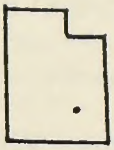
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 248 **NAME:** Mt. Pennell **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 27,300

DATE PREPARED: June 1982 **UPDATE:** August 1982


LOCATION

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

Tract 248 lies in the Henry Mountains Basin--a large structural depression 100 miles long and 50 miles wide that probably developed in late Cretaceous to Eocene time (about 50 to 70 million years ago). During middle Tertiary time (about 45 million years years ago), large masses of igneous rock were injected into the overlying sedimentary strata along a north-trending belt on the east side of the basin. Subsequent erosion has since exposed many of these igneous masses, along with the sedimentary strata that were tilted sharply during intrusion. The five largest masses of exposed igneous rock now stand thousands of feet above the surrounding plateaus and are collectively referred to as the Henry Mountains. Tract 248 encompasses one of these masses, called Mt. Pennell.

Rocks at the surface in Tract 248 consist of diorite- and monzonite-porphyry, surrounded by steeply-dipping sedimentary rocks assigned to the Mancos Shale and Dakota Sandstone of late Cretaceous age. The overall structure of the tract is a dome caused by igneous intrusion (a stock). Smaller domes caused by laccolithic intrusions occur along the northern and eastern sides of the tract.

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	**HYDROELECTRIC:**	f1/c4
URANIUM:	f2/c1	**GOLD:**	f2/c4
COAL:	f4/c4	**SILVER:**	f2/c4
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c4

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 248 lies along the east-flank of the Henry Mountains Basin--a moderately-large and moderately-deep structural depression that presumably developed in Cretaceous time (Hunt, 1980). The axis of the basin trends northerly, similar to most other large structural features on the Colorado Plateau, and lies about 10 miles west of Tract 248. The Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah (including the Henry Mountains Basin) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin east of the Henry Mountains (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Circle Cliffs area 10 miles to the southwest and in the Tar Sand Triangle 20 miles to the northeast (oil-impregnated sandstones; Campbell and Ritzma, 1979).

The geology of Tract 248 is not favorable for oil and gas. As pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon 30 miles to the east and in other parts of the Monument Upwarp. Furthermore, Permian, Triassic, Jurassic, and Cretaceous strata are exposed progressively closer to the tract along the eroded east-flank of the Henry Mountains Basin (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

In addition to the problems outlined above, Tract 248 was intruded by a large mass of igneous rock in middle Tertiary time (a stock and subsidiary laccoliths; see Hunt and others, 1953). The sedimentary rocks into which this igneous mass was intruded now dip about 45° away from the crest of Mt. Pennell, suggesting forceful igneous intrusion (Hunt and others, 1953). The temperature of the intrusion near its contact with the surrounding country rock is estimated by Hunt (1980) to have been about 550°C. At a minimum, the intrusive rock pierced strata as young as Cretaceous age; thus, hydrocarbons and reservoirs that may have existed in older favorable sedimentary rocks near the intrusion were almost certainly destroyed by the heat. The volume of rock that may have been adversely affected by these intrusions is difficult to judge. Metamorphism (and brecciation) of the country rock surrounding Mt. Pennell is slight (Hunt and others, 1953), so it seems reasonable to speculate that petroleum accumulations that had existed a "safe" distance from the intrusions may still exist. Moreover, post-intrusive migration and entrapment of hydrocarbons may have occurred along the sedimentary flanks of the dome caused by these intrusions. Nevertheless, exploratory drilling in the basin has been very discouraging. This fact has lead some geologists to conclude that the Henry Mountains Basin is simply not petroliferous; or that most hydrocarbons have already migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). [The "Tar Sand Triangle" on the east side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. Ritzma (1980), in contrast to part of the discussion above, believes that the oil in the Circle Cliffs deposit did not migrate over great distances.]

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (PIC, 1981). In 1961 Superior Oil drilled a 9,682-foot dry well that penetrated Mississippian rocks about a mile southwest of the tract (Heylmun and others, 1965). In addition, a 6,242-foot well was drilled along the west side of the tract by Webb Oil; it was also dry (PIC, 1981). The only other oil test near Tract 248 was located about 4 miles to the northeast, between Mt. Pennell and Mt. Ellen. The well was drilled along Maze Arch to a total depth of 2,278 feet and also is reported to have been dry (PIC, 1981).

On the basis of the relatively unfavorable igneous history of Tract 248, along with the discouraging results of nearby exploration, we have assigned the tract an oil and gas favorability of f2. If hydrocarbons exist in Tract 248, they would most likely be in small accumulations in pre-Laramide structural traps, and in stratigraphic traps, along the tract's western and southern border. The certainty that oil and gas resources exist (or do not exist) in Tract 248 is very low and has been assigned a value of c1.

URANIUM f2/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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Uranium deposits in the Henry Mountains Basin occur in the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). Most of the known deposits lie a few miles east of the Henry Mountains in a north-trending zone known as the Henry Mountains mineral belt. This mineral belt has accounted for 98 percent of the uranium produced in the Henry Mountains region (Chenoweth, 1980). Deposits that have been mined to date are small; according to Grundy [as reported in Cenoweth (1980, p. 299)], 80 tons of ore is the mean deposit size.

Similar to many of the uranium mining districts on the Colorado Plateau, the Henry Mountains area went through three periods of development--an early period for radium, a middle period for vanadium, and the latest period of uranium exploration and development (Chenoweth, 1980). During the first five decades of this century, very little radium and vanadium were produced from the Henry Mountains area. From 1948 through 1978, the time of maximum uranium/vanadium production, approximately 240 tons of U_3O_8, and 850 tons of V_2O_5, were produced from deposits within the Henry Mountains mineral belt (Chenoweth, 1980).

In the late-1970s, the discovery of three large uranium deposits in the southern part of the Henry Mountains mineral belt was announced by Plateau Resources (Chenoweth, 1980). Cumulative reserves for the three deposits is estimated to be about 2,900 tons of U_3O_8 at an ore grade ranging from 0.04 to 0.50 percent U_3O_8 (Peterson and others, 1980). These discoveries generated a surge of uranium exploration in the Henry Mountains area during the late-1970s that resulted in additional discoveries in the central and northern parts of the mineral belt.

The uranium resource potential of the Henry Mountains Basin is estimated to be relatively large [18,850 tons U_3O_8 of "probable" and "possible" resources according to DOE (1979)]. Most resource potential is assigned to the Salt Wash Member of the Morrison Formation within the Henry Mountains mineral belt east of Tract

248 (Peterson and others, 1980). The Salt Wash Member probably lies from 800 to 2,000 feet below the surface of Tract 248. In their evaluation of the uranium potential of the Escalante 2-degree quadrangle, Peterson and others (1980) considered the area encompassed by Tract 248 not to be favorable for uranium (this includes the Morrison Formation which they consider to be unfavorable in this area, as well as the igneous rocks comprising Mt. Pennell which the authors state are not a good source of uranium because of their relatively basic composition). Nevertheless, the recent discoveries of large uranium deposits in the southern part of the mineral belt (discussed above) suggest that the Morrison Formation throughout this area should be considered at least marginally favorable for uranium. We have therefore assigned the tract a uranium favorability of f2. Because the tract lies outside the generally-recognized boundary of the Henry Mountains mineral belt (Chenoweth, 1980), the certainty that uranium resources occur in the tract is low and has been assigned a rating of c1.

COAL <u>f4/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.

The bulk of the coal in the Henry Mountains Basin lies west of the Henry Mountains. The most important coal beds are in the Mancos Shale (the Emery and Ferron Sandstone Members). Minor coal-bearing carbonaceous beds occur in the older Dakota Sandstone. All the coal is of Cretaceous age and it is best developed along the synclinal axis of the Henry Mountains Basin to the west of Tract 248 (Law, 1980).

Doelling and Graham (1972) estimate that only about 9,000 tons of coal have been produced from the Henry Mountains coal field. The coal was mined during the first half of the century, chiefly for local use; no mines are currently active (Law, 1979).

Coal reserves in the Henry Mountains field are small by Utah standards--only 231 million tons in beds greater than 4-feet thick according to Doelling and Graham (1972). About 80 percent of these reserves are assigned to the Emery Sandstone Member. A little less than one-third of the reserves are considered to be strippable by Doelling and Graham (1972); this is the only advantage that the Henry Mountains field has over nearby coal fields. Otherwise, coal in the Henry Mountains field is relatively thin (except in local areas where beds exceed 9-feet thick), accessibility to the field is poor, and the coal is of somewhat poorer quality compared with other Utah coal fields.

Poor exposures of coal occur along the west side of the tract within the Emery Sandstone Member of the Mancos Shale (Doelling and Graham, 1972). The revised boundary of Tract 248 shown on the attached Mineral-Resource Potential Map, however, excludes a large part of the coal that had previously been included in the tract. Some of the coal beds that now lie a short distance west of the tract are greater than 6-feet thick. A few hundred yards west of the tract's northwest corner, coal beds exceed 8-feet in thickness, and some coal beds up to 9-feet thick occur in the far northwest corner and in the west-central part of the tract (Doelling and Graham, 1972). Much of the coal within the tract has an overburden of less than 100 feet and it could probably be extracted by strip mining. Based on data in Doelling and Graham (1972), we estimate that demonstrated coal reserves in Tract 248 are no more than a few million tons.

On the basis of the foregoing discussion, Cretaceous rocks along the far west side of Tract 248 are very favorable for coal (this, of course, is obvious because thick coal beds occur in the tract). Tract 248 has therefore been assigned a coal favorability of f4 and a certainty of coal occurrence of c4. Coal may also be present at depth in other Cretaceous rocks in the tract (for example, the Ferron Sandstone Member of the Mancos Shale), but the coal would probably be marginally important at best.

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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 248 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant, they are much too old to be considered a present-day heat source. [Radiometric dates reported by Armstrong (1969) indicate an age of 44 to 48 million years old (Eocene) for the igneous rock in the Henry Mountains. Hunt (1980) considers this age to be excessive, and prefers an age of 20 to 25 million years on the basis of regional geologic relationships.] A warm spring (26°C) in Red Canyon, about 25 miles southeast of Tract 248, is the only visible and naturally-occurring manifestation of geothermal energy in the entire region (NOAA, 1980). In addition, two thermal wells a few miles west of Mt. Ellsworth and about 15 miles south of Tract 248 report surface water temperatures of 20°C and 21°C (NOAA, 1980; one well is about 470 feet deep, the other is about 840 feet deep). 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 Henry Mountains area 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 lowered the depth to ground water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 248 a geothermal favorability 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. 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 248. On the basis of this information we have assigned Tract 248 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c4

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975). Hunt and others (1953) characterize the mineralized environments in the Henry's as follows: deposits within fissures in the intrusive rocks (the stocks), and within fissures in the overlying shattered sedimentary rocks; disseminated deposits in surrounding laccoliths; and placer deposits in the alluvial debris that surround the peaks. According to Doelling (1980), about 75 percent of the total value of production was derived from fissure deposits in Bromide Basin on Mt. Ellen--about 700 ounces of gold, 3,000 ounces of silver, and about 9 tons of copper.

The history of mineral exploration and production in the Henry Mountains is colorful and worthy of a brief summary in this report. The account that follows is quoted directly from Doelling (1980, p. 290-291):

> "After gold was discovered in the placers along the Colorado River near Hite in 1883, prospectors eyed the Henry Mountains as the possible mother lode. This possibility was enhanced when the precious metal was found in the streams leading from them. After much painstaking prospecting, gold-bearing fissures were discovered in Bromide Basin in 1889 on the east side of Mt. Ellen above the 10,000-foot level. [Bromide Basin is located about 4 miles north of Tract 248.] Expectations ran high and a small town, known as Eagle City, was built 2 mi below the basin, complete with shops, saloon, and sheriff. The Bromide mine...came into production in 1891..." and "...$15,000 worth of ore was produced between 1891 and 1893....Soon thereafter the bubble burst, a rich chute of ore along the fissure was mined out, and no new economical ore had been blocked out. The mine was closed and Eagle City quickly became a ghost town."

Intermittent mining continued in the Bromide Basin area through about 1939. In 1913, the Bromide fissure was explored to depths of perhaps a few hundred feet below the previous workings, but economic deposits were not discovered (Butler, 1920). According to Doelling (1980), prospecting and assessment work have continued to the present, but that the small near-surface deposits along fissures in Bromide Basin are mined out.

Deposits of gold, silver, and copper occur in Track 248. Doelling (1980) estimates that at most, only $1,000 dollars worth of gold with a little silver was produced from these deposits. Known mineralized areas lie within, and parallel to, the northeast border of the tract. The main prospects accur along a vertical fissure of brecciated rock that is 25 feet wide where visible, and at least 2,000 feet long at the surface (Doelling, 1980). The Viola gold mine in the southeastern corner of the tract, worked in the 1960s and 1970s, is the most recent development in the area (Doelling, 1975; 1980). The mine is located along the contact between highly metamorphosed Cretaceous shale and diorite porphyry. No ore was ever shipped, and Doelling (1980) reports that samples collected across the face of the mine yielded only trace amounts of gold and silver.

In addition to the deposits described above, gold-bearing placers occur in the gravels along some creeks that drain the Henry Mountains. Production, however, is reported only from the northeast side of Mt. Ellen, intermittently from the late-1800s to the 1940s (Doelling, 1980). No more than about 350 ounces of gold were recovered during this period, but with the recent increase in the price of gold, interest in placer gold in the Henry Mountains has also increased. Doelling (1980) states, however, that the gold particles in these placer deposits are very small (flour gold) and often float away during sluicing or panning. Furthermore, large quantities of water to work the gravel are not readily available.

In summary, the mineral potential of the Henry Mountains for gold, silver, and copper is apparently low. Although mineral exploration for these commodities will probably continue in the area, and small mining operations may begin as metal prices increase, the overall resource potential of the Henry Mountains for gold, silver, and/or copper is judged to be low. Tract 248 is therefore assigned a favorability of f2 for this group of minerals, but with a high certainty (c4) that they exist in the tract.

OVERALL-IMPORTANCE RATING 2+

Tract 248 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 rating applies to the westen part of the tract where thick coal beds are known to occur. All other resources evaluated for Tract 248 were assigned favorabilities of f2 or less, and they did not contribute substantially to the assigned OIR.

Although coal was assigned a favorability of f4, an OIR of 2+ rather than 4 was assigned to the tract because (1) the reserves in this part of the Henry Mountains Basin are probably inadequate to support commercial mining operations, (2) access to this area is difficult, and (3) nearby fields containing large, easily-accessible coal reserves have a distinct economic edge over the Henry Mountains coal field.

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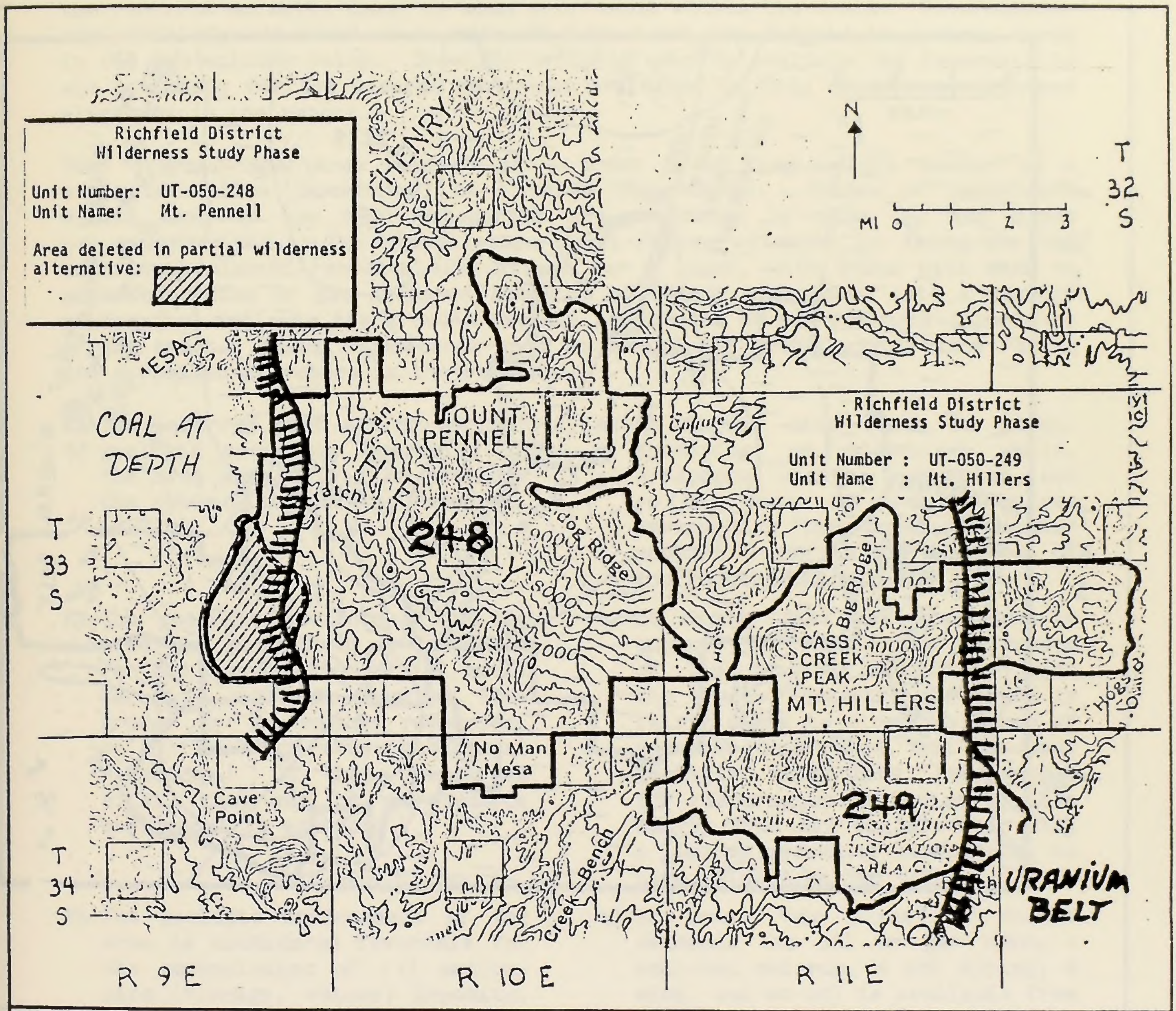
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 248, 249, UTAH

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



EXPLANATION

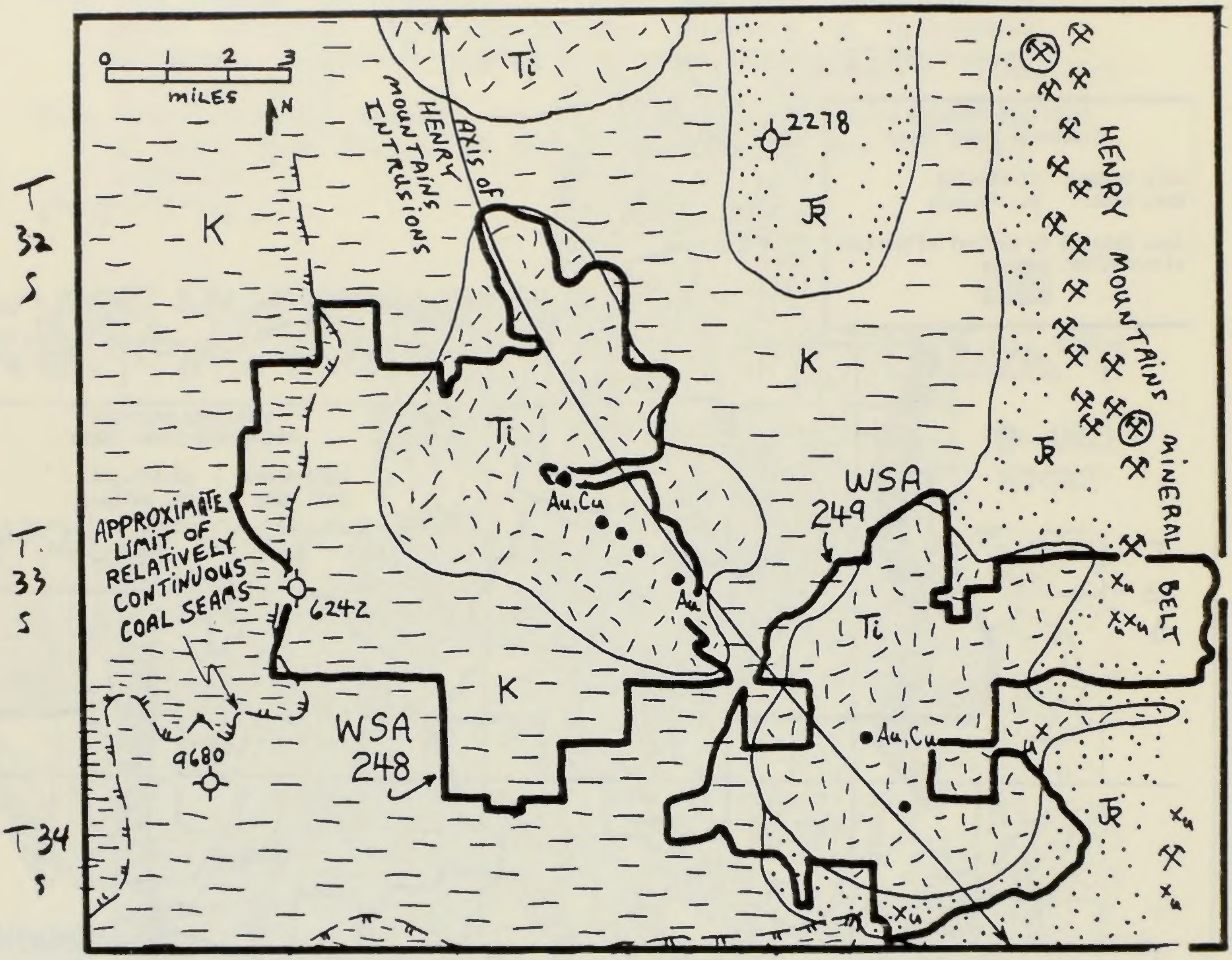
COAL WAS ASSIGNED AN F4 RATING FOR TRACT 248 FOR THE AREA SHOWN ON THE MAP.

URANIUM WAS ASSIGNED AN F3 RATING FOR TRACT 249 FOR THE AREA SHOWN ON THE MAP

SOURCE: BASE MAP FROM BLM, RICHFIELD DISTRICT

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 248 , 249 , 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

Ti - TERTIARY INTRUSIVE ROCKS

K - CRETACEOUS ROCKS, CHIEFLY THE MANCOS SHALE

JR - JURASSIC ROCKS, MORRISON AND OTHERS

⌖ 2207 OIL AND GAS EXPLORATION WELL, SHOWING TOTAL DEPTH (DRY)

⚒ URANIUM DEPOSIT WITH 10 TO 100 TONS PRODUCTION of U_3O_8

⚒ URANIUM, <10 TONS PRODUCTION

Xu URANIUM PROSPECT

SOURCE: GEOLOGIC BASE MAP 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.

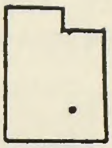
c4-Abundant direct evidence is available from within and/or very near the tract to support or refute the existence of the resource. (When a **c4** certainty is used with an **f1** favorability, it indicates with a high degree of certainty that the resource does not exist in the tract.)

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

TRACT NO: 249 **NAME:** Mt. Hillers **STATE/COUNTY:** UT/Garfield

BLM DISTRICT: Richfield **WSA ACREAGE:** 20,000

DATE PREPARED: June 1982 **UPDATE:** August 1982


LOCATION

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

Tract 249 lies in the Henry Mountains Basin--a large structural depression 100 miles long and 50 miles wide that probably developed in late Cretaceous to Eocene time (about 50 to 70 million years ago). During middle Tertiary time (about 45 million years years ago), large masses of igneous rock were injected into the overlying sedimentary strata along a north-trending belt on the east side of the basin. Subsequent erosion has since exposed many of these igneous masses, along with the sedimentary strata that were tilted sharply during intrusion. The five largest masses of exposed igneous rock now stand thousands of feet above the surrounding plateaus and are collectively referred to as the Henry Mountains. Tract 249 encompasses one of these masses, called Mt. Hillers.

Rocks at the surface in Tract 249 consist of diorite porphyry, surrounded by steeply-dipping sedimentary rocks of Mesozoic age. From oldest to youngest, these strata consist of the Chinle, Wingate, Kayenta, Navajo, Carmel, Entrada, Summerville, Cedar Mountain, Morrison, Dakota, and Mancos Shale (Hackman and Wyant, 1973). The overall structure of the tract is a dome caused by igneous intrusion (a stock). Smaller domes caused by laccolithic intrusions occur along the northern side of the tract.

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: 3

OIL AND GAS:	f2/c1	**HYDROELECTRIC:**	f1/c4
URANIUM:	f3/c3	**GOLD:**	f2/c2
COAL:	f2/c2	**SILVER:**	f2/c2
GEOTHERMAL:	f1/c3	**COPPER:**	f2/c2

RATING JUSTIFICATIONS

OIL AND GAS f2/c1

Tract 249 lies along the east-flank of the Henry Mountains Basin--a moderately-large and moderately-deep structural depression that presumably developed in Cretaceous time (Hunt, 1980). The axis of the basin trends northerly, similar to most other large structural features on the Colorado Plateau, and lies about 15 miles west of Tract 249. The Henry Mountains Basin is one of the few basins in the Rocky Mountain region that is not currently producing petroleum.

The U.S. Geological Survey estimates that southeastern Utah (including the Henry Mountains Basin) and adjacent parts of Colorado contain 1.2 billion barrels of undiscovered, recoverable oil and 3.8 trillion cubic feet of undiscovered, recoverable gas (Dolton and others, 1981; mean estimates for the region designated as the "Paradox Basin"). These estimates indicate that, overall, this region 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 that are related to the development in Pennsylvanian time of the Paradox Basin east of the Henry Mountains (Schneider and others, 1971).

Oil shows in the Henry Mountains Basin have been reported in rocks of Pennsylvanian, Permian, and Triassic age [the Paradox Formation, the Honaker Trail Formation, the White Rim/Coconino Sandstone, the Kaibab Formation, and the Moenkopi Formation (Heylmun and others, 1965; Blakey, 1974, 1977; Campbell and Ritzma, 1979; Irwin and others, 1980)]. In addition, very large accumulations of oil are contained in sandstone deposits now exposed at the surface in the Circle Cliffs area 20 miles to the west and in the Tar Sand Triangle 20 miles to the northeast (oil-impregnated sandstones; Campbell and Ritzma, 1979).

The geology of Tract 249 is not favorable for oil and gas. As pointed out by Irwin and others (1980), a large part of the Pennsylvanian section is exposed in Cataract Canyon 30 miles to the east and in other parts of the Monument Upwarp. Furthermore, Permian, Triassic, Jurassic, and Cretaceous strata are exposed progressively closer to the tract along the eroded east-flank of the Henry Mountains Basin (Hintze, 1980). As a result, Irwin and others (1980) warn the exploration geologist that Pennsylvanian and younger rocks in the Henry Mountains Basin may have little or no reservoir pressure.

In addition to the problems outlined above, Tract 249 was intruded by a large mass of igneous rock in middle Tertiary time (a stock and subsidiary laccoliths; see Hunt and others, 1953). The sedimentary rocks into which this igneous mass was intruded now dip steeply away from the crest of Mt. Hillers, suggesting forceful igneous intrusion (Hunt and others, 1953). The temperature of the intrusion near its contact with the surrounding country rock is estimated by Hunt (1980) to have been about 550°C. At a minimum, the intrusive rock pierced strata as young as Cretaceous age; thus, hydrocarbons and reservoirs that may have existed in older favorable sedimentary rocks near the intrusion were almost certainly destroyed by the heat. The volume of rock that may have been adversely affected by these intrusions is difficult to judge. Metamorphism (and brecciation) of the country rock surrounding Mt. Hillers is slight (Hunt and others, 1953), so it seems reasonable to speculate that petroleum accumulations that had existed a "safe" distance from the intrusions may still exist. Moreover, post-intrusive migration and entrapment of hydrocarbons may have occurred along the sedimentary flanks of the dome caused by these intrusions. Nevertheless, exploratory drilling in the basin has been very discouraging. This fact has lead some geologists to conclude that the Henry Mountains Basin is simply not petroliferous; or that most hydrocarbons have already migrated out of the Henry Mountains Basin and are now exposed in nearby giant oil-impregnated rock deposits (Baars and Seager, 1970; Blakey, 1974 and 1977). [The "Tar Sand Triangle" on the east side of the Henry Mountains Basin is estimated by Ritzma (1979) to contain 12.5 to 16 billion barrels of in-place-oil, chiefly in the White Rim Sandstone of Permian age. The Circle Cliffs deposit on the west side of the basin is estimated by Ritzma (1979) to contain 1.3 billion barrels of in-place-oil, chiefly in the Moenkopi Formation of Permian age. Ritzma (1980), in contrast to part of the discussion above, believes that the oil in the Circle Cliffs deposit did not migrate over great distances.]

Few exploratory wells have been drilled in the vicinity of the Henry Mountains (PIC, 1981). In 1961 Superior Oil drilled a 9,682-foot dry well that penetrated Mississippian rocks a few miles west of the tract (Heylmun and others, 1965). Also, a 6,242-foot well was drilled about 6 miles northwest of the tract by Webb Oil; it was also dry (PIC, 1981). The only other oil test near Tract 249 was drilled along Maze Arch about 6 miles to the north to a total depth of 2,278 feet and it also was reported to have been dry (PIC, 1981).

On the basis of the relatively unfavorable igneous history of Tract 249, along with the discouraging results of nearby exploration, we have assigned the tract an oil and gas favorability of f2. If hydrocarbons exist in Tract 249, they would most likely be in small accumulations in pre-Laramide structural traps, and in stratigraphic traps. The certainty that oil and gas resources exist (or do not exist) in Tract 249 is very low and has been assigned a value of c1.

URANIUM f3/c3

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.

The principal uranium bearing units on the Colorado Plateau are the Morrison Formation of Jurassic age and the Chinle Formation of Triassic age. The most important producing areas are Grants/Laguna in northwestern New Mexico, Lisbon in east-central Utah, the Uravan mineral belt in west-central Colorado, and Monument Valley-White Canyon in southeastern Utah and northeastern Arizona (Fischer, 1968).

Uranium deposits in the Henry Mountains Basin occur in the Salt Wash Member of the Morrison Formation (Johnson, 1959; Hackman and Wyant, 1973; Doelling, 1975; Chenoweth, 1980). Most of the known deposits lie a few miles east of the Henry Mountains in a north-trending zone known as the Henry Mountains mineral belt. This mineral belt has accounted for 98 percent of the uranium produced in the Henry Mountains region (Chenoweth, 1980). Deposits that have been mined to date are small; according to Grundy [as reported in Cenoweth (1980, p. 299)], 80 tons of ore is the mean deposit size.

Similar to many of the uranium mining districts on the Colorado Plateau, the Henry Mountains area went through three periods of development--an early period for radium, a middle period for vanadium, and the latest period of uranium exploration and development (Chenoweth, 1980). During the first five decades of this century, very little radium and vanadium were produced from the Henry Mountains area. From 1948 through 1978, the time of maximum uranium/vanadium production, approximately 240 tons of U_3O_8, and 850 tons of V_2O_5, were produced from deposits within the Henry Mountains mineral belt (Chenoweth, 1980).

In the late-1970s, the discovery of three large uranium deposits in the southern part of the Henry Mountains mineral belt was announced by Plateau Resources (Chenoweth, 1980). Cumulative reserves for the three deposits is estimated to be about 2,900 tons of U_3O_8 at an ore grade ranging from 0.04 to 0.50 percent U_3O_8 (Peterson and others, 1980). These discoveries generated a surge of uranium exploration in the Henry Mountains area during the late-1970s that resulted in additional discoveries in the central and northern parts of the mineral belt.

The uranium resource potential of the Henry Mountains Basin is estimated to be relatively large [18,850 tons U_3O_8 of "probable" and "possible" resources according to DOE (1979)]. Most of the potential is assigned to the Salt Wash Member of the Morrison Formation within the Henry Mountains mineral belt (Peterson and others, 1980). The middle or "Trachyte section" of the Henry Mountains mineral belt trends through the northeast corner of Tract 249 (Hackman and Wyant, 1972). Ore bodies in the Trachyte section are associated with carbonaceous trash and mudstone, and are commonly 50-feet long, 20-feet wide, and 2-feet thick (Chenoweth, 1980). According to Chenoweth (1980), the Trachyte section has produced about 37 percent of the mineral belt's total recorded production of 240 tons of uranium oxide.

About a half-dozen uranium prospects are located in the Salt Wash Member in Tract 249; many deposits with recorded production lie a short distance to the north and south (Hackman and Wyant, 1972; Chenoweth, 1980; Peterson and others, 1980). On the basis of the obvious favorability of the Henry Mountains mineral belt, along with the size of recent discoveries to the south, we have assigned the tract a uranium favorability of f3. The certainty that uranium resources occur in the tract is relatively high (based on many nearby occurrences) and has been assigned a rating of c3.

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.

The bulk of the coal in the Henry Mountains Basin lies west of the Henry Mountains. The most important coal beds are in the Mancos Shale (the Emery and Ferron Sandstone Members). Minor coal-bearing carbonaceous beds occur in the older Dakota Sandstone. All the coal is of Cretaceous age and it is best developed along the synclinal axis of the Henry Mountains Basin to the west of Tract 249 (Law, 1980).

Doelling and Graham (1972) estimate that only about 9,000 tons of coal have been produced from the Henry Mountains coal field. The coal was mined during the first half of the century, chiefly for local use; no mines are currently active (Law, 1979).

Coal reserves in the Henry Mountains field are small by Utah standards--only 231 million tons in beds greater than 4-feet thick according to Doelling and Graham (1972). About 80 percent of these reserves are assigned to the Emery Sandstone Member. A little less than one-third of the reserves are considered to be strippable by Doelling and Graham (1972); this is the only advantage that the Henry Mountains field has over nearby coal fields. Otherwise, coal in the Henry Mountains field is relatively thin (except in local areas where beds exceed 9-feet thick), accessibility to the field is poor, and the coal is of somewhat poorer quality compared with other Utah coal fields.

A belt of Ferron Sandstone extends into the southwestern corner of Tract 249 (Doelling and Graham, 1972). Although coal was reported in this belt by Doelling and Graham (1972), these authors do not show coal beds within the boundary of the tract, except for a minor occurrence south of Cass Creek Peak. Coal in the Ferron in apparently better developed southwest of the tract near the Stanton mine. Doelling and Graham (1972) also report minor occurrences of coal within the tract in the Emery Sandstone.

On the basis of the foregoing discussion, Tract 249 has been assigned a coal favorability of f2. Because of poor exposures, the certainty that coal resources occur in the tract is low and is assigned a rating of c2.

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 occur on the Plateau; Berry and others, 1980). The overall geothermal potential of the Colorado Plateau, including the Henry Mountains Basin, consequently is considered to be very low.

The only geothermal potential associated with Tract 249 is deep-seated, low-temperature thermal waters (between 20°C and 90°C). Although igneous rocks are abundant, they are much too old to be considered a present-day heat source. [Radiometric dates reported by Armstrong (1969) indicate an age of 44 to 48 million years old (Eocene) for the igneous rock in the Henry Mountains. Hunt (1980) considers this age to be excessive, and prefers an age of 20 to 25 million years on the basis of regional geologic relationships.] A warm spring (26°C) in Red Canyon, about 20 miles southeast of Tract 249, is the only visible and naturally-occurring manifestation of geothermal energy in the entire region (NOAA, 1980). In addition, two thermal wells a few miles west of Mt. Ellsworth and about 10 miles south of Tract 249 report surface water temperatures of 20°C and 21°C (NOAA, 1980; one well is about 470 feet deep, the other is about 840 feet deep). 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 Henry Mountains area 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 lowered the depth to ground water over much of the Colorado Plateau; thus, even low-temperature geothermal resources probably lie at considerable depths throughout most parts of the Plateau. On the basis of the geologic characteristics of the Henry Mountains Basin, we have therefore assigned Tract 249 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. 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 249. On the basis of this information we have assigned Tract 249 a hydropower favorability rating of f1 and a certainty of c4 that this resource does not occur in the area.

GOLD/SILVER/COPPER f2/c2

Besides the mineral fuels that have been produced from the Henry Mountains region (coal, uranium/vanadium), small amounts of gold, silver, and copper have also been discovered and mined in the Henry Mountains (Hunt and others, 1953; Doelling, 1975). Hunt and others (1953) characterize the mineralized environments in the Henry's as follows: deposits within fissures in the inrusive rocks (the stocks), and within fissures in the overlying shattered sedimentary rocks; disseminated deposits in surrounding laccoliths; and placer deposits in the alluvial debris that surround the peaks. According to Doelling (1980), about 75 percent of the total value of production was derived from fissure deposits in Bromide Basin on Mt. Ellen--about 700 ounces of gold, 3,000 ounces of silver, and about 9 tons of copper.

The history of mineral exploration and production in the Henry Mountains is colorful and worthy of a brief summary in this report. The account that follows is quoted directly from Doelling (1980, p. 290-291):

> "After gold was discovered in the placers along the Colorado River near Hite in 1883, prospectors eyed the Henry Mountains as the possible mother lode. This possibility was enhanced when the precious metal was found in the streams leading from them. After much painstaking prospecting, gold-bearing fissures were discovered in Bromide Basin in 1889 on the east side of Mt. Ellen above the 10,000-foot level. [Bromide Basin is

> about 4 miles north of Tract 249.] Expectations ran high and a small town, known as Eagle City, was built 2 mi below the basin, complete with shops, saloon, and sheriff. The Bromide mine...came into production in 1891..." and "...$15,000 worth of ore was produced between 1891 and 1893....Soon thereafter the bubble burst, a rich chute of ore along the fissure was mined out, and no new economical ore had been blocked out. The mine was closed and Eagle City quickly became a ghost town."

Intermittent mining continued in the Bromide Basin area through about 1939. In 1913, the Bromide fissure was explored to depths of perhaps a few hundred feet below the previous workings, but economic deposits were not discovered (Butler, 1920). According to Doelling (1980), prospecting and assessment work have continued to the present, but that the small near-surface deposits along fissures in Bromide Basin are mined out.

Two mines and a few prospects occur along fissures on Mt. Hillers within Tract 249 (no production is reported from these mines; Hunt and other, 1953; Doelling, 1980). Doelling (1980) reports that only some of the many north-trending fissures on Mt. Hillers are mineralized and that they contain chalcopyrite, bornite, copper carbonate, chrysocolla, and some molybdenite.

In addition to the deposits described above, gold-bearing placers occur in the gravels along some creeks that drain the Henry Mountains. Production, however, is reported only from the northeast side of Mt. Ellen, intermittently from the late-1800s to the 1940s (Doelling, 1980). No more than about 350 ounces of gold were recovered during this period, but with the recent increase in the price of gold, interest in placer gold in the Henry Mountains has also increased. Doelling (1980) states, however, that the gold particles in these placer deposits are very small (flour gold) and often float away during sluicing or panning. Furthermore, large quantities of water to work the gravel are not readily available.

In summary, the mineral potential of the Henry Mountains for gold, silver, and copper is apparently low. Although mineral exploration for these commodities will probably continue in the area, and small mining operations may begin as metal prices increase, the overall resource potential of the Henry Mountains for gold, silver, and/or copper is judged to be low. Tract 249 is therefore assigned a favorability of f2 for this group of minerals, with a relatively low certainty (c2) that these resources exist in the tract.

OVERALL-IMPORTANCE RATING 3

Tract 249 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 rating is based chiefly on the uranium potential of the northeast part of the tract, rated at f3, the high certainty of resource occurrence. All other resources evaluated for Tract 249 were assigned favorabilities of f2 or less, and they did not contribute substantially to the assigned OIR.

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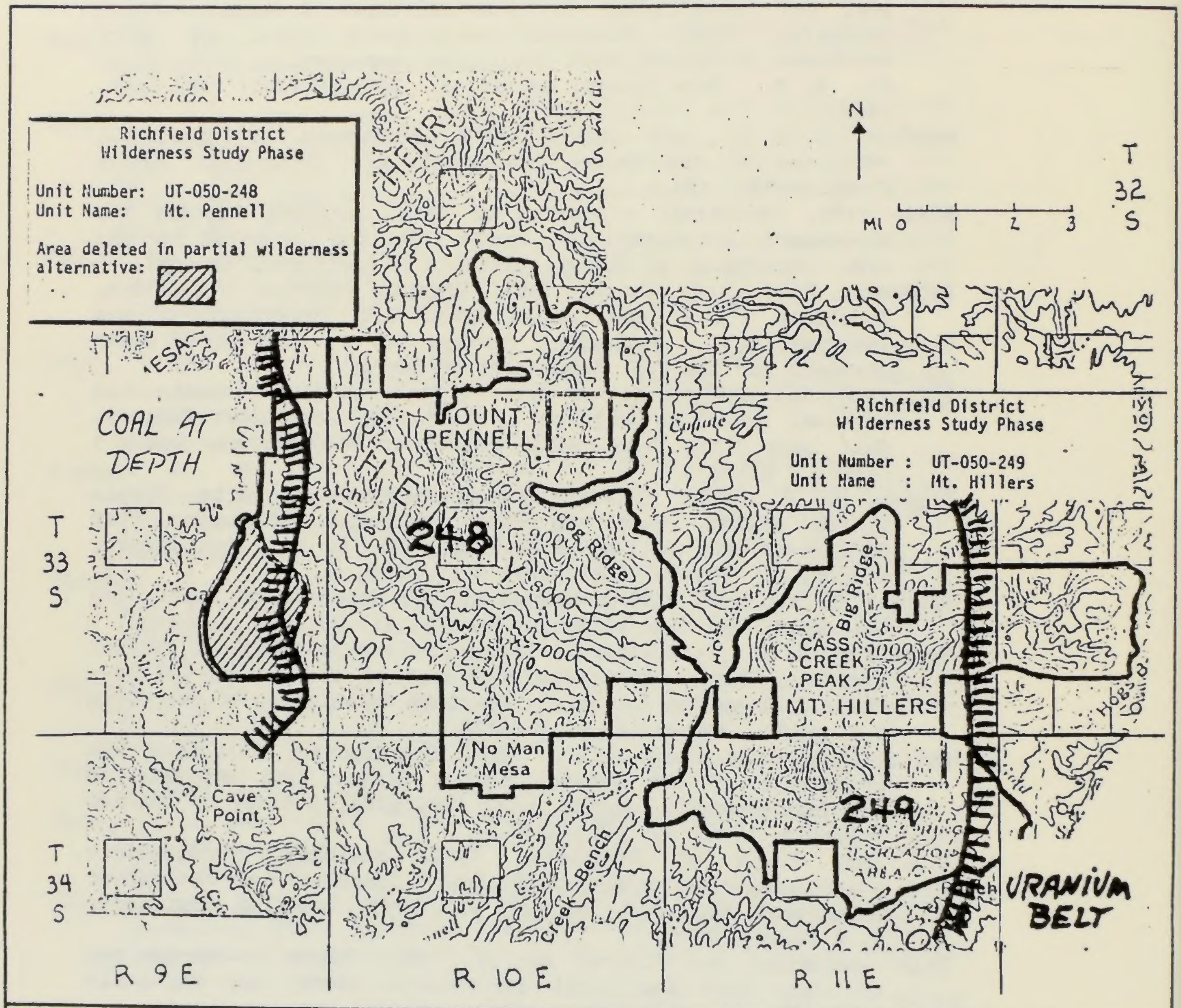
MINERAL-RESOURCE POTENTIAL MAP OF WILDERNESS STUDY AREA (WSA) 248, 249, UTAH

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



EXPLANATION

COAL WAS ASSIGNED AN F4 RATING FOR TRACT 248 FOR THE AREA SHOWN ON THE MAP.

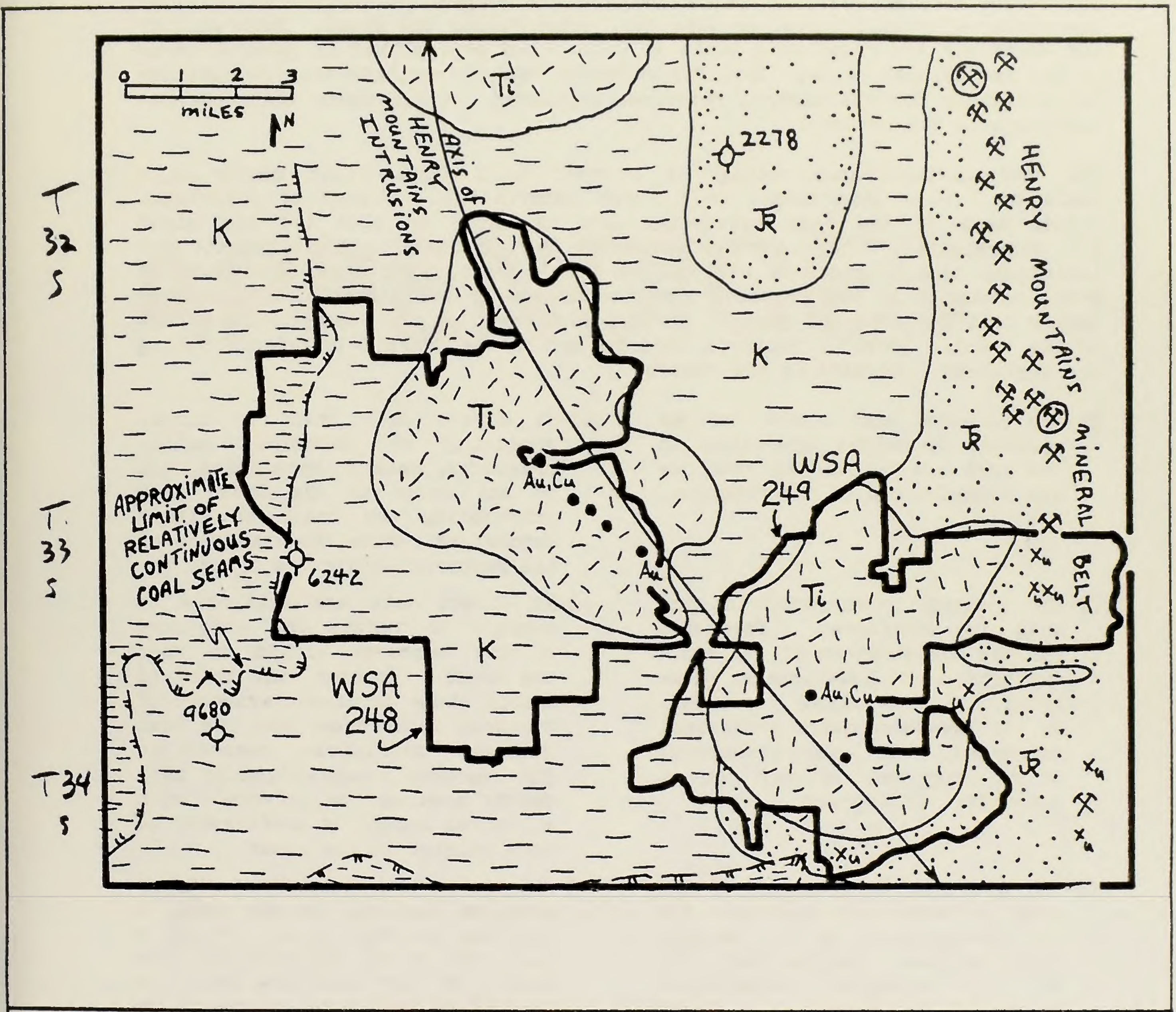
URANIUM WAS ASSIGNED AN F3 RATING FOR TRACT 249 FOR THE AREA SHOWN ON THE MAP

SOURCE:

BASE MAP FROM BLM, RICHFIELD DISTRICT

GEOLOGIC SKETCH MAP OF WILDERNESS STUDY AREA (WSA) 248, 249, 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

Ti - TERTIARY INTRUSIVE ROCKS

K - CRETACEOUS ROCKS, CHIEFLY THE MANCOS SHALE

JR - JURASSIC ROCKS, MORRISON AND OTHERS

⌖ 2207 OIL AND GAS EXPLORATION WELL, SHOWING TOTAL DEPTH (DRY)

⊗ URANIUM DEPOSIT WITH 10 TO 100 TONS PRODUCTION OF U_3O_8

(X) URANIUM, <10 TONS PRODUCTION

Xu URANIUM PROSPECT

SOURCE:

GEOLOGIC BASE MAP 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.)

APPENDICES

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 concommitant 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, postive 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 those 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 these 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 those 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 coppar 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.]