Mineral Resources of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1746–B

Chapter B

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U.S. GEOLOGICAL SURVEY BULLETIN 1746

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHWESTERN UTAH

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Parunuweap Canyon (UT–040–230) Wilderness Study Area, Kane County, Utah.

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1. Geologic and mineral resource potential map of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah

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Mineral Resources of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah

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SUMMARY

Abstract

The Parunuweap Canyon Wilderness Study Area (UT–040–230) is in southwestern Utah adjacent to Zion National Park. A small part of the study area contains identified (known) resources of gypsum, and the study area also contains inferred subeconomic resources of sandstone, sand and gravel, and ornamental stone. The study area has a moderate resource potential for undiscovered oil and gas; a low potential for undiscovered uranium and silver resources, and for undiscovered geothermal energy and coal resources; and no potential for gypsum outside the small area that has identified resources.

Character and Setting

The Parunuweap Canyon Wilderness Study Area is in southwestern Utah in the western part of Kane County. It is about 15 mi (miles) northwest of Kanab, 3 mi west of Mount Carmel Junction, and 10 mi east of the Springdale entrance to Zion National Park (fig. 1). At the request of the U.S. Bureau of Land Management, mineral surveys were conducted on about 18,000 acres of the Parunuweap Canyon Wilderness Study Area. In this report, the area studied is called wilderness study area, or simply study area. The study area consists almost entirely of canyon lands cut by the East Fork of the Virgin River and its tributaries. The boundary closely follows the rims of the canyons, except where parcels of State and private land are excluded, and the western boundary adjoins Zion National Park. Access is from the north by secondary roads leading off State Highway 9, from the east and south from jeep trails leading off a gravel road south of Mount Carmel Junction, and from a paved road north of Coral Pink Sand Dunes State Reserve. Popular hiking trails follow the East Fork of the Virgin River through the canyon. These trails begin southwest of Mount Carmel Junction along the river and at several points on the south rim of the canyon.

Parunuweap Canyon is cut almost entirely in Navajo Sandstone. Natural arches, pinnacles, and large areas of "slickrock" are common features, and most of the canyon walls are steep. Local relief averages about 800 ft (feet); maximum relief is about 1,400 ft. The lowest point (elevation 4,600 ft) is on the East Fork of the Virgin River at the western boundary of the study area.

The Parunuweap Wilderness Study Area is in the western part of the Colorado Plateau, a tectonically stable province that was uplifted during the Cenozoic Era. (See geologic time chart in Appendix.) Uplift was accompanied here by faulting, basaltic volcanism, and deep erosion.

Only Jurassic rocks are exposed in the wilderness study area. These include, in ascending order, the Navajo Sandstone, the Temple Cap Sandstone, and the Carmel Formation. The Navajo Sandstone (Lower Jurassic) is the bedrock in about 80 percent of the study area, and at least 1,500 ft of the unit is exposed in Parunuweap Canyon. It is

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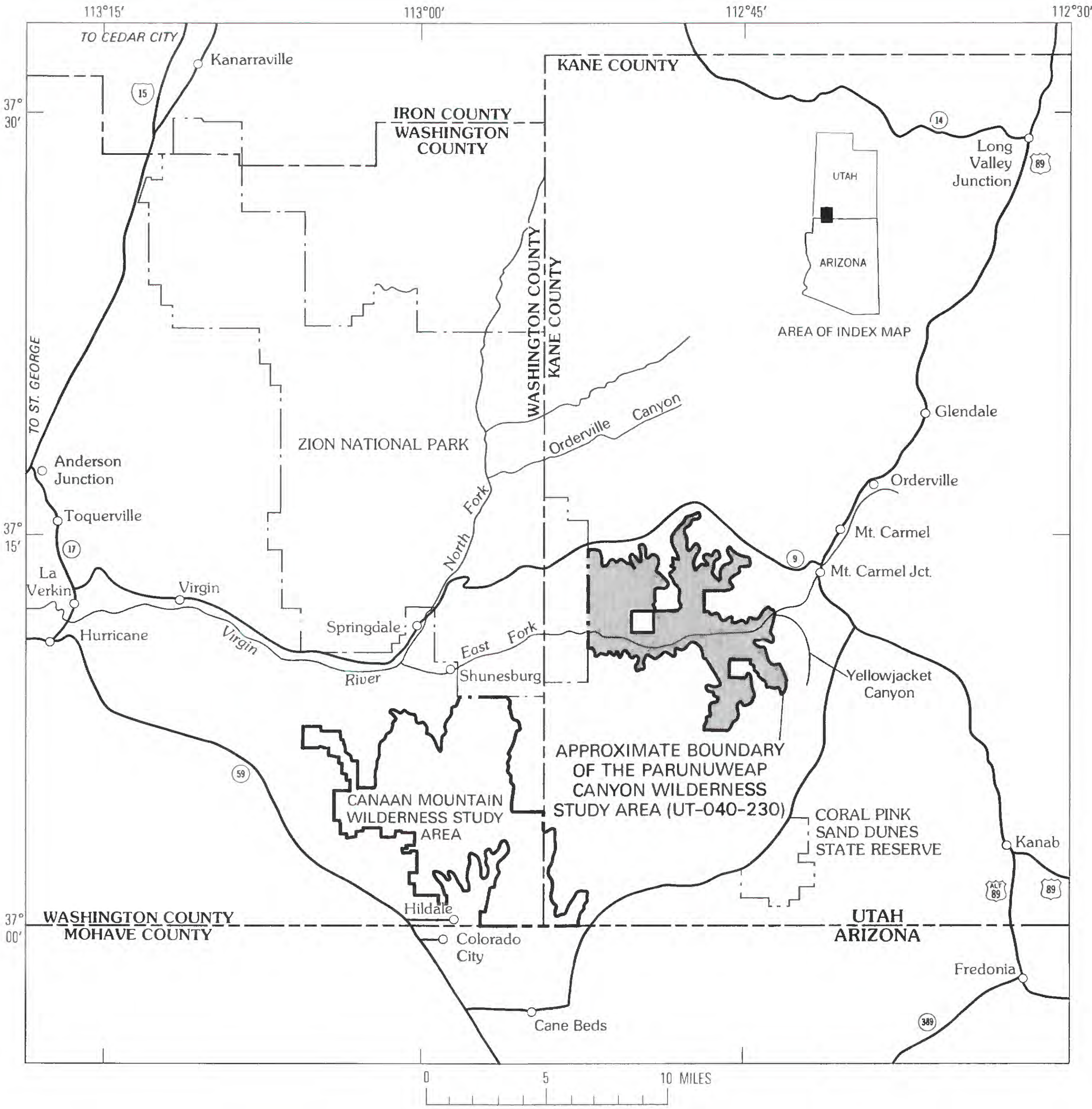


Figure 1. Location of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah.

not known to contain ore deposits in this region; however, it is an excellent aquifer. The Temple Cap Sandstone (Middle Jurassic) overlies the Navajo and consists of about 150 ft of sandstone, siltstone, and mudstone. The uppermost rock unit exposed in the study area is the Carmel Formation (Middle Jurassic) of the San Rafael Group. It is about 600 ft thick and consists of four members: the limestone, banded, and gypsiferous members, and the Winsor Member. Although no commodities have been produced from this formation in the study area, elsewhere limestone from the formation has been exploited for road metal, and gypsum has been exploited for artistic and ornamental uses. Rocks of Cretaceous age are not present in the study area but are exposed along the northern boundary. Coal has been mined nearby from the Tropic Shale (Upper Cretaceous) north of State Highway 9, and uranium was mined from conglomerates of the Dakota Sandstone (Upper Cretaceous) 8 mi north in Orderville Canyon. Extensive sand and silt deposits cover much of the land surface of the study area. Some of this material is susceptible to the wind, forming small sand dunes derived mainly from the Navajo Sandstone. Dune sands in the Coral Pink Sand Dunes State

Reserve, 10 mi south of the study area, illustrate current eolian processes of the region.

Rocks in the subsurface of the Parunuweap Canyon study area, of Paleozoic and early to middle Mesozoic ages, are more than 9,500 ft thick. Several of these rock units could serve as reservoirs for oil and gas. The Paleozoic rocks are a thick sequence of clastic and carbonate rocks and minor evaporite rocks. The Chinle Formation (Upper Triassic) is known for its uranium-bearing strata in many areas of Utah, and the Moenave Formation (Lower Jurassic) is known for its silver deposits in the Silver Reef district at Leeds, 30 mi west of the study area.

Identified Resources

The Parunuweap Canyon Wilderness Study Area contains identified resources of gypsum. The gypsiferous member of the Carmel Formation crops out along Meadow Creek in the extreme northern part of the study area (fig. 2). Six million tons of gypsum occurs there; however, larger amounts occur just outside the study area. The gypsiferous member crops out for many miles to the northwest and southeast, and most of the outcrop area is more accessible than the study area. Large quantities of common-variety sandstone, sand, gravel, and limestone also occur in the study area, but they are classified as inferred subeconomic resources. There are no mines, prospects, or mineral leases within the study area. Two unpatented lode claims are on ground underlain by Navajo Sandstone along and partly inside the eastern boundary. No oil and gas exploration drilling has been done within the study area.

Potential for Undiscovered Resources

The Parunuweap Canyon Wilderness Study Area has a moderate potential for undiscovered resources of oil and gas. The stratigraphic setting of the study area is similar to that of the nearby Virgin oil field. That field, about 15 mi west of the study area, has produced about 200,000 barrels of oil since 1907, from structural and stratigraphic traps in the Lower Permian Kaibab Limestone and in the Lower Triassic Timpoweap Member of the Lower and Middle(?) Triassic Moenkopi Formation. These and other favorable Paleozoic reservoir rocks occur more than a thousand feet beneath the study area.

The study area has a low potential for any undiscovered resources of uranium and silver, and for undiscovered geothermal energy and coal resources. The formations exposed in the study area are not known to contain mineral or energy resources anywhere in the region, and geologic mapping and geochemical sampling have not revealed any anomalous values. Geophysical data do not indicate any anomalies at depth in the study area.

Although the Chinle is an important host rock for uranium deposits in many parts of the Colorado Plateau, it has not proven to be a favorable host in this region. The Moenave is host to rich deposits of silver and uranium nearby in the Silver Reef district, but other such deposits are not known.

The study area lies in terrane shown by Muffler (1978) as having low heat flow and therefore has low potential for geothermal energy resources.

Coal occurs north of the study area in Cretaceous rocks in the Kolob coal field, but there are no rocks of this age in the study area, nor do any exposed rock units contain coal. The area therefore has a low potential for coal.

The gypsiferous member of the Carmel Formation is present only in the area shown as having identified resources of gypsum (fig. 2); no potential exists for other deposits of this commodity in the study area.

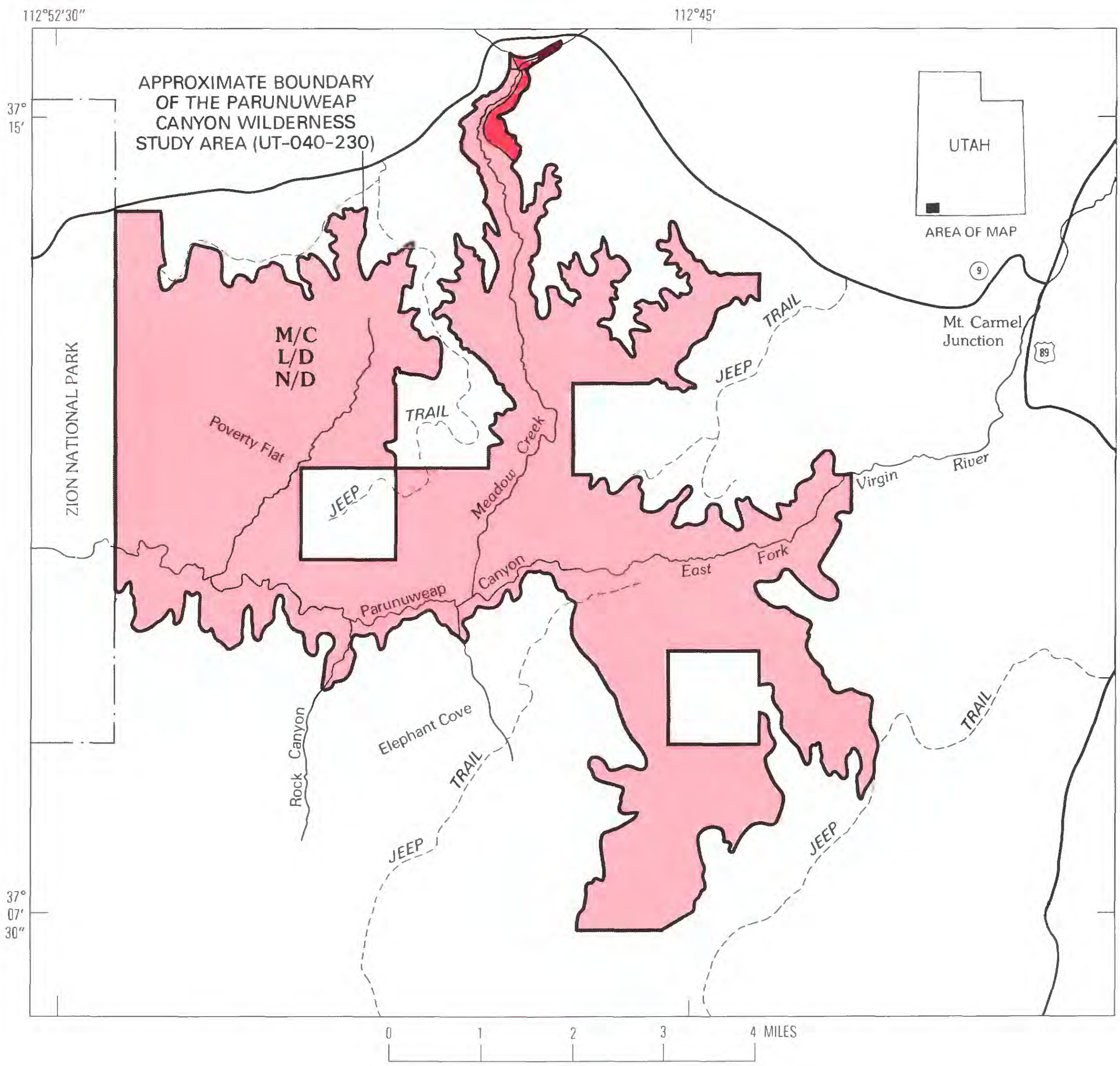
INTRODUCTION

The Parunuweap Canyon Wilderness Study Area (UT–040–230) is in the central western part of Kane County, Utah, about 15 mi northwest of Kanab and 3 mi west of Mount Carmel Junction (fig. 1). This study area is one of 12 wilderness study areas bordering Zion National Park.

The Parunuweap study area consists almost entirely of canyon lands cut by the East Fork of the Virgin River and its tributaries. The boundary follows closely the rims of the canyons, except where parcels of state and private land are excluded. The western boundary, about 4 mi long, adjoins Zion National Park (fig. 1).

State Highway 9, which runs between Mount Carmel Junction and Zion National Park, provides access to several secondary roads that approach the study area from the north. One road follows parts of the north canyon rim (northwest part of the study area) and connects with a road down into Poverty Flat (fig. 2). A gravel road branching off State Highway 89 south of Mount Carmel Junction passes through Yellowjacket Canyon and runs along the edge of the Coral Pink Sand Dunes State Reserve. Several jeep trails branching off this road provide access to the eastern and southern parts of the study area. These trails can be difficult for travel because they cross large areas of sand. A few of these trails go as far as the south rim of Parunuweap Canyon, and hikers can gain access into the canyon where these trails end. Some of the popular hiking routes down the canyon begin at these points. Hiking the Parunuweap Canyon from here or from the river below Mount Carmel Junction to Shunesburg is probably the principal recreational activity provided by the study area.

The study area has a desert climate. Except during the early spring runoff and during periods of heavy rains the volume of water in the East Fork of the Virgin River is modest, and the tributary streams are mostly ephemeral. Vegetation consists mostly of pinon pine, oak, sage brush, and manzanita. Although grass is not abundant, cattle grazing appears to be the only commercial activity within the study area. There is no



EXPLANATION OF MINERAL RESOURCE POTENTIAL

(red)	Area having identified resources of gypsum, as well as a moderate resource potential for oil and gas
M/C	Geologic terrane having a moderate resource potential for oil and gas, with certainty level C—Applies to entire study area
L/D	Geologic terrane having a low resource potential for uranium and silver, and for geothermal sources and coal, with certainty level D—Applies to entire study area
N/D	Geologic terrane having no potential for gypsum, with certainty level D—Applies to that part of the study area not containing identified resources of gypsum

Figure 2. Mineral resource potential of the Parunuweap Canyon Wilderness Study Area, Kane County, Utah.

evidence of mining or exploration within the area. Prior to 1985 the area was leased for oil and gas, but these leases have since expired and have not been renewed by the Bureau of Land Management (BLM). Coal was mined just north of the study area boundary, and some trees along the north rim have been cut for timber and for firewood.

The Parunuweap Canyon Wilderness Study Area is underlain by rocks of Jurassic age. These include, from oldest to youngest, the Navajo Sandstone, the Temple Cap Sandstone, and the Carmel Formation. The banded and gypsiferous members and the Winsor Member (a sandstone unit) of the Carmel are exposed only in the northern part of the study area along Meadow Creek. The bulk of the study area is underlain by Navajo Sandstone, a rock unit renowned in this region for its spectacular landforms. During the Cenozoic Era, the region has been uplifted several thousand feet and all younger rocks have been removed by erosion. Erosion of the Navajo Sandstone is controlled largely by a pervasive set of fractures (joints), and accelerated weathering along these fractures is responsible for many of the landforms characteristic in this region. Natural arches, pinnacles, and large areas of "slickrock" are common in this terrain. The walls of Parunuweap Canyon are steep and in part overhanging. Local relief in the study area averages about 800 ft, and maximum relief is about 1,400 ft. The lowest point (elevation 4,600 ft) is on the East Fork of the Virgin River at the western boundary of the study area.

Investigations by the U.S. Bureau of Mines

The Bureau of Mines field investigation of the Parunuweap Canyon Wilderness Study Area was preceded by a review of various sources of minerals information, including published and unpublished literature and Bureau files, regarding the geology and mineral resources of the region. BLM files in Cedar City and Salt Lake City, Utah, were reviewed for information on mining claims and oil, gas, coal, and geothermal leases. BLM geologists, National Park Service personnel at Zion National Park, and local residents were consulted regarding minerals information for the area in and near Parunuweap Canyon.

Field investigations, consisting of a search for mines, prospects, and mineralized areas in or within 1 mi of the study area, were conducted in September 1986 and May 1987. Twelve chip samples of sandstone and limestone outcrops were taken and analyzed by Skyline Labs, Inc., of Wheat Ridge, Colo. The seven sandstone samples were analyzed for gold, silver, and copper by atomic absorption spectrometry. Sieve analyses were performed on two of these samples. Whole-rock analyses were performed on all 12 samples, and 10 were analyzed for 31 elements by optical emission spectrography. (See Zelten, 1987.) Additional information is available from the U.S. Bureau of Mines, Intermountain Field Operations Center, Resource Evaluation Branch, P.O. Box 25086, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

The assessment of the potential for undiscovered resources in the Parunuweap Canyon Wilderness Study Area is based largely on consideration of the geologic setting, geophysical data, and results from geochemical sampling. Field work for these studies was done in parts of the months of May 1985, September 1985, June 1986, and September 1986.

The area was field mapped in 1986 by Sable and Van Loenen, who used color aerial photographs of 1:24,000 scale and black-and-white aerial photographs of 1:33,200 scale in compilation of the geologic map. Geologic maps by Cashion (1967a) and Sargent and Philpott (1985, 1987) were also used with modifications in compiling the northern and eastern parts of the mapped area.

The top of the Navajo Sandstone was contoured over parts of the study area to help identify structures that might affect mineral resources. (See figure 3.) Geophysical studies herein interpreted by Blank included gravity (fig. 5), aeromagnetic (fig. 4), and aeroradiometric surveys. Some new gravity stations were established by Blank, and data obtained from them were used in this report. Thirty stream-sediment samples were collected and analyzed in the geochemical survey. Analytical data and sample locations are by Bullock and others (1988).

Information used in establishing oil and gas potential is taken largely from Ryder (1983) and Molenaar and Sandberg (1983). Other sources of data are Bahr (1963), who described the Virgin oil field, Oakes and others (1981), who evaluated energy resources for the study areas; and the U.S. Department of Energy (1979), which evaluated uranium resources for the region.

Pertinent literature on the geology of the areas in and surrounding the study area includes a comprehensive report on the geology of the Zion National Park region (Gregory, 1950) and an overall geologic perspective with diagrammatic illustrations of geologic history and stratigraphic units of Utah (Hintze, 1973). Areal geologic reports and maps are by Cashion (1967a), Sargent and Philpott (1985, 1987), and Hamilton (1978). Stratigraphic studies include discussions of lower and middle Mesozoic units (Wilson and Stewart, 1967; Cashion, 1967b) and a review and interpretation of the Navajo

Sandstone and other Jurassic units (Peterson and Pipiringos, 1979). A recent comprehensive report on the geologic history and landforms of Zion National Park by Hamilton (1984) is oriented towards both professional and nonprofessional audiences.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown in the Appendix of this report. Identified resources are studied by the USBM. Mineral resource potential is the likelihood of occurrence of undiscovered metals and nonmetals, industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984), which also is shown in the Appendix. Undiscovered resources are studied by the USGS.

APPRAISAL OF IDENTIFIED RESOURCES

By J.E. Zelten
U.S. Bureau of Mines

Mining and Mineral Exploration History

The nearest mining district to the Parunuweap Canyon Wilderness Study Area is the Silver Reef (Harrisburg) district, about 30 mi to the west. Between 1875 and 1910 nearly $8,000,000 of high-grade silver ore (over 7,000,000 ounces of silver), with small amounts of associated copper, uranium, and vanadium, was produced from the Upper Triassic(?) Springdale Sandstone Member (locally referred to as the "Silver Reef Sandstone") of the Moenave Formation in this district (Heyl, 1978; Proctor, 1953). In 1950, 8.68 tons of ore averaging 0.56 percent uranium was shipped (Gregory, 1950). The Moenave is present beneath the study area, but there is no surface evidence that it is mineralized.

Mines, Prospects, Mining Claims, and Leases

No mines, prospects, or mineral leases are present in the study area, and the area is not included in any mining district. Two unpatented lode claims are on the Navajo Sandstone along and partially inside the eastern boundary. There are no workings on these properties and there is no visible evidence of mineralization.

Petroleum has been produced from several fields in this part of Utah, the nearest being the Virgin and Anderson Junction oil fields, about 17 and 22 mi to the west, respectively. In the Virgin field, oil and small amounts of gas were produced intermittently from the Timpoweap Member of the Moenkopi Formation and the underlying "Rock Canyon Conglomerate" unit. Total oil production from this field between 1907 and 1970 was over 200,000 barrels (Stowe, 1972). Several test holes drilled to various depths below the Moenkopi within 5 mi east of the study area were dry and abandoned. Approximately 1,380 barrels of oil were produced from the Pennsylvanian Callville Limestone in the Anderson Junction field between 1968 and 1970. The field was shut-in in 1971. Both the Moenkopi and Callville Formations are probably present at depth beneath Parunuweap Canyon, but there has been no local drilling to determine if they contain oil or gas. (See Peterson, 1974.)

Rounded to irregularly shaped iron concretions commonly weather out of the Navajo. Some that have unusual shapes, coloration, or internal structures are sometimes collected and sold as curiosities. Most of the popular collecting sites are east of Parunuweap Canyon. Concretions like the ones found in the Navajo in Parunuweap Canyon are abundant and readily available throughout the region.

Identified Resources

Identified resources present in the study area include about 6 million tons of gypsum and large quantities of common-variety sandstone, sand and gravel, and limestone, which are classified as inferred subeconomic resources according to the system of the U.S. Bureau of Mines and U.S. Geological Survey (1980), which is shown here in the Appendix.

Gypsum

A gypsum bed in the Carmel Formation, averaging about 35 ft in thickness and dipping about 1° to the northeast, crops out along Meadow Creek in the extreme northern part of the study area (fig. 2, pl. 1). This gypsum can be followed for many miles to the northwest and southeast and has been used as a marker bed throughout the region. Inferred subeconomic resources of surface-minable gypsum were calculated for an area inside the study area and within ¼ mi of its boundary. Resource estimates were based on an average thickness of 35 ft and an assumed continuity of gypsum back from the outcrop, and were limited to the gypsum covered by no more than

100 ft of overburden. About 30 million tons of gypsum are in this area; of this tonnage, at least 6 million tons lie inside the study area. Any mining would most likely occur outside the boundary, in the more flat-lying area east of Meadow Creek and south of Highway 9, where the gypsum is more readily accessible.

Examination and sampling of gypsum from this bed at various localities have shown its quality to be fairly consistent (Zelten, 1987). The gypsum is pure enough to have value for use in building materials, fertilizer, cement, and many other products. Gypsum is a low-unit-value, high-bulk commodity, and the most important factor in evaluating a deposit is its proximity to markets. Deposits of high quality and commercial size are so widespread in the United States that development largely depends on the accessibility and the demand for gypsum and gypsum products in the region near the deposit. (See Moyer, 1939; Bates, 1969; and Appleyard, 1983.) Because of the absence of a nearby market and the presence of large, minable deposits elsewhere in Utah nearer to markets, this deposit is not likely to be developed at this time or in the foreseeable future.

Sandstone, Sand, and Gravel

An inferred subeconomic resource of sandstone, which underlies the entire study area and crops out over about 80 percent of it, as well as sand and gravel present in the drainages, could be used locally for construction purposes. Because these are high-volume, low-unit-value commodities, transportation costs are a major factor in determining the value of a deposit. The remoteness and relative inaccessibility of most of these deposits make their development unlikely for other than local use. Some of the sandstone units could be used as bulk aggregate, but most of the rock is too friable for this purpose. Large deposits of material suitable for construction purposes and at locations closer to transportation systems and markets are sufficient to supply present and projected future local use.

Industrial (silica) sand is used mostly in glassmaking, as foundry sand, and for abrasives. The sand should consist mainly of quartz grains and must be free of contamination; rigid specifications of purity, silica content, and grain size must be met. (See Coope and Harben, 1977; Davis and Tepordei, 1985.) Whole rock and sieve analyses of sandstone samples from the study area indicate that the sand contains either too little silica, too much iron oxide, or grains that are too large to have industrial value.

Samples from the Navajo, Temple Cap, and Carmel contained no unusual concentrations of elements (Zelten, 1987).

Ornamental Sand and Sandstone

Bleached or stained sand from the study area can be used for sand painting and other decorative purposes. The most desirable sand deposits are those which contain unusual as well as multiple colors in one locality, such as at one mine near Kanab, Utah. The sand in and around Parunuweap Canyon is not of unusual color. Large deposits near Kanab are closer to current markets and are sufficient to supply present and future demands.

Picture rock is cross-bedded sandstone that has been stained by iron oxide, resulting in interesting and unusual designs. The best known deposits are in the Navajo and the Chinle near Kanab. Picture rock is often cut into slabs that are sold as wall-hangings, or it may be ground into spheres or other decorative shapes. Iron stains and Liesegang bands (secondary nested rings or bands caused by periodic or rhythmic precipitation within a fluid-saturated rock) are common in the cross-bedded Navajo Sandstone in the study area, but no picture rock was observed.

Limestone

An inferred subeconomic resource of limestone, suitable for agricultural purposes, exists in the Carmel Formation in and near the study area. Crushed limestone could be used locally for aggregate, but sufficient quantities of similar material are available closer to markets. Because the Carmel possesses no unique characteristics that would make it more desirable than limestone present elsewhere in the region and closer to markets, development of this material is unlikely.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By R.E. Van Loenen, E.G. Sable, H.R. Blank, Jr., H.N. Barton, and K.L. Cook[2]
U.S. Geological Survey

Geology

The Parunuweap Wilderness Study Area lies in the western part of the Colorado Plateau, a region consisting of gently dipping rock strata interrupted by faults and gentle to sharp flexures. Major faults near the study area

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are the Hurricane and Sevier faults, which are respectively 25 mi to the west and 5 mi to the east. About 3,200 ft of sedimentary rocks of Mesozoic (Jurassic and Cretaceous) age are exposed in and peripheral to the study area (pl. 1). Older sedimentary strata of Paleozoic and early Mesozoic ages more than 9,500 ft thick occur in the subsurface. Younger rocks of latest Mesozoic and Cenozoic ages, which were probably more than 2,000 ft thick, once covered the presently exposed rocks but have been removed by erosion.

Subsurface Rocks

Rocks of Paleozoic and Mesozoic age in the subsurface of the Parunuweap Canyon study area are more than 9,500 ft thick. The description of these rocks given here is extrapolated from descriptions of them in the Grand Canyon and Zion National Park regions (Hintze, 1973), in the Canaan Mountain Wilderness Study Area (Van Loenen and others, 1988), and in core samples from wells, including Pintura, 23 mi northwest of the study area (Cary, 1963); North Virgin Imperial; #19–1 Federal, about 25 mi northwest; and Huston Oil and Minerals #41–11 Federal, 13 mi northeast. Information on the latter two wells was obtained from files of the Utah Geological and Mineralogical Survey.

The oldest Paleozoic rocks in the sequence, of Cambrian and Devonian ages, comprise more than 2,500 ft of interlayered clastic rocks (shale, mudstone, siltstone, sandstone, and conglomerate), carbonate rocks (limestone and dolomite), and minor evaporite rocks (gypsum and anhydrite). These are overlain in turn by the Redwall Limestone (Mississippian), about 800–900 ft thick; the Callville Limestone (Pennsylvanian), 600–800 ft thick; and four units of Early Permian age: the Pakoon Limestone, 750 ft thick; the combined Queantoweap Sandstone and Coconino Sandstone, 1,350 ft thick; the Toroweap Formation, 550 ft thick; and the Kaibab Limestone, about 260 ft thick. The latter two units contain evaporite rocks. Of these formations, the Redwall, Pakoon, Queantoweap, Coconino, Toroweap, and Kaibab are thought to be potential oil and gas reservoir units. Strata of the Lower and Middle(?) Triassic Moenkopi Formation overlie these Permian units in the subsurface of the study area and are about 400 ft thick. The Moenkopi includes, in ascending order, the Timpoweap Member, lower red member, Virgin Limestone Member, middle red member, Shnabkaib Member, and upper red member, of which the Timpoweap is a potential reservoir rock unit. The lower, middle, and upper red members are essentially reddish siltstone and mudstone; the Virgin Limestone Member consists mostly of fine-grained impermeable gray limestone with interbedded brownish shale; and the Shnabkaib Member is largely reddish siltstone and mudstone with beds, lenses, nodules, and stringers of non-commercial-grade gypsum. Overlying the Moenkopi, the Chinle Formation (Upper Triassic) in the study area consists only of the Shinarump Member (about 80–140 ft) and the Petrified Forest Member (240–280 ft). The Shinarump is predominantly sandstone and conglomerate with minor shale, and the Petrified Forest Member is variegated claystone and shale including volcanically derived clay with stream channel-fill sandstones. Both members contain uranium-bearing strata in many parts of the Colorado Plateau, although no economic deposits are known in the vicinity of the study area. The top of the Chinle is estimated to be about 2,200–3,400 ft below the surface in the study area.

The Moenave Formation (tentatively Lower Jurassic) of the Glen Canyon Group (Peterson and Pipiringos, 1979) is about 400 ft thick and consists of three members (ascending): the Dinosaur Canyon Sandstone, Whitmore Point, and Springdale Sandstone Members. They consist of reddish to gray siltstone, mudstone, shale, and sandstone of fluvial and lacustrine origin. The Springdale Sandstone Member in the Silver Reef district at Leeds, Utah (about 30 mi west of the study area), was mined principally for silver in the late 19th century and for uranium in the early 1950's, but no other metal deposits are known in the Springdale Member.

The Kayenta Formation (tentatively Lower Jurassic) of the Glen Canyon Group—550 to 720 ft thick in the Canaan Mountain Wilderness Study Area, 10 mi southwest of the study area—consists of reddish to reddish-orange siltstone, sandstone, and shale of fluvial origin. No mineral or energy resources are known to occur in the Kayenta Formation.

Surface Rocks

Jurassic strata more than 2,200 ft thick make up most of the bedrock in the study area. The units are the Navajo Sandstone, the Temple Cap Sandstone, and the Carmel Formation. Rocks of Late Cretaceous age (the basal part of the combined Tropic Shale and Dakota Sandstone unit (map unit Ktd)) crop out just north of the study area along Meadow Creek. Thicknesses of units given in the following discussion are approximate.

Jurassic Rocks

At least the upper 1,500 ft of the Navajo Sandstone of the Glen Canyon Group (map unit Jn) is exposed in the westernmost part of the study area. The Navajo is as much as 2,220 ft thick to the west, in Zion National Park, and 1,800–2,000 ft thick to the east, in the Kanab quadrangle (Sargent and Philpott, 1987). In the study area it is exposed in spectacular, nearly vertical canyon walls both north and south of the East Fork of the Virgin

River, and as upland surfaces. It is a fine- to medium-grained, well-sorted sandstone which exhibits medium- to large-scale eolian crossbedding. The Navajo can be subdivided roughly into a lower brown unit with beds of moderate thickness (1–10 ft), a middle pinkish and gray unit, and an upper nearly white unit; the latter two contain thick sets of crossbeds. These color boundaries of the units do not, however, coincide with bedding. The colors are probably due to postdepositional factors, such as ground-water staining or bleaching agents. The porosity and permeability of the Navajo make it an excellent aquifer. East of the study area it has been mined locally for its varicolored sand, which is used for artistic purposes and in sand collections. With its spectacular crossbedding features and joint patterns, the Navajo provides more scenic features than all other formations in the study area and in the region at large. It was deposited in an extensive desert "sand sea" that encroached southward from highlands north of the study area about 180 million years ago.

The Moenave, Kayenta, and Navajo have for many years been considered to be Triassic or Triassic and Jurassic in age. Peterson and Pipiringos (1979), however, consider them to be tentatively Early Jurassic on the basis of palynomorphs in the Moenave. Their usage is used in this report.

The Temple Cap Sandstone (Middle Jurassic) (map unit Jtc), overlying the Navajo Sandstone, is about 120–170 ft thick in the study area. Two members, the Sinawava and White Throne Members (Peterson and Pipiringos, 1979) constitute the Temple Cap. The Sinawava is a slope-forming unit of interbedded reddish sandstone, siltstone, and mudstone. The overlying White Throne Member is cliff-forming, light-gray to tan, fine-grained, crossbedded sandstone of variable thickness, which, like the Navajo, is of eolian origin. The Temple Cap contains no known mineral or energy resources.

The Carmel Formation (Middle Jurassic) averages about 600 ft thick and varies lithologically. Its members (ascending) are the limestone member (units Jcll and Jclu), the banded member (unit Jcb), the gypsiferous (unit Jcg), and the Winsor Member (unit Jcw). Depositional environments of these strata ranged from shallow marine, perhaps in restricted embayments or lagoons, to marginal marine flood plains, to shallow evaporite-precipitating coastal plain environments. The only known exploited commercial resources in the Carmel are limestone for road metal, and alabaster (gypsum) used in sculpture or for ornamental objects. Alabaster is locally mined near Cedar City, 40 mi north of the study area.

The limestone member of the Carmel Formation, about 220–260 ft thick, consists of two map units roughly equal in thickness. The lower, ledge-forming unit (Jcll) consists of thin- to medium-bedded, extremely fine-grained, tan-weathering limestone, which grades upwards into shaly limestone and interbedded greenish to reddish shale; and the upper, cliff-forming unit (Jclu) is relatively pure limestone much like that in the lower unit. Pelecypods, gastropods, crinoid remains, and other marine fossils are locally common but generally sparse; minor oolitic limestone is most common in the upper unit.

The banded member (Jcb), 120–160 ft thick, is generally poorly exposed and forms gentle to moderate slopes. Alternating beds of light-gray and reddish-brown, thin-bedded, friable sandstone and siltstone form a banded pattern where well exposed.

A lower ledge-forming unit of white to very light gray to pinkish gypsum and an upper slope-forming unit of grayish and greenish gypsiferous limestone, sandstone, and shale constitute the gypsiferous member (Jcg). The member is less than 60 ft thick. The lower and upper contacts are not well defined, although a thin fossiliferous limestone bed at least locally marks the top of the member (Cashion, 1967b). Where weathering surfaces that predate canyon cutting are seen on rocks of the upper unit, they display a reddish soil.

The 180- to 200-ft-thick Winsor Member (Jcw) is generally very poorly exposed and weathers to smooth, gentle slopes. It is largely very fine grained to fine-grained friable sandstone with thin interbeds of reddish-brown mudstone. The upper part is light gray to yellowish gray; the lower part is pinkish to reddish in hue.

Jurassic-Cretaceous Unconformity

A pronounced unconformity representing Late Jurassic and Early Cretaceous time, an interval of about 60 million years, underlies the lowest Cretaceous strata throughout southwestern Utah. Post-Carmel Formation Jurassic units, which are present in the Bryce Canyon and Kaiparowits Plateau areas, 40 to 60 mi east and northeast, are absent in the vicinity of Zion National Park and to the west of the park. The absence of these units, the result of erosion or nondeposition, probably stemmed from crustal movements in the Sevier orogenic belt west of the study area.

Cretaceous Rocks

Upper Cretaceous rocks north of the study area are as much as 3,500 ft thick. The basal beds of the combined Tropic Shale and Dakota Sandstone unit (unit Ktd) in this general region are commonly sandstone and conglomerate as much as 80 ft thick, but these are locally absent and are replaced by a thin conglomerate with shale matrix. Complete sections of the Tropic-and-Dakota unit north of the study area are about 900–1,400 ft thick (Cashion, 1967a). They are composed of the basal sandstone and conglomerate overlain by a coal-bearing member about 200–400 ft thick consisting of carbonaceous shale, sandstone, and coal. This member is delimited by upper and lower coal zones. The succeeding shaly member of the Tropic Shale (unit Kts), about 500–1,200 ft thick, is mostly gray carbonaceous shale, minor shoreline-deposited sandstone, and thin coal beds. The Straight Cliffs Sandstone (unit Ksc), about 120–600 ft thick, of which only part is exposed in the mapped area, overlies and intertongues with the Tropic Shale, according to Cashion (1967a). Gray, planar-bedded sandstone, deposited mostly under marine shoreline conditions, is interbedded with gray marine shale.

Younger Cretaceous and Tertiary sedimentary rocks exposed north of the study area are probably more than 2,000 ft thick and were mostly deposited on land. These have been removed by erosion from the study area. Farther north, thick successions of Tertiary volcanic rocks are exposed, but it is not known if they extended this far south. Younger basalt flows and vent features, present as close as 10 mi to the west in Zion National Park, are not present in the study area.

Cenozoic Deposits and Features

Sedimentary deposits of Quaternary and possible Tertiary ages consist of fluvial, colluvial, and eolian sediments. Cenozoic erosional features are canyons and arroyos cut into an older surface(s) of more subdued topography than that existing today. In places that topographic surface beveled Cenozoic unconsolidated deposits as well as bedrock.

A few small remnant gravel deposits of late Tertiary(?) or early Quaternary age (unit QTg) are exposed high above present streams in the northeastern part of the area. Other such deposits may be present elsewhere in the area but were not encountered during mapping. The gravels are semiconsolidated, fluvial in origin, and contain well-rounded pebbles and cobbles of quartzite and of silicified Paleozoic limestone in a sand matrix.

Eolian sand, silt, and clay (unit Qes) occur in relatively small, currently active dunes and sheets, in more extensive, older stabilized dunes and sheets, and in thin residual clay soils. The sand and silt are light gray to yellowish gray, buff, and reddish orange, fine to medium grained, and composed mostly of quartz with very minor amounts of heavy minerals. The Navajo Sandstone is the chief source rock for the sand and silt. Stabilized sand, silt, and clay, the products of eolian and other weathering processes, overlie bedrock and surficial units in many parts of the mapped area. Deposits are estimated to be several inches to tens of feet thick. In the northern and southeastern parts of the area, the unit includes a thin residual clay soil that is largely derived from rocks of the limestone member of the Carmel Formation. In the southwestern part, sand and silt occur as remnants of eolian sheet sands that overlie an eroded surface of Navajo Sandstone. In the southeastern part, they form sand ramps or aprons, which have encroached onto cliffs and hillsides made up mostly of Navajo Sandstone. Where these stabilized deposits have not been dissected by hillside runoff or by wind, their upper surfaces are relatively smooth, planar to gently curving, and support what appears to be a mature vegetation cover. These upper surfaces are the weathered, erosional surface expressions of the underlying materials; they represent remnants of an ancient topography that predates the Quaternary canyon- and arroyo-cutting processes in this region. The age of these surfaces and the underlying materials is not known; it is estimated to be middle to late Quaternary but may be in part older.

Mass movement deposits (unit Qm), as mapped, are large-scale debris flow, slide, slump, and creep deposits that involve both bedrock and surficial materials. Only one such feature occurs in the map area. It is about 0.7 square mile in area, is shown in the northernmost part of the geologic map, and is crossed by Utah State Highway 9. It consists mostly of disrupted shale and sandstone of the Tropic-and-Dakota unit. The age of initial movement of this mass is not known, but current movement is evidenced by sags in the present highway and displacements in the older road downslope.

Colluvium is a general term for surficial material that has moved downslope under the influence of gravity. The colluvium shown as map unit Qc includes talus from rockfalls, relatively small landslides, and products of soil slump and creep which obscure the underlying bedrock.

Alluvium and colluvium (unit Qac) consist of unconsolidated clay, sand, gravel, and silt which occur in channel, flood-plain, and lacustrine deposits and locally in alluvial fan deposits. In addition to modern channel and flood-plain deposits, one or two higher terraces of the above materials are present along larger streams, commonly within 20 ft of present stream levels. The unit also includes eolian sand and silt intermixed with alluvial and colluvial material, particularly in upland deposits such as those south of Elephant Cove.

Structure

Bedrock structure in the Parunuweap Canyon Wilderness Study Area is relatively simple and consists of a northeasterly dipping homocline with an average dip of slightly over 1°, as indicated by structure contours drawn on the top of the Navajo Sandstone (fig. 3). This regional dip is interrupted by a few steeply dipping, north-northwest- to north-northeast-trending normal faults in the northwestern and eastern parts of the mapped area.

Those in the eastern part appear to be related to the Sevier fault zone, which lies about 5 mi east of the area. Recorded dips are as high as 9° in that part of the area. Details of the general homoclinal dip include an east-northeast-plunging structural nose associated with the faults in the northwestern part of the area. An apparent platform or local dome structure in the southeastern part of the area may also be related to faulting. Some of the apparent structural details, however, may be due to differences in depositional thicknesses of the Navajo Sandstone, which thins eastward from Zion National Park.

Numerous northerly trending, nearly vertical fractures or joints are well expressed in the Navajo

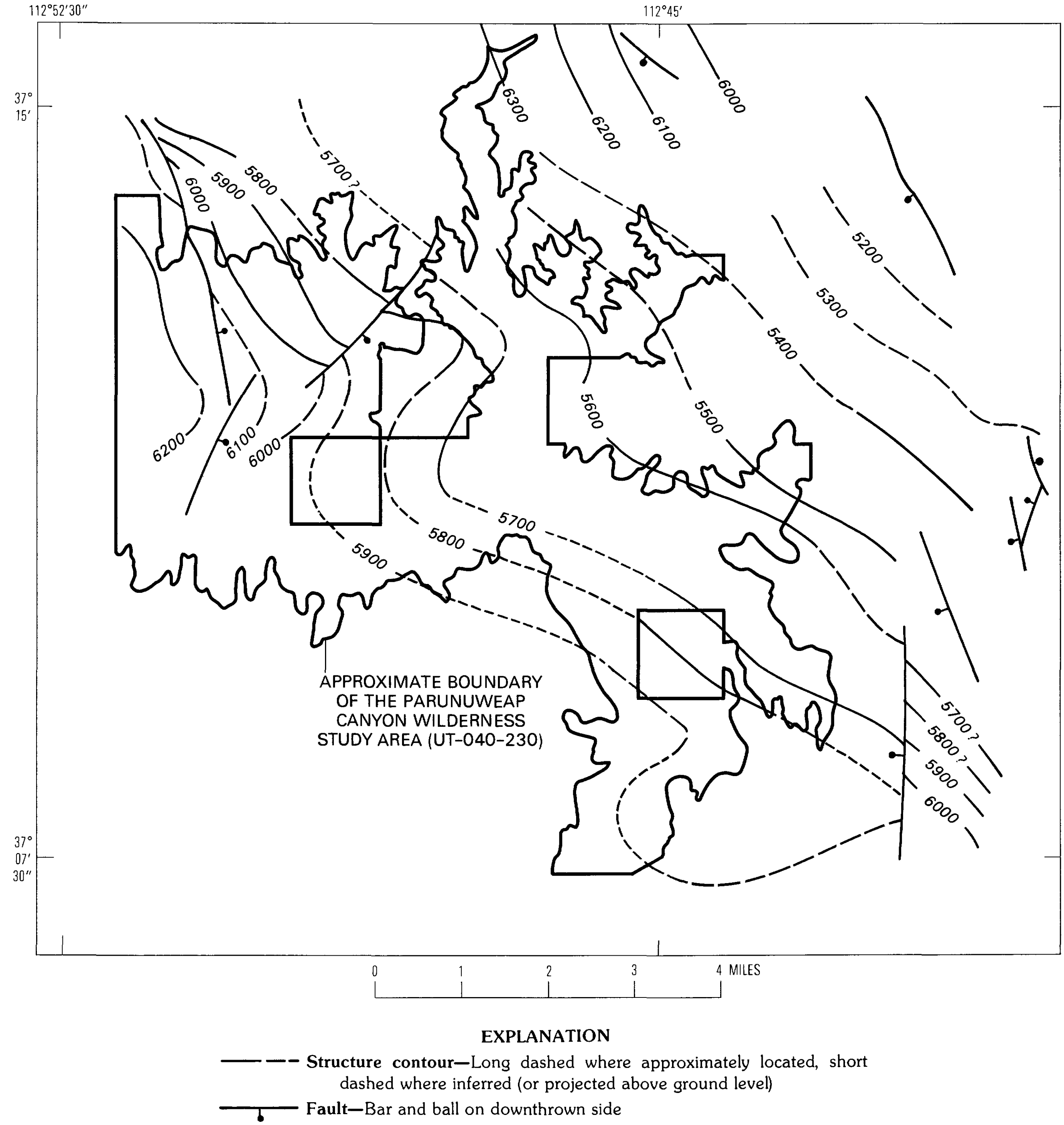


Figure 3. Structure contours in and near the Parunuweap Canyon Wilderness Study Area, Kane County, Utah, drawn on top of Navajo Sandstone, except for small area north of 37°15′ N., where contours (from Cashion, 1967a) are drawn on top of Tropic Shale. Datum is mean sea level; contour interval 100 ft.

Sandstone (pl. 1). Some of these may be expressions of faults, but the homogeneous nature of the Navajo Sandstone makes interpretation of faults within it uncertain. No known alteration or mineralization is associated with these structures.

Geochemistry

Methods

A reconnaissance geochemical survey was conducted in the Parunuweap Canyon study area to determine the abundance and distribution of elements possibly related to unknown mineral deposits. Stream sediments and heavy-mineral concentrates separated from stream sediment were the sample media used for this survey. Stream sediments are a natural composite of the rocks and soils that occur upstream in the drainage basin. Analysis of the stream sediments and their corresponding heavy-mineral constituents may identify basins that contain anomalous concentrations of elements that might be related to mineral occurrences.

Stream sediments were panned, and heavy minerals were separated from the panned concentrates in the laboratory using heavy liquids and an electromagnet. Most ore-related sulfide and oxide minerals are relatively heavy and nonmagnetic. The removal of most of the lighter rock-forming silicates, clays, and organic material permits the determination of some elements present in the concentrates that are not easily detectable in bulk stream sediments by normal analysis.

Thirty stream-sediment samples were collected from tributaries of the East Fork of the Virgin River in the Parunuweap Canyon study area. The stream sediments were screened and dried prior to analysis. The stream sediments and the heavy-mineral concentrates separated from them were analyzed for 31 elements by emission spectrographic methods. In addition, the stream sediments were analyzed for arsenic, antimony, bismuth, cadmium, gold, uranium, and zinc by chemical methods. Radioactivity was measured at all of the sampling sites. Analytical data and a description of the sampling and analytical methods are in Bullock and others (1988).

Results

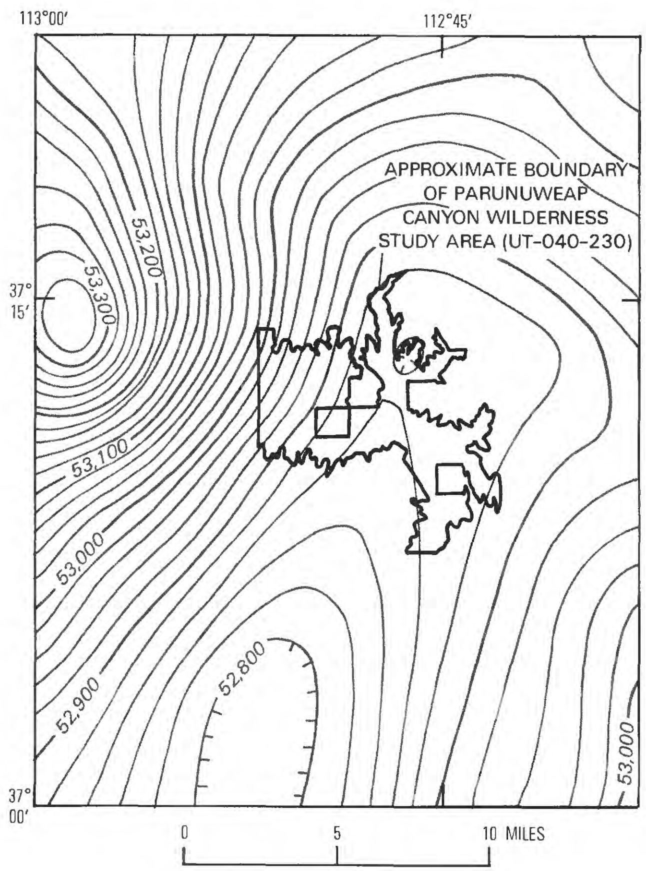
Threshold values (concentrations considered anomalous for particular elements) for bulk stream sediments and nonmagnetic heavy-mineral concentrates separated from the stream sediments were determined by inspection of the analytical data. None of the stream sediments or the concentrates collected from the Parunuweap Canyon Wilderness Study Area had anomalous amounts of any of the analyzed elements.

Geophysics

Regional aeromagnetic and gravity maps of the Parunuweap Canyon Wilderness Study Area and vicinity have been compiled as an aid to investigation of the general geologic framework. The aeromagnetic data were obtained from digital files of total-intensity data used for a published aeromagnetic map of Utah (Zietz and others, 1976). In the area of interest these data were recorded on airborne traverses flown 2–4 mi apart at a constant barometric elevation of 12,000 ft under the direction of R.T. Shuey (Univ. of Utah). Additional aeromagnetic data are available from flights conducted for the National Uranium Resource Evaluation (NURE) program but are not utilized here. The gravity data consist of observations at 111 stations, of which 36 are old stations (principal facts obtained from the National Center for Geophysical and Solar-Terrestrial Data, Boulder, CO 80301), and the remainder are new stations established for BLM wilderness-related investigations. All gravity data have been reduced and terrain-corrected using standard USGS procedures. (See, for example, Cordell and others, 1982.)

The aeromagnetic map (fig. 4) shows a total-intensity relief somewhat less than 560 gammas. The core component of total intensity (main Earth's field) increases north-northeasterly in this vicinity at about 10 gammas/mi. The residual field relief is due principally to a high that is centered near the western margin of the map; a rough estimate of the depth to the source of this anomaly is 10,000–13,000 ft, approximately the depth to the surface of the Precambrian crystalline basement, based on the estimated total thickness of the Phanerozoic sedimentary section. (See section on "Subsurface rocks.") No anomaly sources of Phanerozoic age are known within the map area, and none is indicated by the magnetic data. The disturbance pattern does not exclude the possibility of basement topographic relief, but the lack of correlation between aeromagnetic and gravity anomalies suggests that such relief, if any, is of very low amplitude.

Relief on the Bouguer gravity anomaly map (fig. 5) amounts to about 54 milligals, expressed mainly as a northerly decrease in anomaly values. This gradient corresponds roughly to a northerly increase in average regional elevation, as well as to a gradual northerly to northeasterly increase in depth to basement. It is markedly nonuniform, being steepest in a relatively narrow belt that trends across the northern half of the wilderness study area, and much less pronounced in the southern half of the area of coverage. The sharp salient in this steep gradient belt near the western margin of the map at lat 37°15' N. reflects strong topographic relief in the vicinity of Zion Canyon, which is carved principally in low-density Navajo Sandstone. On maps corrected using



EXPLANATION

— *52,800* — **Isopleth**—Showing total intensity in gammas

Aeromagnetic low

Figure 4. Aeromagnetic map of the Parunuweap Canyon Wilderness Study Area and vicinity, Washington and Kane Counties, Utah. Contour interval 20 gammas.

a reduction density of 2.4 grams per cubic centimeter, which is probably closer to the mean density of rocks in this area than the standard reduction density of 2.67 grams per cubic centimeter used for the map of figure 5, the salient is largely eliminated, and the overall anomaly relief of the region is diminished by about 25 percent. The steep gradient approximately delineates the southern limit of outcrop of the Middle Jurassic Carmel Formation and younger rocks. Similarly, an anomaly trough extending south-southwest from the eastern margin of the wilderness study area to the southern margin of the map area is associated with a southerly extension of Carmel exposures, although the anomaly axis is displaced eastward from the axis of the Carmel upland. This displacement probably results from the influence of low-density alluvium adjacent to the Sevier fault. Thus, in a general way, the gravity field appears to reflect the thickness of the sedimentary section. Structural offset of the basement surface may also be reflected in the regional gradient but cannot be proved. The main belt of steep gradient does not seem to be affected by the presence of the Sevier fault where this high-angle normal structure has been mapped just east of the study area. This suggests that the gradient does originate in part from an east-west-trending basement step, and that the step is not substantially offset by the fault; therefore the fault must flatten at depth. No fault-controlled hydrothermal or igneous intrusive activity is indicated along the trend of the gradient in the wilderness study area.

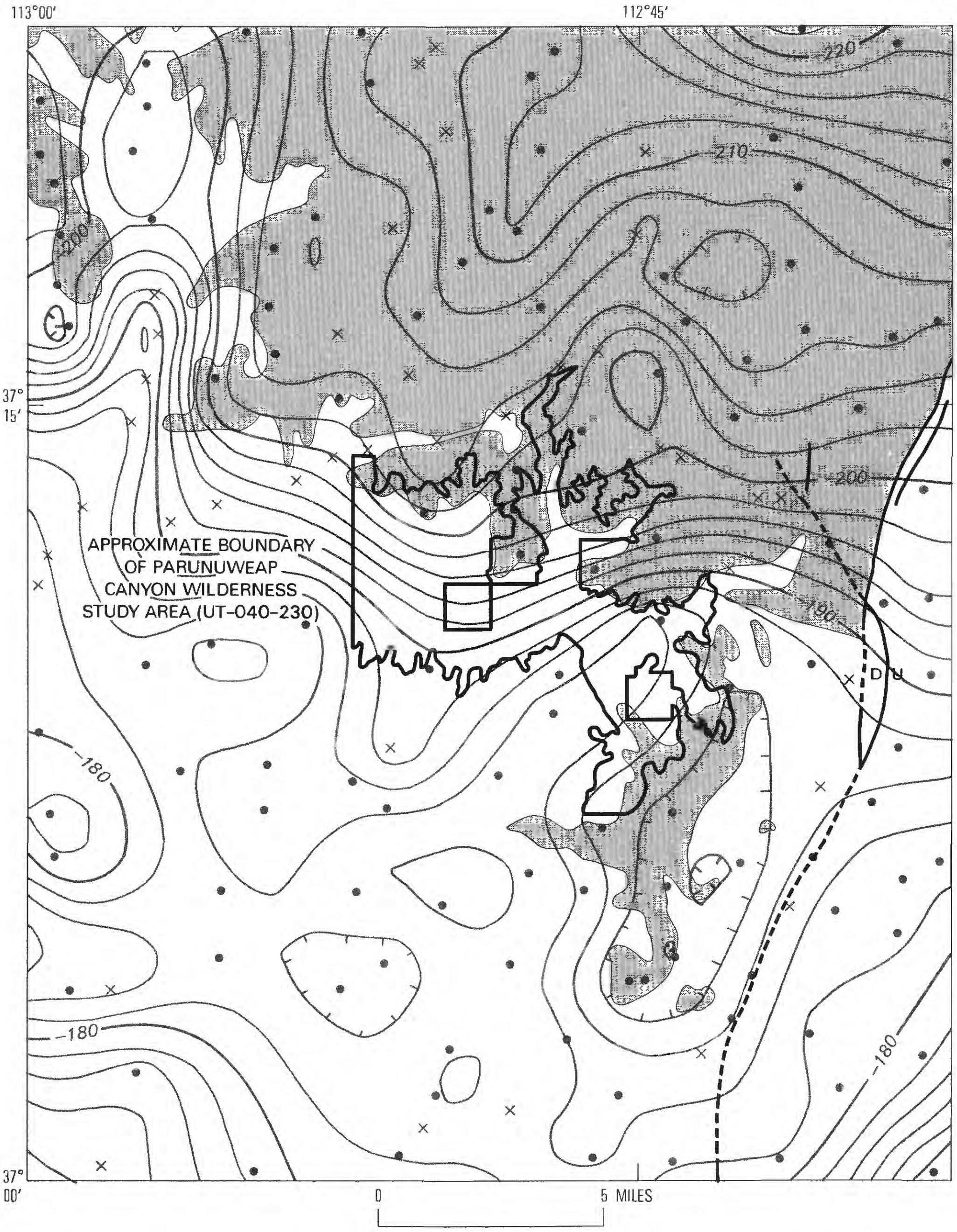
Four flight lines of the NURE aeroradiometric survey run across or near the study area. Aerial gamma-ray spectroscopy is a technique that provides estimates of the near-surface concentrations of percent potassium (K), parts per million equivalent uranium (ppm eU), and parts per million equivalent thorium (ppm eTh). Because the uranium and thorium measurements are based on radioactive daughter nuclei, which are chemically distinct from the parent nuclei, the uranium and thorium data are described as equivalent concentrations. These data (K, eU, eTh) provide a partial geochemical representation of the near-surface materials. For a typical aerial survey each measurement reflects average concentrations for a surface area on the order of 15 acres to an average depth of about 1 ft (J.S. Duval, USGS, written commun., 1987). Examination of the data by Duval indicates that the Parunuweap Canyon Wilderness Study Area has overall low radioactivity, with concentrations of 0.8–1.2 percent K, 0.1–1.0 ppm eU, and 1–2 ppm eTh.

Mineral and Energy Resources

There has been no mining activity within the Parunuweap Canyon Wilderness Study Area. The region, including the study area, was explored in the late 1800's, for deposits similar to those at Silver Reef, and again in the early 1950's, during the "uranium boom." Coal was mined just outside the northern boundary of the study area. Gypsum and limestone occur inside the study area, but neither has been exploited commercially. Identified resources of gypsum occur in a small area along Meadow Creek in the northern part of the study area. Rock units that underlie the study area have yielded modest amounts of oil and gas elsewhere in southwestern Utah. The following sections discuss the attributes of nearby localities where specific commodities have been produced and compare those attributes to the ones present within the study area.

Oil and Gas

Utah's oil and gas production comes primarily from three areas: the thrust belt of north-central Utah, the Paradox basin of southeastern Utah, and the Uinta



EXPLANATION

× Gravity station previously established

• Gravity station established for wilderness studies

—*-230*— **Isopleth**—Showing gravity anomaly intensity in milligals

Bouguer gravity low

U/D **Fault of Sevier fault system**—After Hintze, 1973. U, upthrown side; D, downthrown side; dashed where approximately located or concealed

Carmel Formation and younger rocks—After Hintze, 1973

Figure 5. Complete Bouguer gravity anomaly map of the Parunuweap Canyon Wilderness Study Area and vicinity, Washington and Kane Counties, Utah. Contour interval 2 milligals.

basin of northeastern Utah. A few small fields outside these three areas have produced or are currently producing oil and gas. The only producing field in southwestern Utah is the Upper Valley field near Escalante, about 75 mi northeast of the study area. The abandoned Anderson Junction and Virgin fields are 22 and 17 mi, respectively, west of the study area.

Because the Virgin field is nearby and has a similar geologic setting, its attributes are used in the evaluation of oil and gas potential beneath the study area. Oily tar that occurs in seeps in and near the Virgin field prompted exploration for oil and gas, and the first well drilled there in 1907 opened the Virgin field. Since 1907, more than 150 wells have been drilled in and near the Virgin field, the latest being in 1986. Some of the wells produced as much as 30 barrels of oil per day (BOPD), but most wells yielded only 1–4 BOPD. The wells were shallow, ranging from 500 to 800 ft deep. Total production from the Virgin field has been slightly more than 200,000 barrels of asphalt-paraffin base oil. Most wells produced little or no gas.

The reservoir rocks in the Virgin field are lime-matrix conglomerates in the upper part of the Kaibab Limestone and sandy limestones of the Timpoweap Member of the Moenkopi Formation. Oil in the Virgin field apparently accumulated in a structural low on the nose of a very gentle, broad, plunging anticline. Differences in the physical properties of oil from well to well may indicate separate stratigraphic traps within the structural low (Bahr, 1963). A structural high adjacent to and northeast of the Virgin field was tested by drilling in 1986. This well bottomed in the Pennsylvanian Callville Limestone. Traces of dead oil were seen in some samples, and massive amounts of fresh water were encountered in limestone in the Toroweap, the Kaibab, and the Timpoweap. The well was considered dry and was abandoned (P. Carter, BLM, Cedar City, Utah, written commun., 1987).

Other structural highs in the region have been tested for oil but none successfully. Four wells were drilled, one as recently as 1985, on a small anticline just 12 mi west of the study area. Commercial quantities of oil were not found in any of the wells.

The prominent Virgin anticline (not to be confused with the Virgin field), about 25 mi southwest of the study area, has been tested for oil without success.

Nineteen wells were drilled south of the study area in northern Arizona, and all were dry; however, oil shows were reported in 13 of the wells in the Redwall and Kaibab Limestones and the Timpoweap Member (Ryder, 1983).

Strata adjacent to the Sevier fault about 5 mi east of the study area have been tested in five drill holes. Traces of oil were found but no production was established (C. Brandt, Utah Geological and Mineralogical Survey, written commun., 1987).

The Colorado Plateau has had a favorable thermal history for the generation of oil and gas (Ryder, 1983, p. C15), and some oil in this area may have been generated locally in Paleozoic and lower Mesozoic rocks; however, there are no hydrocarbon-rich source rocks near the study area. Examples of such "rich" source rocks are the organic-rich shales of Pennsylvanian and Permian age from which oil is generated in the Paradox and Uinta basins. The source of oil in this part of the Colorado Plateau province may be the abundant organic-rich Paleozoic rocks of the adjoining Basin and Range physiographic province in eastern Nevada and western Utah (Giardina, 1979). The most significant of these is the Mississippian Chainman Shale, which has had a favorable thermal history and provides oil to fields in east-central Nevada (Poole and Claypool, 1984). This source rock may have supplied hydrocarbons that subsequently migrated long distances, across a structural hinge line and updip into southwestern Utah and northwestern Arizona. The hinge line is the boundary between the tectonically stable Colorado Plateau and the Basin and Range province to the west.

Oil and Gas Potential

The Parunuweap Canyon Wilderness Study Area has a moderate energy resource potential for oil and gas at certainty level C, based on its structural and stratigraphic setting, its proximity to the Virgin oil field, and the results of exploration in the region. This assessment concurs with the rating given the area by Molenaar and Sandberg (1983).

Structural traps such as the mild upwarping of the sedimentary rocks in the Virgin oil field may be present beneath the study area, although no surface manifestations of significant structures are known in the area. These subtle features, if present, would be difficult to locate in the study area. The possible reservoir rocks within the study area boundaries are buried beneath 3,000–4,000 ft of Triassic and Lower Jurassic rocks. Structural contours drawn on the top of the Navajo Sandstone (fig. 3) reveal only a gently northeastward dipping surface.

Stratigraphic traps resulting from facies changes in favorable rocks may form reservoirs for oil and gas beneath the study area. Regionally the study area is updip from and on the eastern edge of a Paleozoic geosyncline, in which accumulations of sediments thin eastward from more than 20,000 ft in the deeper parts of the basin to about 5,000 ft in this area. An environment such as this, wherein formations thin or wedge out on a continental shelf, is conducive to forming facies-change stratigraphic traps. Exploration in the region indicates that the most favorable reservoirs for oil and gas are (in stratigraphically descending order) in the Timpoweap Member of the Moenkopi Formation (Triassic); the Kaibab Limestone, the Toroweap Formation, the Coconino Sandstone, the Queantoweap Sandstone, and the Pakoon Limestone (Lower Permian); the Callville Limestone (Pennsylvanian); and the Redwall Limestone (Mississippian). These formations are probably present at depth beneath the study area.

The potential for oil and gas in the region is not high, because the available reservoir rocks have been and still are susceptible to flushing by fresh water, which was first introduced into the rocks in late Tertiary time after the region was uplifted and deeply dissected by erosion (Ryder, 1983). The presence of fresh water is not well documented in drilling records; however, it may be pervasive. The well drilled northeast of the Virgin field in 1986, mentioned earlier in this report, contained massive amounts of water in the Toroweap, Kaibab, and Timpoweap units, all potential reservoir rocks (P. Carter, BLM, Cedar City, Utah, written commun., 1987). Drilling records from a well drilled in the Anderson Junction field, about 22 mi northwest of the study area, showed fresh water flowing in the Redwall and Callville Limestones (Giardina, 1979).

As noted above, the study area has been assigned a moderate energy resource potential for oil and gas, with a C level of certainty. The surface geologic setting is well known, but there are no subsurface data. Exploration by drilling would be required to identify petroleum resources, and none has been done within the study area.

Metals

The Parunuweap Canyon Wilderness Study Area has low potential with a certainty level D for any undiscovered resources of silver and uranium. The formations exposed in the study area (Navajo Sandstone, Temple Cap Sandstone, and Carmel Formation) are not known to contain mineral or energy resources anywhere in the region, and no such commodities have been observed within the study area.

Silver

The Moenave Formation, host of rich silver deposits and associated uranium at the Silver Reef district, 30 mi to the west, is present in the subsurface; however, its depth from the surface ranges from about 2,000 to 3,000 ft. No mineral deposits are known in this formation outside the Silver Reef district, and it is therefore unlikely that any such deposits occur in the study area. The potential for silver is low, with a D level of certainty.

Uranium

The study area has a low mineral resource potential for uranium, with a certainty level D. The significant uranium deposits of southeastern Utah occur in the Chinle and Morrison Formations. The Morrison, however, is not present in southwestern Utah, and the Chinle lies beneath the study area at more than 2,000 ft depth. Southwestern Utah has not been a major producer of uranium, although some has been mined locally near the study area. Uranium was reportedly mined from the Chinle Formation south of the study area in Arizona (Kreidler, 1986), but other similar deposits in the Chinle are not known in this region. Abandoned uranium mines are located in the Silver Reef district (as discussed above), where uranium was produced from the Springdale Sandstone Member of the Moenave Formation, and about 8 mi north in the Orderville Canyon area, where uranium was mined from the Dakota Sandstone of Late Cretaceous age. Some breccia pipes contain commercial deposits of uranium nearby in northern Arizona, but in this region such features generally are restricted to Triassic and older strata and cannot be detected where these rocks are not exposed. An aerial gamma-ray survey shows no radioactive anomalies and low overall radioactivity for the study area.

Coal

Coal has been mined just north of the study area in the Kolob coal field. Coal in this field, as in most other fields throughout Utah, occurs in rocks of Cretaceous age. There are no rocks of this age in the study area, nor are any rock units exposed there known to contain coal. A low potential exists for coal in the study area, with a D level of certainty.

Geothermal Energy

The study area has a low potential for geothermal energy resources, with a D level of certainty. The study area is along the western edge of the Colorado Plateau province, a tectonically stable province that is characterized by low heat flow (Muffler, 1978). By comparison, the adjoining Basin and Range physiographic province is tectonically active, has a high heat flow, and a favorable outlook for geothermal sources. The study area is about 25 mi east of thermal springs that discharge warm water (106 °F, 41 °C) into the Virgin River near Hurricane, Utah. These springs are along, and probably controlled by, fractures in the Hurricane fault zone. This major structure is in the transition zone between the Colorado Plateau and the Basin and Range province, an area characterized by relatively high heat flow. Warm springs do not occur in the study area nor is the geologic setting favorable for geothermal sources.

Gypsum

The gypsiferous member of the Carmel Formation occurs only in the area shown as having identified resources of gypsum and is not present in the subsurface of the study area. Therefore no potential exists for other resources in the study area, with a D level of certainty.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

LOW mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics define a geologic environment in which the existence of resources is unlikely. This broad category embraces areas with dispersed but insignificantly mineralized rock as well as areas with few or no indications of having been mineralized.

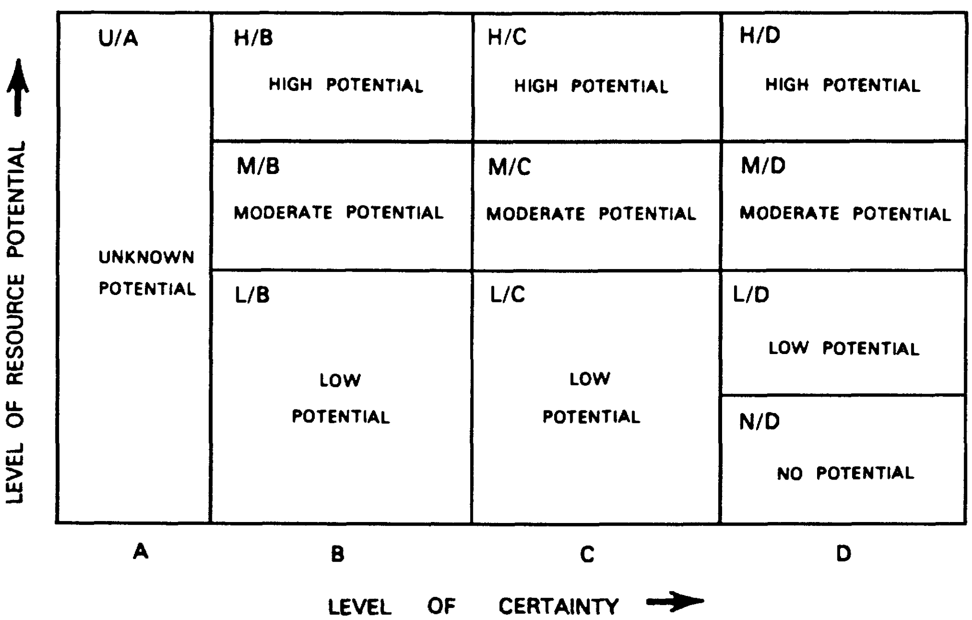
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application of mineral-deposit models indicates favorable ground for the specified type(s) of deposits.

HIGH mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a high degree of likelihood for resource accumulation, where data support mineral-deposit models indicating presence of resources, and where evidence indicates that mineral concentration has taken place. Assignment of high resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

UNKNOWN mineral resource potential is assigned to areas where information is inadequate to assign low, moderate, or high levels of resource potential.

NO mineral resource potential is a category reserved for a specific type of resource in a well-defined area.

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.
B. Available information suggests the level of mineral resource potential.
C. Available information gives a good indication of the level of mineral resource potential.
D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

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RESOURCE/RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from U. S. Bureau of Mines and U. S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U. S. Geological Survey Circular 831, p. 5.

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

EON	ERA	PERIOD		EPOCH	BOUNDARY AGE IN MILLION YEARS
Phanerozoic	Cenozoic	Quaternary		Holocene	0.010
				Pleistocene	1.7
		Tertiary	Neogene Subperiod	Pliocene	5
				Miocene	24
			Paleogene Subperiod	Oligocene	38
				Eocene	55
				Paleocene	66
	Mesozoic	Cretaceous		Late	96
				Early	138
		Jurassic		Late Middle Early	205
		Triassic		Late Middle Early	~ 240
	Paleozoic	Permian		Late Early	290
		Carboniferous Periods	Pennsylvanian	Late Middle Early	~ 330
			Mississippian	Late Early	360
		Devonian		Late Middle Early	410
		Silurian		Late Middle Early	435
		Ordovician		Late Middle Early	500
		Cambrian		Late Middle Early	~ 570[1]
Proterozoic	Late Proterozoic				900
	Middle Proterozoic				1600
	Early Proterozoic				2500
Archean	Late Archean				3000
	Middle Archean				3400
	Early Archean				3800?
pre-Archean[2]					4550

[1] Rocks older than 570 m.y. also called Precambrian, a time term without specific rank.

[2] Informal time term without specific rank.

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