Mineral Resources of the Spring Creek Canyon Wilderness Study Area, Iron County, Utah

U.S. Department of the Interior Bureau of Mines

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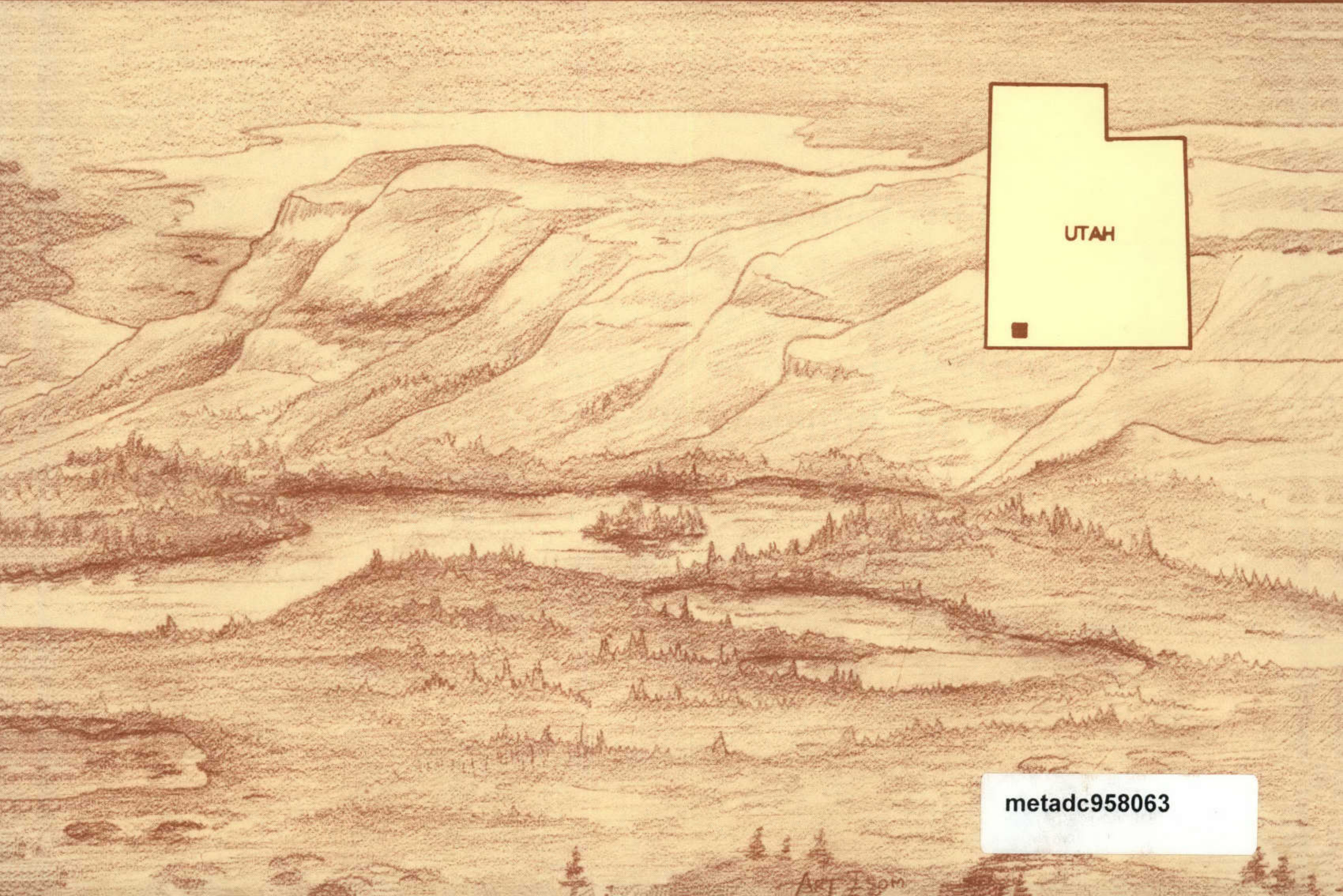

Chapter F

Mineral Resources of the Spring Creek Canyon Wilderness Study Area, Iron County, Utah

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHWESTERN UTAH

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

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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 Spring Creek Canyon (UT–040–148) Wilderness Study Area, Iron County, Utah.

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PLATE

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FIGURES

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—SOUTHWESTERN UTAH

Mineral Resources of the Spring Creek Canyon Wilderness Study Area, Iron County, Utah

By R.E. Van Loenen, H.R. Blank, Jr.,
E.G. Sable, G.K. Lee, *and* K.L. Cook[1]
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ABSTRACT

The Spring Creek Canyon Wilderness Study Area (UT–040–148) is in southwestern Utah adjacent to the northern boundary of Zion National Park and covers about 4,433 acres. Inferred subeconomic resources of common variety sand, sandstone, and limestone occur in the study area. The study area has a moderate potential for undiscovered resources of oil and gas and low potential for all metallic resources (including copper, silver, and uranium) and geothermal resources. No potential exists for coal and gypsum resources.

SUMMARY

Character and Setting

The Spring Creek Canyon Wilderness Study Area occupies an area of about 4,433 acres in the southeast corner of Iron County about 7 mi (miles) southwest of Cedar City, Utah (fig. 1). The study area is bounded on the south by Zion National Park, on the west by Cedar Valley, and it extends for about 5 mi north to Murie Creek. The study area boundary is essentially a legal land net that separates State, private, and National Park land from U.S. Bureau of Land Management (BLM) administered land. The study area is easily accessible from Kanarraville by foot or from a gravel road in Cedar Valley that extends along the western part of the study area. A road along Murie Creek, about 2 mi northeast of Kanarraville, provides access to the northern and eastern parts of the study area. Two established trails, Spring Creek Canyon and Red Rocks trails, cross the study area from east to west.

The Hurricane Cliffs are the dominant topographic feature in the study area. This impressive west-facing fault scarp extends from north of Cedar City southward through the study area and into northern Arizona. Imposing views of the cliffs are seen from Interstate Highway 15 when traveling between Cedar City and St. George, Utah. This highway passes within 2 mi of the study area. Elevations range from about 5,600 ft (feet) in Cedar Valley at the base of the cliffs to nearly 7,900 ft on the plateau in the eastern part of the study area. Two major canyons of Kanarra and Spring Creeks dissect the escarpment. These creeks have perennial water flow and they, as well as other ephemeral streams, flow into the internal drainage basin of Cedar Valley.

Structurally, the study area is at the western edge of the transition zone between the Colorado Plateaus physiographic province to the east and the Basin and Range province to the west. Structural elements characteristic of both provinces are present in the study area. Strata in the western part of the study area were folded into a large anticline during Mesozoic time (see geologic time chart in Appendix). During the Neogene this large ancestral fold was nearly bisected by the Hurricane fault, a dominant structural feature in southwestern Utah. Rocks west of the Hurricane fault in this region were

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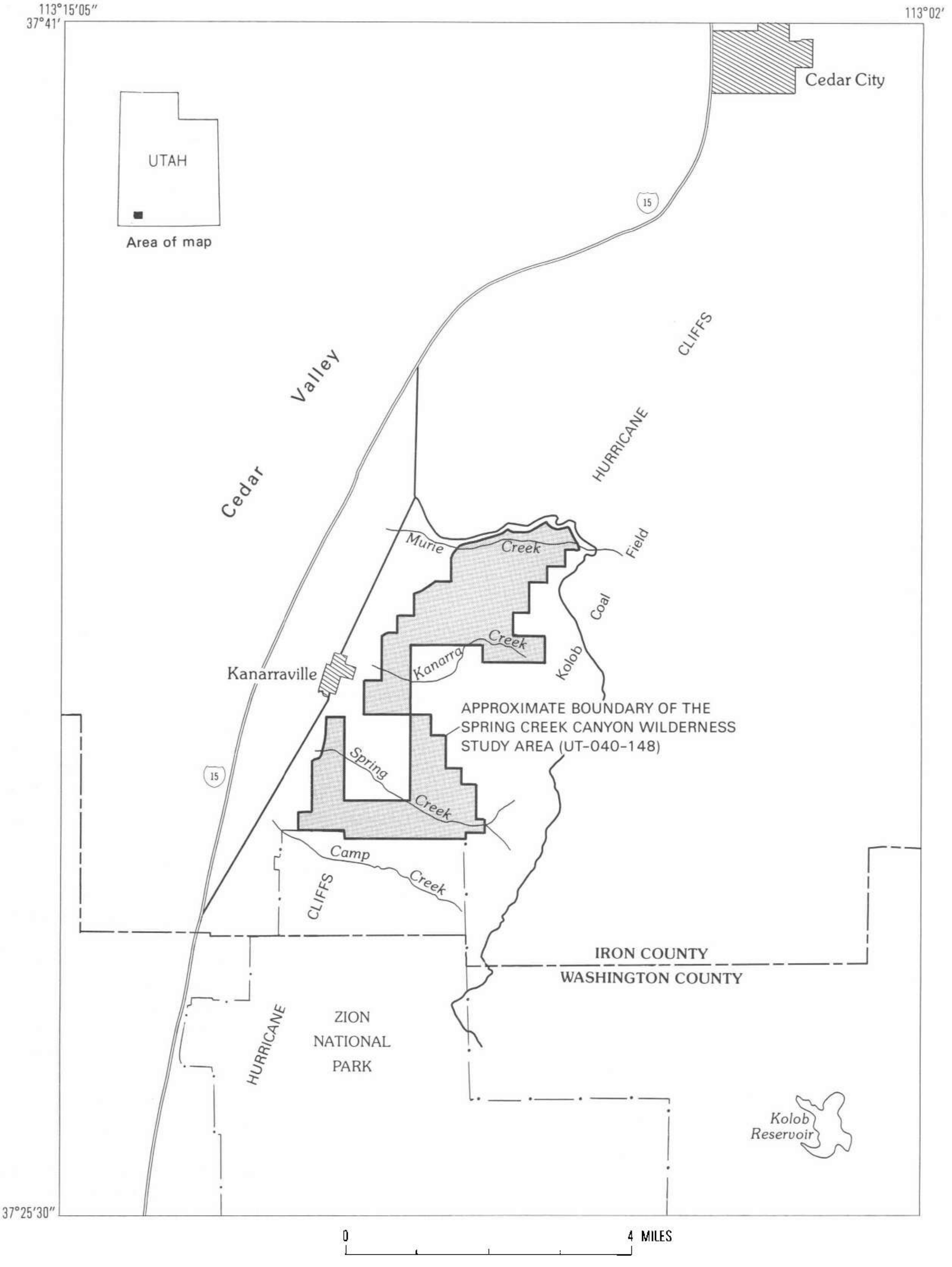


Figure 1. Index map showing location of the Spring Creek Canyon Wilderness Study Area, Iron County, Utah.

displaced nearly 8,000 ft, relative to the Hurricane Cliffs, into what is now Cedar Valley. Subsequent erosion has removed a large part of the eastern flank of the fold. Those rocks remaining dip steeply to the east into the Hurricane Cliffs; some strata in the northern part of the study area are overturned. Rocks in the eastern part are more gently dipping. Sedimentary rocks ranging in age from Permian through Jurassic are exposed in the study area in an arcuate pattern that parallels the Hurricane Cliffs; the oldest rocks are exposed at the base of the cliffs and youngest on the plateau to the east.

Stratigraphic units exposed in and near the study area include, in ascending order, the Kaibab Limestone (Lower Permian), the Moenkopi Formation (Lower and Middle? Triassic), Chinle Formation (Upper Triassic), Moenave Formation, Kayenta Formation, Navajo Sandstone (Lower Jurassic), and Carmel Formation (Middle Jurassic).

The Kaibab Limestone is exposed along the base of the Hurricane Cliffs in the western part of the study area. About 18 mi south of the study area the uppermost part of the Kaibab is a reservoir rock for oil and gas in the Virgin oil field. The Moenkopi Formation unconformably overlies the Kaibab Limestone and consists of six members which are alternating units of limestone, slope-forming red beds, and evaporite beds. One of its members, the Timpoweap Member, is a reservoir rock for oil and gas in the Virgin field, but no other resources are known from the Moenkopi. The Chinle Formation consists of two members, both of which contain sandstone-hosted uranium deposits in many parts of the Colorado Plateau. The Moenave Formation, which overlies the Chinle, consists of two members; the upper one, the Springdale member, hosts silver-uranium deposits in the Silver Reef mining district, near Leeds, Utah, about 25 mi southwest of the Spring Creek Canyon Wilderness Study Area. The sedimentary rocks of the Kayenta overlie the Moenave Formation and are mainly of fluvial (river) origin, but a unit of eolian sandstone resembling the overlying Navajo Sandstone occurs in about the middle of the formation. The Navajo Sandstone is not known to contain mineral deposits but is an excellent aquifer. The Carmel Formation, which overlies the Navajo, consists of four members, in ascending order: the informal limestone, banded, and gypsiferous members, and Winsor Member. The gypsiferous member is mostly massive gypsum with limestone beds in the upper and lower parts; only a small part of this member is present in the study area and it consists of limestone. Limestone from the limestone member has been quarried and used locally outside the study area as road metal, and gypsum from the gypsiferous member has been used for ornamental purposes.

Cretaceous rocks, which unconformably overlie the Carmel Formation east of the study area, include the Tropic Shale and the Straight Cliffs and Wahweap Sandstones. Coal has been mined from the Tropic in the Kolob coal field about 1 mi east of the study area. Tertiary igneous rock consists of quartz monzonite intruded into the Kaibab Limestone in the southwest corner of the study area, and a small patch of a basalt flow that is preserved along the northern border. Surficial deposits are sparse in the study area, but Cedar Valley, to the west, is partially filled with sediment eroded from the Hurricane Cliffs and the plateaus behind the escarpment.

Subsurface rocks of Paleozoic age in the study area are probably more than 8,500 ft thick. This thick rock sequence includes clastics, carbonates, and minor evaporites. Limestone of Mississippian, Pennsylvanian, and Permian ages locally contains traces of hydrocarbons.

Identified Mineral Resources

Large quantities of common variety sand, sandstone, and limestone, classified as inferred subeconomic resources, occur in the Spring Creek Canyon Wilderness Study Area. There are no mines, prospects, or patented claims within the boundaries. Two blocks containing 11 unpatented lode claims are on ground underlain by the Moenkopi Formation and Kaibab Limestone along and partly inside the southwestern part of the study area. Oil and gas lease applications cover about 480 acres in the northern part of the study area. No oil or gas wells have been drilled in the study area.

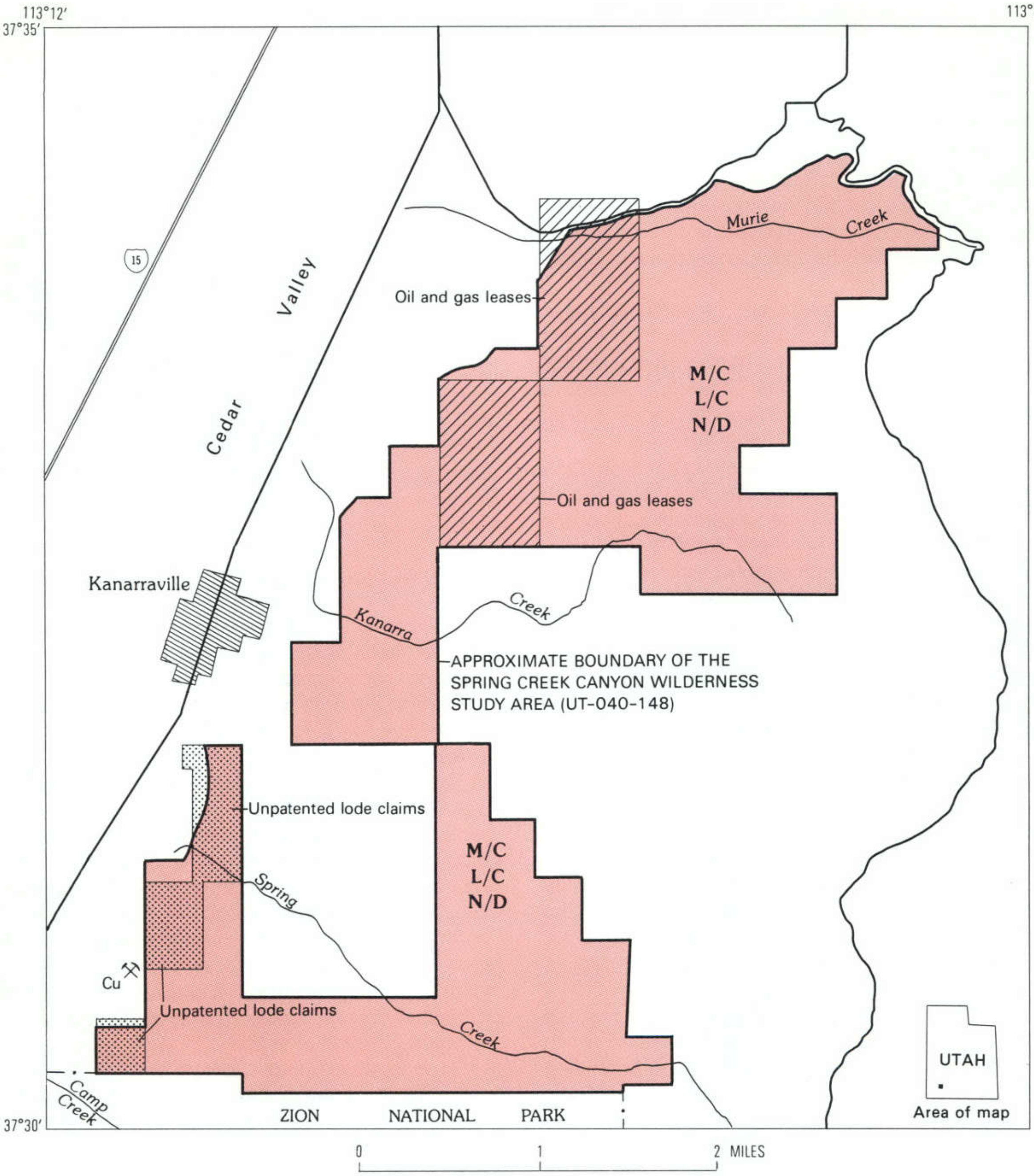
Mineral Resource Potential

Samples of altered rocks and stream-sediment samples were analyzed, and none was found to have anomalous concentrations of metals, except for samples collected in the area of mineralized and altered rock along the southwest part of the study area. This is an area of known mineralized rock that was explored earlier; several prospect pits were dug in this area along the study area boundary.

Geophysical data from gravity, aeromagnetic, and aeroradiometric surveys were interpreted in regard to mineral resources of the study area. Although this data aids in understanding the geologic framework of the area, it did not delineate or suggest the existence of mineral deposits.

The Spring Creek Canyon Wilderness Study Area has a moderate potential for undiscovered resources of oil and gas in small fields (fig. 2). The stratigraphic and structural setting of the study area is similar to that of the nearby Virgin and Anderson Junction oil fields.

The study area has a low potential for metallic mineral resources, including copper, silver, and uranium, and for geothermal energy resources. Formations exposed here, that elsewhere are mineralized, were given special attention in the study area. Among those were the Chinle Formation, which is known for its uranium deposits elsewhere in Utah. Conditions for mineralization in the Chinle were apparently unfavorable in the study area. No anomalous concentrations of metals were found nor were any of the tested outcrops found to be radioactive. The Springdale Sandstone Member of the Moenave Formation was enriched in silver and uranium 25 mi southwest, in the Silver Reef district, but nothing was found in the study area that might indicate similar mineralization. Copper-bearing minerals occur in fractures in the Kaibab Limestone just outside the southwest part of the study area. Several other elements were detected in samples from that area indicating that a weak hydrothermal mineralizing system may have existed there, but lack of both strong alteration and sulfides does not suggest a potential for metallic resources.



EXPLANATION OF RESOURCE POTENTIAL

M/C Geologic terrane having moderate energy resource potential for oil and gas, with certainty level C—Applies to entire study area

L/C Geologic terrane having low resource potential for all metals including copper, silver, uranium, and geothermal sources, with certainty level C—Applies to entire study area

N/D Geologic terrane having no resource potential for coal and gypsum, with certainty level D—Applies to entire study area

Levels of certainty

D Data indicate geologic environment, indicate level of resource potential, but do not establish activity of resource-forming processes

C Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Figure 2. Summary map showing mineral and energy resource potential of the Spring Creek Canyon Wilderness Study Area, Iron County, Utah.

The study area has low potential for geothermal resources. The study area is in terrane defined as having low heat flow. The Hurricane fault may tap deep sources of circulating hot water but the only evidence at the surface is a warm spring at Hurricane, Utah, 25 mi to the south. The Hurricane fault, at depth, is outside the study area. There are several Known Geothermal Resource Areas a few miles west of the study area in the Basin and Range province.

The study area has no potential for gypsum or coal. There are large amounts of commercial grade gypsum in the gypsiferous member of the Carmel Formation nearby but the gypsum-bearing part of the member is not present in the study area. Coal was mined in the Kolob coal field from the Tropic Shale about 1 mi east of the study area, but these rocks are not present in the study area. None of the exposed rocks or subsurface rock units in the study area are known to contain coal.

INTRODUCTION

The Spring Creek Canyon Wilderness Study Area occupies an area of 4,433 acres in the southeast corner of Iron County, about 10 mi southwest of Cedar City, Utah. The study area is one of 12 wilderness study areas that border Zion National Park and are being studied by the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM). The study area includes a 5-mi-long segment of the Hurricane Cliffs adjacent to and east of the town of Kanarraville, Utah. The Hurricane Cliffs are an impressive fault scarp that extends from north of Cedar City southward into Arizona. Imposing views of the cliffs and the high plateaus are seen from Interstate Highway 15 between Cedar City and St. George, Utah. This highway passes within 2 mi of the study area.

The study area borders the northern part of Zion National Park, and State and private lands form the remaining boundary. About 2 mi of roadway define the northern border. The study area is easily accessible by foot from Kanarraville or from a gravel road that extends along the western part of the study area in Cedar Valley. Two well-maintained hiking trails cross the study area from east to west. The Red Rock trail begins at Kanarraville and continues upward over the Hurricane Cliffs and joins with a road on the plateau east of the study area. This trail was originally made as a livestock driveway for access to the high plateau summer range lands. The Spring Creek Canyon trail begins about 1 mi south of Kanarraville and follows the creek through nearly the entire stratigraphic section exposed in the study area, which includes a spectacular gorge cut into the Navajo Sandstone. A road along Murie Creek, about 2 mi northeast of Kanarraville, climbs up the Hurricane Cliffs and then heads southward across the plateau east of the study area. This road serves livestock operations, provides access to the northern part of Zion National Park, and once provided access to many coal mines in the area. Several roads branching off this road approach the eastern boundary of the study area. A road up Kanarra Creek, just east of Kanarraville extends about 0.5 mi into the study area.

Streams flow from east to west across the study area into Cedar Valley, an internal drainage basin. Kanarra and Spring Creeks drain most of the study area through two deeply incised canyons and their tributaries along the escarpment. These creeks are perennial, and resourceful use of the water is maintained by levees and pipe lines before it empties into the alluvium in Cedar Valley. Other small streams exist in the study area but they are mostly ephemeral.

The study area is on the western edge of what has been termed the transition zone between the Colorado Plateaus and Basin and Range physiographic provinces. The Hurricane fault zone, along this western edge, trends northeast along the western boundary of the study area. The Hurricane Cliffs fault scarp results from several thousand feet of displacement along the fault. Cedar Valley is west of the fault. Structural elements characteristic of the Basin and Range are present in the western part of the study area. Strata there, preserved in the Hurricane Cliffs, are folded and faulted while strata to the east in the study area are relatively flat lying and more characteristic of geologic structure in the high plateaus of the Colorado Plateaus province. Elevations range from about 5,600 ft in Cedar Valley near the base of the cliffs to nearly 7,900 ft on the plateau in the eastern part of the study area.

Sedimentary rocks ranging in age from Permian through Jurassic are exposed in the study area. These include marine limestone and dolostone, some evaporites, and fluvial, lacustrine, and eolian clastic rocks.

This region, in terms of mineral and energy resources, is best known for its iron mines west of Cedar Valley, silver and uranium mines to the south near Leeds, the small oil field near Virgin, Utah, and coal from the Kolob coal field. There is no evidence of mining or mineral exploration within the study area although there are several small prospect pits outside the southwest part of the study area. The terrain in and near the study area is best known for its esthetic values. The colorful rock units as displayed along the escarpment and the deep canyons are not unlike much of the picturesque terrain to the south in Zion National Park.

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 USBM and the USGS. Identified resources are classified according to the system of the USBM and USGS (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 resources (coal, oil, gas, oil shale, and geothermal resources). It is classified according to the system of Goudarzi (1984) and also is shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

The Bureau of Mines field investigation of the Spring Creek 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 mining claims and oil, gas, coal, and geothermal lease information. BLM geologists, National Park Service personnel at Zion National Park, and local residents were interviewed regarding minerals information in the region.

A field investigation, consisting of a search for mines, prospects, and mineralized areas in and within 1 mi of the study area, was conducted in September 1986 and in May 1987. Ten chip and grab samples taken from outcrops and a prospect were analyzed by Skyline Labs, Inc., of Wheat Ridge, Colo. Five sandstone samples were taken from outcrops and analyzed for gold, silver, and copper by atomic absorption spectrometry; sieve analysis was performed on one of the samples. Whole-rock analyses were performed on all sandstone samples and three limestone samples taken from outcrops. All of the rock samples were analyzed for 31 elements by optical emission spectrographic methods. Two siltstone samples from a prospect just outside the southwestern part of the study area were analyzed for gold, silver, and copper using the above methods, and for uranium by fluorimetry.

The ten samples contained no unusual concentrations of elements. Sample descriptions and analytical results are presented in Zelten (1987). Additional information is available from the Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

The assessment of the potential for undiscovered resources in the Spring Creek Canyon Wilderness Study Area is based mostly on consideration of the geologic setting, results from geochemical sampling, geophysical data, and the production history of similar rock formations in the region. Field work for these studies was done in parts of June and October of 1987. Geophysical studies include aeromagnetic, aeroradiometric, and gravity surveys. Some new gravity stations were established, and data obtained from them were used in this report. Other gravity data were provided by K.L. Cook of the University of Utah. Stream-sediment and altered-rock samples were collected and analyzed in the geochemical survey. Analytical data and sample localities are shown in Hopkins and Lee (in press). The geologic map for the study area is mostly by Averitt (1962, 1967). These maps were combined and modified slightly to accommodate additional field data obtained for this study. Information used in establishing oil and gas potential is taken partly from Ryder (1983) and Molenaar and Sandberg (1983). Other sources of data are Bahr (1963), who described the Virgin oil field, Peterson (1974), who described the Anderson Junction oil field, Oakes and others (1981), who evaluated energy resources for the study area, and the U.S. Department of Energy (1979), who evaluated the uranium resources of the region. Data for the Kolob coal field is from Doelling and Graham (1972).

Pertinent literature on the geology of the area in and surrounding the study area includes, in addition to Averitt (1962, 1967), 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). Hamilton (1978) compiled a geologic map of Zion National Park. Stratigraphic studies include discussion of lower and middle Mesozoic units (Wilson and Stewart, 1967) 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. Evaluations of the other eleven wilderness study areas adjacent to Zion National Park are included in three separate reports by Van Loenen and others (1988a, b, c).

APPRAISAL OF IDENTIFIED RESOURCES

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

Mining and Mineral Exploration History

No mines, prospects, or patented claims are in the Spring Creek Canyon Wilderness Study Area, and the area is not included in any mining district. The nearest mining district is the Silver Reef (Harrisburg) district, about 20 mi to the southwest. Between 1875 and 1910, over $8,000,000 of high-grade silver ore (over 7,000,000 oz (ounces) silver), with small amounts of associated copper, uranium, and vanadium, was produced from the 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 Springdale crops out in and is present beneath the study area, but there is no surface evidence that it is mineralized.

Mines and Prospects, Mining Claims and Leases

Unpatented lode claims and oil and gas lease applications cover parts of the study area (fig. 2); two oil fields are within 18 mi of the boundary.

Two separate blocks containing a total of 11 unpatented lode claims on the Moenkopi Formation and Kaibab Limestone are partly inside the southwestern part of the study area. Azurite and malachite staining at small prospects in the vicinity indicate that the claims may have been staked for copper. There are no workings on these claims.

Oil and gas lease applications cover about 480 acres in the northern part of the study area (Bureau of Land Management, Salt Lake City, Utah, June 1987). Oil and some gas have been produced from several fields in this part of Utah, the nearest being the Virgin and Anderson Junction oil fields, about 18 mi and 15 mi south and southwest, respectively.

In the Virgin field, oil and small amounts of gas were produced intermittently from the uppermost part of the Kaibab Limestone and the Timpoweap Member of the Moenkopi Formation (Bahr, 1963; Irwin, 1976). Total oil production from this field between 1907 and 1970 was over 200,000 barrels (Stowe, 1972). 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. Neither the Moenkopi nor the Callville have been tested in the study area to determine if they contain oil or gas. (See Peterson, 1974.)

Identified Resources

Inferred subeconomic resources in the study area include common sand, sandstone, and limestone. Coal occurs within 1 mi east of the study area, but coal-bearing formations are stratigraphically above the youngest formations in the study area. Iron concretions, often sold in rock shops, weather out of the Navajo Sandstone in scattered locations throughout the region.

Construction and Industrial Sandstone and Sand

An inferred subeconomic resource of sandstone, which underlies virtually all of the study area and crops out over most of its surface, could be used locally for construction purposes. Because it is a high-volume, low-unit-value commodity with transportation costs being a major factor in determining the commercial value of a deposit, the remoteness and relative inaccessibility of most of the sandstone make its 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 closer to transportation systems and markets are sufficient to supply present and projected future local use.

Industrial (silica) sand is used mostly in glassmaking, foundry, and abrasives industries. The sand should consist mainly of quartz grains and be free of contaminants; rigid specifications of purity, silica content, and size must be met. (See Coope and Harben, 1977; Davis and Tepordei, 1985.) Whole-rock analyses of sandstone samples from the study area and surrounding region indicate that the sand contains either too little silica or too much iron oxide to have industrial value (Zelten, 1987).

Ornamental Sand and Sandstone

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

Picture rock is crossbedded sandstone that has been stained by iron oxide, resulting in interesting and unusual patterns. The best known deposits are in the Navajo Sandstone and the Chinle Formation near Kanab. Picture rock is often cut into slabs that are sold as ornaments or 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 mineral precipitation of mostly iron oxides within a fluid-saturated rock) are common in the crossbedded Navajo Sandstone in the study area, but none of picture rock quality was observed and no such resources identified.

Limestone

An inferred subeconomic resource of limestone suitable for agricultural purposes exists in the Carmel Formation in and near the study area. Crushed limestone also 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.

Iron Concretions

Rounded to irregularly shaped iron concretions commonly weather out of the Navajo Sandstone. Those with unusual shapes, coloration, or internal construction are sometimes collected and sold as curiosities. Most of the popular collecting sites are more than 20 mi southeast of the study area. Concretions found in the Navajo in the study area are typical of those that are abundant and readily available throughout the southwest.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By R.E. Van Loenen, H.R. Blank, Jr., E.G. Sable, G.K. Lee, and K.L. Cook
U.S. Geological Survey

Geology

The Spring Creek Canyon Wilderness Study Area terrane was folded, faulted, and uplifted by tectonic forces during the past 500 million years.

The study area is on the west edge of the transition zone between the Colorado Plateaus and the Basin and Range physiographic provinces and is along a segment of the Hurricane fault. The study area is underlain by about 9,000 ft of Phanerozoic rocks that are folded and faulted along the west side and nearly flat-lying to the east. Beginning in Late Triassic time and continuing to early Cenozoic time, a crustal block that is to the west of the study area and is now part of the Basin and Range province, moved eastward during the Sevier orogeny. Thrust faults and folds, characteristic features of the Sevier orogeny, developed. The Kanarra fold (Gregory and Williams, 1947) is a large anticlinal structure along the west part of the study area. It is a product of the orogeny and represents one of the easternmost folds of the thrust and fold belt as the allochthonous terrane abuts the more stable Colorado Plateaus province. The axis of the fold nearly parallels the Hurricane fault. Rocks as young as Late Cretaceous were involved in folding in the area northeast of the study area (Averitt, 1962). Following periods of erosion and volcanic activity during the Paleogene, the tectonic style changed with the onset of the Neogene (about 25 m.y. ago). During this period, uplift and block faulting resulting from extensional forces formed mountains and valleys typical of the Basin and Range province. Uplift of the Colorado Plateau began and continued during the Neogene. The Hurricane fault, a product of this period, marks the easternmost extent of major Basin and Range faulting in this region. It is a fault having the eastern block upthrown several thousand feet relative to the western block; it nearly bisected the older Kanarra fold. A zone of weakness caused by tight folding of the strata may have in part controlled the location of the fault. The east limb of the fold is partly preserved in the study area and the west limb is buried beneath the alluvial fill in Cedar Valley (see cross section on pl. 1).

Subsurface Rocks

Subsurface Paleozoic strata in the Spring Creek Canyon Wilderness Study Area are probably more than 8,500 ft thick. Information pertaining to these rocks is extrapolated from that given for the Grand Canyon and Zion National Park regions (Hintze, 1973) and from well records. Records for no. 1 Shurtz Creek (Mountain Fuel Supply) and no. 1 Cedar City (Odessa Natural Gas Corporation) were obtained from Utah Geological and Mineral Survey files, 1975. The record for no. 1 Pintura (Pan American Petroleum) is from Cary (1963). The wells are 14, 19, and 21 mi northeast, north, and southwest, respectively, of the study area. Paleozoic rocks, discussed here in ascending order and with approximate thicknesses, include probably more than 3,000 ft of quartzite, shale, limestone, and dolostone of Cambrian age; 200 ft of cherty dolostone (Ordovician? and Silurian?); 800 ft of dolostone (Devonian); and 700–800 ft of limestone and cherty limestone of the Redwall Limestone (Mississippian). Strata of Pennsylvanian age consists of 600–800 ft of limestone, dolostone, and sandstone of the Callville Limestone. Permian units include 750 ft of limestone and dolostone of the Pakoon Formation, 930–1,350 ft of the Queantoweap and Coconino Sandstones, and 500–1,570 ft of the Toroweap Formation (as interpreted in the Mountain Fuels-Shurtz Creek well record). The Toroweap Formation and Kaibab Limestone contain evaporite beds, dolostone, and sandstone in addition to limestone deposited in open marine and restricted marginal marine environments.

Possible oil and gas reservoir units are generally considered to be Devonian and younger Paleozoic rocks including the Redwall, Pakoon, Toroweap, and Kaibab units.

Surface Rocks

Permian, Triassic, and Jurassic sedimentary rocks and a very small amount of Tertiary age intrusive and extrusive rocks are exposed in the Spring Creek Canyon Wilderness Study Area. Cretaceous rocks east of the study area are shown on the geologic map (pl. 1). The sedimentary rocks crop out in an arcuate pattern roughly paralleling the Hurricane fault and Hurricane Cliffs.

The oldest exposed unit is the Kaibab Limestone (map unit Pk) of Early Permian age. The upper part of the Kaibab crops out at the base of the Hurricane Cliffs along the west edge of the study area. The unit consists of yellowish- to light-gray, massive limestone that is locally dolomitic, cherty, fossiliferous, and in part cavernous. It is reported to be as much as 450 ft thick in nearby drill holes. The Kaibab is a reservoir rock for oil in the Virgin field.

The Moenkopi Formation of Early and Middle(?) Triassic age unconformably overlies the Kaibab Limestone and includes over 2,000 ft of mostly slope-forming red beds, carbonates, and evaporites. These rocks are shown on plate 1 as four separate map units as described by Averitt (1962, 1967). The lowermost unit of the formation is the Timpoweap Member (unit TRmt) which consists of local basal conglomerate overlain by alternating beds of gray shale and yellowish-gray, fossiliferous, sandy limestone. Quartzite cobbles that are scattered along the base of the Hurricane Cliffs weather out of the basal conglomerate. The Timpoweap is also a reservoir rock in the Virgin field.

The lower red member of the Moenkopi (unitTR ml) is mainly reddish-brown silty shale and mudstone which locally contain thin interbeds of gypsum. The Virgin Limestone Member (unit TRmv) consists of several ledge-forming, very fine grained, fossiliferous limestone beds interbedded with shale and mudstone, and it separates the lower and middle red-bed members. The middle red member, Shnabkaib Member, and upper red member, undivided (unit TRmu), form a thick sequence of reddish-brown siltstone and mudstone beds separated by light-gray beds of gypsiferous siltstone and mudstone. These units are easily erodable and form slopes in contrast to the hard rocks of the Virgin Member and the overlying Chinle Formation.

The Shinarump Member of the Chinle Formation (unit TRcs) consists mainly of gray to yellowish-brown, crossbedded sandstone with lesser amounts of conglomerate and siltstone deposited in channels and on flood plains. Petrified wood occurs in some of the channel deposits. The Shinarump ranges from 50 to 100 ft thick in the study area. The Shinarump was a favorable host rock for uranium deposits in many areas of the Colorado Plateau. The Petrified Forest Member of the Chinle (unit TRcp), about 500 ft thick, is a succession of variegated clay shale intercalated with stream-channel-fill sandstone. Volcanic ash makes up a large part of the clay-shale and contributes to the colorful patterns that are characteristic of the member throughout much of the Colorado Plateau. Grays, reds, purples, browns, and greenish hues blend to give weathered outcrops a purplish cast. Along the Hurricane Cliffs, this rock unit forms badlands topography above the resistant ridge of Shinarump. The sandstone within the Petrified Forest hosts important uranium deposits on the Colorado Plateau.

The Moenave Formation of the Lower Jurassic Glen Canyon Group, which overlies the Chinle, is divided into two members (Averitt, 1962), the Dinosaur Canyon Member (unit Jmd) and the Springdale Sandstone Member (unit Jms). The Dinosaur Canyon, about 400 ft thick, consists of slope-forming, reddish-brown mudstone, gray shale, and lesser amounts of sandstone that grade upward into the cliff-forming, pale-red, crossbedded Springdale Sandstone Member. The Springdale is about 100 ft thick. The Moenave Formation was deposited in continental fluvial and lacustrine environments. The Springdale hosts the silver-uranium ore deposits in the Silver Reef district near Leeds, Utah.

The Kayenta Formation (unit Jk) of the Glen Canyon Group (Lower Jurassic) is over 500 ft thick and consists of pale-red to reddish-brown siltstone, sandstone, and shale of fluvial and possibly lacustrine origin. The contact between the Kayenta and the overlying Navajo Sandstone is gradational. Averitt (1962) mapped a sandstone bed within the Kayenta that resembles the Navajo and identified it as the Shurtz Sandstone Tongue of the Navajo. This sandstone tongue (not shown on pl. 1) pinches out in the study area and thickens to the northeast.

The Navajo Sandstone (unit Jn) of the Glen Canyon Group (Lower Jurassic) consists of over 2,000 ft of fine- to medium-grained, well-sorted, reddish-orange to pink sandstone. The Navajo was deposited in an extensive desert "sand sea" that encroached generally southwestward from highlands north of the study area about 180 million years ago. It exhibits outstanding examples of medium- to large-scale eolian crossbedding. The Navajo is not known to contain ore deposits but it is an excellent ground-water aquifer. Water is discharged through many springs in the canyons of Spring and Kanarra Creeks from the Navajo and this water accounts for most of the water flowing in the creeks during the dry season. The reddish colors of the Navajo are caused by oxidation of contained iron minerals. The Navajo is exposed in the spectacular canyons cut by Kanarra and Spring Creeks and on upland surfaces along the eastern parts of the study area.

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

The Carmel Formation (Middle Jurassic) overlies the Navajo; it consists of four members totaling more than 1,000 ft in thickness. The basal unit, the limestone member (unit Jcl), consists of ledge-forming, thin- to medium-bedded, mostly lithographic, tan-weathering limestone, which grades upward into slope-forming shaly limestone containing interbedded greenish and reddish shale and an upper cliff-forming limestone similar to that in the lower part. Marine fossils (pelecypods, gastropods, and crinoid remains) are common locally; oolitic limestone is common in the upper part. Thin beds of reddish-brown sandstone and mudstone and gray limestone at the base of the Carmel Limestone are included in this map unit. These beds probably belong to the Temple Cap Sandstone (Averitt, 1962). The Temple Cap, although very thin or absent here, thickens to nearly 200 ft to the south in Zion National Park. The banded member (unit Jcb) of the Carmel Formation is a poorly exposed slope-forming unit of alternating beds of light-gray and reddish-brown, thin-bedded, friable sandstone and siltstone. It is exposed in the slopes along the east part of the map area; a small part of it is in the study area. The gypsiferous member (unit Jcg) is composed mostly of massive gypsum although the lower and upper parts of the member contain limestone beds similar to those found in the limestone member. Only the basal part of this member is present within the study area. Near the study area, gypsum in this member has commercial qualities (Averitt, 1962). The Winsor Member (unit Jcw), the uppermost unit of the Carmel, is a slope-forming, fine-grained, friable sandstone containing thin interbeds of reddish-brown mudstone similar to those present in the banded member. The Winsor is present along the eastern edge of the map area outside the study area.

Cretaceous rocks unconformably overlie the Carmel Formation along the eastern part of the map area; none are present within the study area. These map units are the Tropic Shale (unit Kt) and the Straight Cliffs and Wahweap Sandstones (unit Kws). The Tropic includes sandstone and conglomerate at the base that probably correlate with the Dakota Sandstone. The remainder of the Tropic consists of a coal-bearing and shaly members that total nearly 1,000 ft in thickness. The coal-bearing member consists of carbonaceous shale and thin beds of sandstone; coal beds occur in the upper and lower parts. The upper coal bed was an important source of coal in the region and was mined from several nearby localities. The Tropic is overlain by the Straight Cliffs and Wahweap Sandstones unit. These units combined are about 1,600 ft thick (Averitt, 1962) and are mainly sandstone, siltstone, and shale. The Wahweap contains several coal beds of minor importance.

A small exposure of quartz monzonite is present in the southwest corner of the study area. The quartz monzonite appears to have been intruded into the Kaibab Limestone along fractures that are associated with the Hurricane fault. The intrusive is relatively unaltered, but the limestone is slightly altered and iron stained.

The fanglomerate deposit (unit Tf) in the northern part of the map area (pl. 1) was assigned a late Tertiary age by Averitt (1962). Material in this deposit, ranging from sand to boulders more than 10 ft in diameter, is made up mostly of quartzite, sandstone, and quartz monzonite. This deposit covers several square miles, but most of it is north of the map area.

Basalt of Quaternary age (unit Qb) is widespread in the region, but it covers only a very small area in the northern part of the study area. In this area, the basalt flowed out over part of the fanglomerate deposit. The basalt is fresh appearing, homogeneous, black to gray, massive to vesicular, and contains olivine.

An accumulation of talus (unit Qt) occurs along the northern boundary. The talus is mostly composed of large blocks of basalt, some of which may represent fragmented flow edges produced during flow activity.

Alluvium (unit Qal) consists of unconsolidated clay, sand, and gravel that have accumulated at the base of the Hurricane escarpment in Cedar Valley.

Structure

The dominating structural features within the Spring Creek Canyon Wilderness Study Area are the Hurricane fault and the Kanarra fold (anticline). The Kanarra fold was nearly bisected along its axis by the Hurricane fault, which downdropped the west limb into Cedar Valley relative to the east limb which was uplifted and partly preserved (see cross section, pl. 1, modified from Averitt, 1967). The Kanarra fold trends north-northeast across the study area to near Cedar City and also extends several miles south of the study area. Sedimentary rocks ranging from Permian to Cretaceous age were folded and, in some places, overturned. Erosion has removed the bulk of the rock from the crest of the anticline.

The Hurricane fault is beneath alluvium in Cedar Valley and is mostly west of the study area. Displacement along the fault here is not known, but in the Cedar Mountain quadrangle it is thought to be between

8,000–10,000 ft (Averitt, 1962). The fault remains active as indicated by recent earthquake activity (Averitt, 1962). Subordinate fracturing, probably related to the Hurricane fault, has occurred in rock along the base of the Hurricane Cliffs. Minor alteration is associated with the fractures.

The Murie fault trends east-west across the northern part of the study area and generally follows Murie Creek. The fault, downdropped to the south, also has right-lateral strike-slip movement (Averitt, 1962). Averitt (1962) estimated the stratigraphic displacement along the fault east of the study area to be about 1,200 ft.

Several other faults occur in the study area. These faults, all relatively small, are probably related to stresses that developed concurrently with the Kanarra fold.

Terrane east of the fold on the Kolob Terrace in the eastern part of the map area is free of faults and folds. The strata there dip gently 5°-6° eastward. This is slightly more than the regional dip found in most of the Kolob Terrace.

Geochemistry

A reconnaissance geochemical survey was conducted in the Spring Creek Canyon Wilderness Study Area in 1987. Eighteen stream-sediment, thirteen heavy-mineral panned-concentrate, and eight rock samples were collected and analyzed for the study. Analyses of stream-sediment samples represent the chemistry of the rock material eroded from the drainage basin upstream from each sample site. In addition, the fine (silt) fraction of the sediment provides nuclei for the adsorption of dissolved metals contained in the stream water. Such information is useful in identifying those basins which contain concentrations of elements that may be related to mineral deposits.

Analyses of heavy-mineral-concentrate samples provide information about the chemistry of certain minerals in eroded rock material derived from the contributing drainage basins. The selective concentration of heavy minerals, many of which may be ore related, permits determination of some elements which are not easily detected in stream-sediment samples.

Analyses of altered or mineralized rocks, where present, may provide useful geochemical information about the major- and trace-element assemblages associated with a mineralizing system.

Methods

Stream-sediment samples were collected from the most active stream drainages in the study area. At each sample site a composite of fine material from several localities within the stream bed was taken and later air dried for sieving and analysis.

Stream-sediment panned-concentrate samples were generally taken close to stream-sediment samples but were derived from coarser material representing a relatively high energy depositional environment in the stream. A heavy-mineral concentrate was obtained by panning, after which the concentrate samples were submitted to the laboratory for drying and analysis.

Rock samples were taken at several localities where visible alteration was found, and the most mineralized or altered material was collected preferentially.

Rock samples were crushed, ground, split, and analyzed. Stream-sediment samples were sieved through an 80-mesh (0.007 in.) screen and the fraction finer than 80 mesh was analyzed. Panned-concentrate samples were dried and a small split of each sample was separated for spectrographic analysis. The entire remainder of each concentrate was weighed and chemically analyzed for gold content.

Six-step semiquantitative emission spectrographic analyses were made of all samples by R.T. Hopkins, Jr. Each spectrographic analysis included determinations of 35 elements for rock and stream-sediment samples and 37 elements for heavy-mineral-concentrate samples. Atomic-absorption spectrometry for gold was performed by P.L. Hageman on the panned-concentrate samples. Inductively coupled plasma-atomic emission spectrometry determinations for antimony, arsenic, bismuth, cadmium, and zinc were made on the stream-sediment and rock samples by P.H. Briggs and A.H. Love. All stream-sediment and rock samples were analyzed for uranium by T.A. Roemer.

The results of the analyses, a map showing sample localities, and a description of analytical methods for the stream-sediment, heavy-mineral panned-concentrate, and rock samples collected from the Spring Creek Canyon Wilderness Study Area are in Hopkins and Lee (in press).

Results

Inspection of the analytical data and consideration of average crustal abundances of the elements in comparable lithologic terranes (Rose and others, 1979) suggest that the study area is, for the most part, generally lacking in mineral enrichment. An exception is the area along the southwest edge of the study area between Spring Creek and Camp Creek which shows evidence of at least minor mineralization along the Hurricane fault. Several rock samples collected at prospect pits in this area showed anomalous concentrations for silver (as much as 50 ppm), arsenic (as much as 12,000 ppm), cadmium (as much as 6.9 ppm), copper (to greater than 20,000 ppm), germanium (as much as 100 ppm), manganese (as much as 5,000 ppm), molybdenum (as much as 30 ppm), antimony (as much as 500 ppm), uranium (as much as 26 ppm), vanadium (as much as 2,000 ppm), tungsten (as much as 50 ppm), and zinc (as much as 870 ppm). In addition, a heavy-mineral-concentrate sample from Murie Creek at the north end of the study area contains concentrations of cobalt (70 ppm), copper (100 ppm), and nickel (200 ppm). These elements reflect the presence of Quaternary basaltic rocks in the drainage basin upstream from the sample locality.

Geophysics

Geophysical data provide additional constraints on interpretation of the geologic framework of the Spring Creek Canyon Wilderness Study Area and on evaluation of its mineral resource potential. The data consist of results from regional gravity, aeromagnetic, and aeroradiometric surveys.

Gravity

A complete Bouguer gravity anomaly map of the Spring Creek Canyon Wilderness Study Area and vicinity is shown on figure 4. The map was prepared from a data base of 73 gravity stations on file with the U.S. Defense Mapping Agency (obtained through the National Geophysical Data Center, NOAA, Code E/GC, 325 Broadway, Boulder, CO 80303) and 17 new stations established for the present study. Gravity observations were reduced according to standard USGS procedures (Cordell and others, 1982) and were terrain-corrected by computer out to a radius of 100 mi from each station using the method of Plouff (1977).

The total Bouguer anomaly relief over the map area is only about 22–23 mGals (milligals). Most or all of this relief arises from density contrasts above the magnetic basement. Thus, the lowest anomaly values are associated with alluvial fill of Cedar Valley and the highest values with Paleozoic carbonate rocks immediately east of the Hurricane fault zone. The complex fault system itself is expressed by the zone of steep gradients over alluvium near the foot of the Hurricane Cliffs and in the vicinity of the North Hills. At the northern margin of figures 3 and 4, the aeromagnetic and Bouguer contours are nearly orthogonal, confirming the inference that the gravity field is dominated by effects of the Hurricane fault rather than by relief on the northwest-trending magnetic basement structure in that region. The eastward decrease in gravity levels in the eastern part of the map reflects the density deficiency of rock units exposed on the high Markagunt Plateau relative to the reduction density.

Aeromagnetics

Total-intensity aeromagnetic coverage was obtained concurrently with aeroradiometric surveys carried out for the National Uranium Resource Evaluation (NURE) program. The NURE traverses in this region were flown along east-west flight lines spaced a nominal 3 mi apart at 400 ft above the terrain (Geodata International, 1980). Where the topography is especially severe, for example, over the Hurricane Cliffs, it was not unusual for the actual terrain clearance to depart from the specified value by several hundred feet. The study area is also covered by two earlier aeromagnetic surveys having north-south flight-lines spaced 2 mi apart. One survey was flown at 9,000 ft altitude and the other at 12,000 ft altitude (barometric) west and east of the Hurricane Cliffs, respectively; data from these surveys were subsequently merged for the aeromagnetic map of Utah (Zietz and others, 1976).

We have removed the core field (International Geomagnetic Reference Field) from the NURE data and analytically continued the residual field upward from the drape elevations to a uniform level of 12,000 ft above sea level. Upward continuation is, in effect, a low-pass filtering operation that acts to suppress anomalies produced by shallow sources relative to those produced by deeper sources. Thus the sharp field fluctuations recorded during low-level flights over strongly magnetic terrain tend to be smoothed out at higher altitudes, and the signatures of deep sources are more readily apparent.

The upward-continued map is shown on figure 3. It reveals a strong, subcircular magnetic high (A) to the northeast of the study area, a weak magnetic ridge or nose of a ridge (B) in the southeast, and a smoothly varying, arcuate regional gradient, with field intensity decreasing westerly. The total magnetic relief is about 270 nanoTeslas (nT). (In contrast, the residual field at the drape elevations has over 700 nT total relief and is much more irregular.)

Magnetic anomaly A (fig. 3) corresponds in position to a sheet of gently inclined Quaternary basalt flows at the western edge of the Markagunt Plateau. The flows are about 200 ft thick (Averitt, 1967) and about 2,000-3,000 ft below the synthetic level of observation. The anomaly characteristics suggest a source whose apex is at or near the land surface but which has considerable depth extent. The probable source is not the relatively thin flows, but rather, a volcanic neck or plug associated with the Lone Tree Mountain cinder cone, located immediately north of the recorded anomaly maximum. A second NURE traverse detected a weaker anomaly close to the summit of Pryor Knoll, a basaltic cinder cone 3 mi south of Lone Tree Mountain. Results from these two traverses served to delineate anomaly A. The anomaly did not appear on the results of the earlier surveys, apparently because the north-south traverse lines did not pass sufficiently close to the source.

A third cinder cone overflown on a NURE traverse, Pine Spring Knoll, about 3 mi southwest of Pryor Knoll, produced only a very weak magnetic anomaly, which disappeared altogether when the data were projected upward to the 12,000-ft level.

Magnetic anomaly B (fig. 3) marks the rising crest of a broad, generally south-southwest-trending magnetic positive interpreted in a previous study as the expression of structural relief on the Precambrian crystalline basement (Houser and others, 1988). Alternatively, the anomaly could be a reflection of intrabasement magnetization contrasts or some combination of intrabasement contrasts and structural relief. The anomaly is apparently not sharply offset by the Hurricane fault. This fault approximately parallels the axis of the anomaly along its western flank but cannot be directly correlated with any disturbance of the magnetic field.

Magnetic basement in the vicinity of the study area may be in part quartz monzonite of Miocene age, as is the case in nearby areas to the west (Pine Valley Mountains, Stoddard Mountain, Iron Springs district). The monzonites of southwestern Utah are commonly iron rich and strongly magnetic at high structural levels in the intrusions (see, for example, Blank and Mackin, 1967). Averitt (1962) has mapped "pyroxene biotite latite" intrusive rock within the Hurricane fault zone near Kanarraville, and similar rock has recently been noted in the fault zone 4 mi farther south by E.G. Sable. Rock of both occurrences is petrographically similar to strongly magnetic quartz monzonite porphyry elsewhere in southwestern Utah. However, no anomalies were recorded on NURE flights over these two bodies, implying that they have very limited extent.

The regional gradient seen on figure 3 is controlled by the proximity of a broad magnetic high of unknown origin that extends off the map to the northwest from anomaly A and by the south-southwest-trending inferred basement structure associated with anomaly B. The northwest-trending feature merges with magnetic highs related to the Miocene intrusions of the Iron Springs district and may represent a deeply buried ridge of quartz monzonite porphyry.

Aeroradiometrics

Aerial gamma-ray spectroscopy is a technique that provides estimates of near-surface (<20 in. depth) concentrations of potassium, uranium, and thorium. Examination of NURE aeroradiometric data yielded no indications of significant anomalous near-surface concentrations of these elements in or near the study area. This result must be considered inconclusive because of the wide traverse spacing and the fact that terrain clearance on parts of the traverses exceeded the effective range of the detector.

Mineral and Energy Resources

The geologic setting of the study area was not a favorable environment for the formation of mineral deposits. Although there are rock formations present that elsewhere are mineralized, those similar mineralizing processes were apparently not in operation here. Coal has been mined nearby and two abandoned oil fields are relatively close to the study area. 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

Petroleum exploration has had very little success in southwestern Utah. 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 basin of northeastern Utah. A few small fields have been discovered outside these areas and the only producing field in southwestern Utah is the Upper

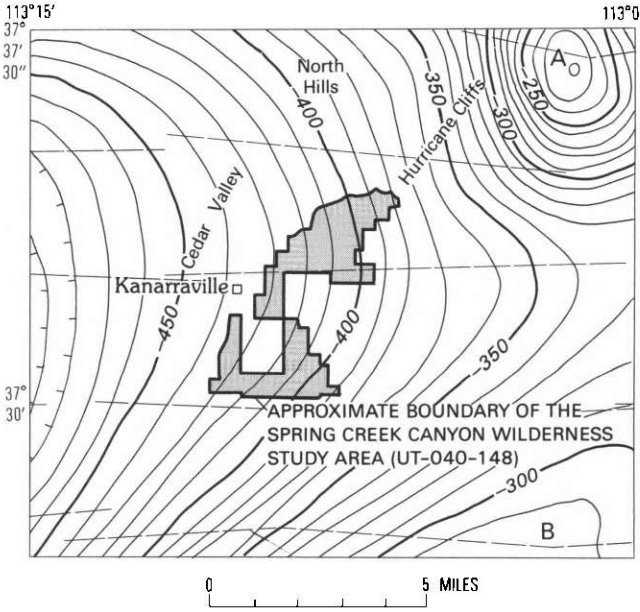


Figure 3. Residual total-intensity aeromagnetic map of the Spring Creek Canyon Wilderness Study Area (shaded) and vicinity, Utah. Contour interval 10 nanoteslas; dashed lines are flight lines; magnetic anomalies (labeled A and B) are referred to in the text; hachures indicate closed low; survey flown 400 ft above terrain and continued upward to 12,000 ft ASL; IGRF removed. Source of data is NURE survey (Geodata International, Inc., 1980).

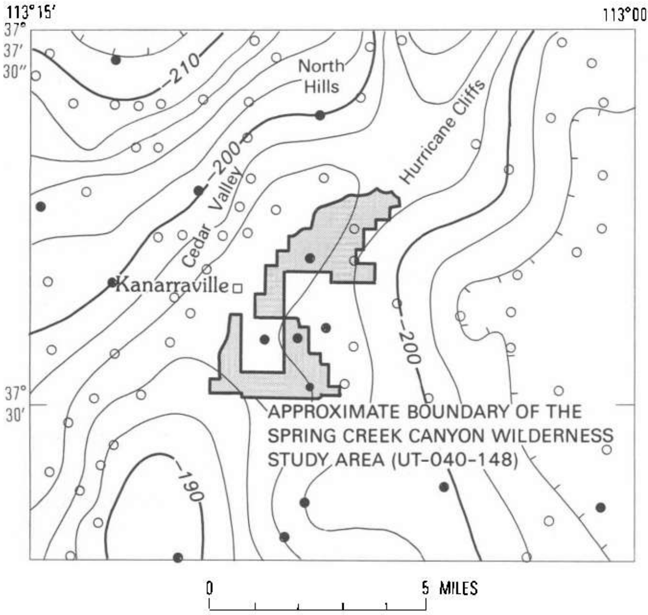


Figure 4. Complete Bouguer gravity anomaly map of the Spring Creek Canyon Wilderness Study Area (shaded) and vicinity, Utah. Contour interval 2 mGals; reduction density 2.67 g/cm³; terrain corrected to 100 mi. Gravity stations (U.S. Defense Mapping Agency files) indicated by solid dots; gravity stations (this study) indicated by open dots; hachures indicate closed low.

Valley field near Escalante, Utah, about 80 mi east of the study area. The now-abandoned Anderson Junction and Virgin fields are about 15 mi southwest and 18 mi south, respectively, of the study area. Because the Anderson Junction and Virgin fields are nearby and have similar geologic settings, their attributes are used in the evaluation of oil and gas potential beneath the study area.

The Virgin field was discovered in 1907 when a shallow well was drilled in the vicinity of oily tar seeps that occur near Virgin, Utah. Since 1907, more than 150 wells have been drilled in and near the Virgin field, the latest being in 1986. A few of the wells produced as much as 30 barrels of oil per day (BOPD), but most wells yielded only 1–4 BOPD from shallow wells ranging from 500 to 800 ft deep. Total production from the field has been slightly more than 200,000 barrels of asphalt-paraffin-base oil and little or no gas (Bahr, 1963).

The reservoir rocks in the Virgin field are the upper part of the Kaibab Limestone and the lime-matrix conglomerate provisionally interpreted to be in sandy limestone 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 the Toroweap Formation, the Kaibab Limestone, and the Timpoweap. The well was considered dry and was abandoned (P. Carter, BLM, Cedar City, Utah, written commun., 1987).

The Anderson Junction field is on the upthrown side of the Hurricane fault on the Hurricane Cliffs and on the east flank of the Kanarra fold, a geologic setting similar to that in the study area. Two wells drilled there had meager production from limestone and dolostone of the Pennsylvanian Callville Limestone. Oil was apparently trapped there by a composite structure associated with the Hurricane fault and the Kanarra anticline (Peterson, 1974). Another well was drilled on the downthrown side of the Hurricane fault in the Anderson Junction area near the axis of the ancestral Kanarra anticline. It was drilled into Cambrian rocks about 7,000 ft deep, but no shows of oil were found.

Many other structures in the region have been tested for oil by drilling, but none were successfully completed although traces of oil were reported. Among those were the Virgin anticline (southwestern Washington County), the Grafton anticline (8 mi southeast of the Virgin field), both sides of the Sevier fault (near Orderville, Utah), the Pintura anticline (10 mi southwest of the study area), and two wells on either side of the Hurricane fault (2 and 5 mi north of the study area (Veal, 1976)).

The Colorado Plateau has had a favorable thermal history for the generation of oil and gas (Ryder, 1983), and some oil in this area may have been generated locally in Paleozoic and Mesozoic rocks; however, there is a paucity of source rocks rich in hydrocarbons. Such source rocks, for example, are the organic-rich shale 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 Plateaus province may be organic-rich Paleozoic rocks of the adjoining Basin and Range province (Giardina, 1979); these rocks are abundant in eastern Nevada and western Utah. The most significant of these is the Mississippian Chainman Shale, and it, after having had a favorable thermal history, provides oil to fields in east-central Nevada (Poole and Claypool, 1984). This source rock may have supplied hydrocarbons that subsequently migrated across a structural hingeline updip into southwestern Utah and northwestern Arizona. The hingeline is the boundary between the tectonically stable Colorado Plateau and the Basin and Range province to the west.

The Spring Creek Canyon Wilderness Study Area has a moderate energy resource potential for oil and gas fields at certainty level C. This assessment is based on the structural and stratigraphic setting, results of exploration in the region, and proximity of the Virgin and Anderson

Junction oil fields. The surface geology is well known in the study area, but there are no subsurface data. Exploration by drilling would be required to identify petroleum resources, but no drilling has been done within the study area. This assessment concurs with the rating given the study area by Molenaar and Sandberg (1983).

The study area may contain structural elements that were responsible for trapping oil in both the Virgin and Anderson Junction fields. The stratigraphy is virtually the same in all three areas. Mild upwarping or doming such as occurred in the Virgin field may exist out on the gentle monocline east of the Kanarra fold. However, if traps do occur, they will probably resemble those found in the Anderson Junction field. Traps there are probably related to structures associated with the Hurricane fault (Peterson, 1974). The structural setting of the study area is remarkably similar to that in the Anderson Junction field. Both are on the upthrown side of the Hurricane fault and both contain a part of the east limb of the ancestral Kanarra fold (see cross section, pl. 1). At the Anderson Junction field, however, the level of erosion is much deeper. In the study area, traps may have formed in Permian and older Paleozoic rock. Trap possibilities might occur along the Kanarra fold, beneath drag folds along the Hurricane fault, or where reservoir rock abuts against the Hurricane fault plane. Conversely, the steep angle of the fault and the steeply dipping beds would seem to permit easy migration of oil to the 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 where accumulations of sediment thin eastward from more than 20,000 ft in the deeper parts of the basin to about 8,500 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 the Timpoweap Member of the Moenkopi Formation (Triassic); the Kaibab Limestone, the Toroweap Formation, Queantoweap and Coconino Sandstones, and the Pakoon Formation (Permian); Callville Limestone (Pennsylvanian); and the Redwall Limestone (Mississippian). These units either are present in outcrop (Timpoweap and Kaibab) or 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 that 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 mentioned earlier in this report, drilled northeast of the Virgin field in 1986, 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 showed fresh water flowing in the Callville and Redwall Limestones (Giardina, 1979).

Metals

The study area has low potential with certainty level C for undiscovered metallic mineral resources including copper, silver, and uranium. South of the study area, rich deposits of silver (with minor amounts of uranium) were mined from the Springdale Sandstone Member of the Moenave Formation in the Silver Reef district near Leeds, Utah. This is apparently a unique deposit in the Springdale; other similar occurrences are not known. No evidence was found to indicate that the Springdale may have been similarly mineralized in the study area.

The Chinle Formation is one of the principal host rocks for sandstone-type uranium deposits in Utah. Both the Shinarump and Petrified Forest Members of the Chinle contain world-class deposits, but none are known in southwestern Utah and it is unlikely that any occur in the study area. The Chinle is well exposed in the study area, but no radioactivity or metal anomalies were found nor did the NURE airborne survey detect any radioactivity. Averitt (1962) noted that outcrops of the Chinle were closely inspected during the uranium "boom" of the 1950's, but no mineralization was found. Sandstone-hosted uranium deposits occur in gently dipping strata; the attitude and permeability of strata control the movement of ground water which carries and deposits uranium. The Chinle in most of the study area is vertical or very steeply dipping. In view of the absence of radioactive anomalies and the attitude of the Chinle beds, it is unlikely that any resources of uranium occur in the study area.

A copper occurrence is a few hundred feet outside the southwest part of the study area (pl. 1; fig. 2). Copper occurs there as oxides and carbonates that coat fracture surfaces in the Kaibab Limestone. The occurrence is at the north end of a zone of mild fracturing that extends for about 0.5 mi along the base of the Hurricane Cliffs. The Kaibab Limestone in this zone is slightly altered and stained with limonite. Alteration is slightly more intense around the small quartz monzonite intrusion at the southern end of the fracture zone. The intrusion appears unaltered, and no skarn development was seen along its contact with the limestone. The fracture zone is probably related to movement along the Hurricane fault, and the quartz monzonite may have been intruded along this zone of weakness. Furthermore, it is doubtful that the quartz monzonite body is an apophysis of a larger body at depth. Should one exist, the favorability for mineralization would be higher. Iron deposits are associated with the Pine Valley quartz monzonite laccolith to the west of Cedar Valley. However, the geophysical studies did not detect the exposed quartz monzonite in the study area nor did they reveal any larger body or extension of the body at depth. Analyses of several rock samples collected from the zone of alteration reveal anomalous amounts of several elements that indicate hydrothermal activity, but the paucity of mineralization elsewhere along the length of the Hurricane fault, the lack of sulfide minerals, and the relatively slight degree of alteration of the host rocks indicate that the mineralization processes that operated here were very weak.

Geothermal Energy

The study area has a low potential for geothermal energy, with a C level of certainty. The study area is near the western edge of the Colorado Plateau, a tectonically stable province characterized by low heat flow that provides only a meager basis for geothermal resources (Muffler, 1978). By comparison, the adjoining Basin and Range province contains several known geothermal resource areas, and large areas are favorable for discovery and development of local sources of low-temperature water. These areas of resources begin about 25 mi west and 15 mi south of the study area. The study area is about 25 mi north of thermal springs that discharge warm water (105 °F) into the Virgin River near Hurricane, Utah. These springs are along and are probably controlled by fractures in the Hurricane fault zone. The Hurricane fault may tap deep sources of hot water, but other warm springs are not known to occur along it, including that terrain at the base of the Hurricane Cliffs adjacent to the study area. There are no warm springs in the study area nor does the geologic setting appear to be favorable for geothermal sources. The trace of the Hurricane fault, at depth, is outside the study area.

Gypsum

The study area has no potential for undiscovered deposits of gypsum. This assessment is made with a D level of certainty. There are massive amounts of gypsum in the gypsiferous member of the Carmel Formation nearby, but they are east of the study area.

Coal

There is no potential for undiscovered coal deposits in the study area. This assessment is made with a D level of certainty. Coal was mined within 1 mi of the study area from the Tropic Shale in the Kolob coal field. Coal in this field, as in most others throughout Utah, occurs in rocks of Cretaceous age. There are no rocks of this age in the study area, nor are any exposed or subsurface rock units in the study area known to contain coal.

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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.

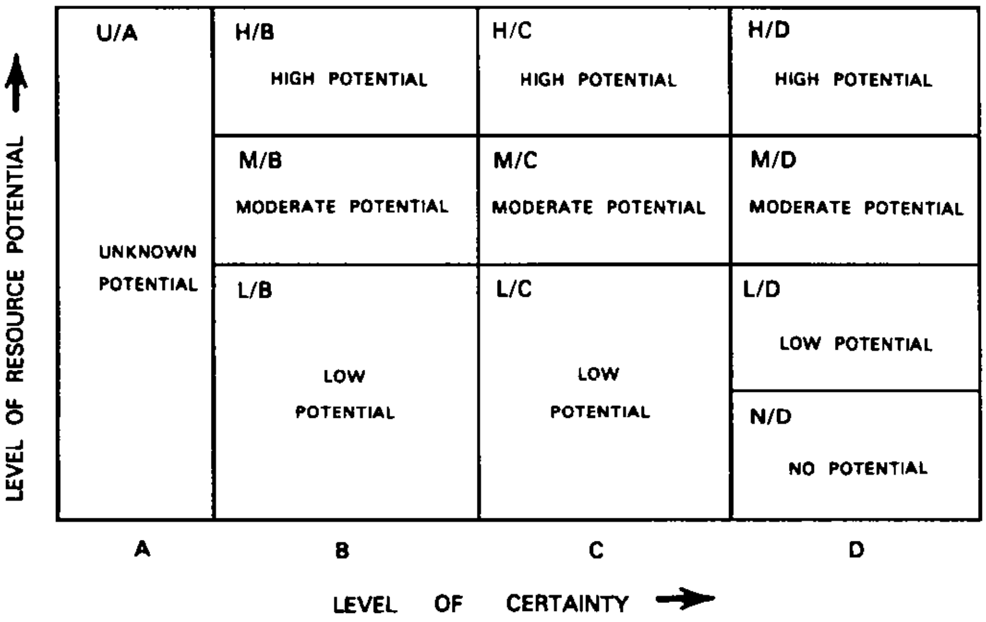
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application 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



<table>
<tr><td rowspan="4">U/A
UNKNOWN POTENTIAL</td><td>H/B
HIGH POTENTIAL</td><td>H/C
HIGH POTENTIAL</td><td>H/D
HIGH POTENTIAL</td></tr>
<tr><td>M/B
MODERATE POTENTIAL</td><td>M/C
MODERATE POTENTIAL</td><td>M/D
MODERATE POTENTIAL</td></tr>
<tr><td rowspan="2">L/B
LOW POTENTIAL</td><td rowspan="2">L/C
LOW POTENTIAL</td><td>L/D
LOW POTENTIAL</td></tr>
<tr><td>N/D
NO POTENTIAL</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td></tr>
</table>

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:

Taylor, R. B., and Steven, T. A., 1983, Definition of mineral resource potential: Economic Geology, v. 78, no. 6, p. 1268–1270.

Taylor, R. B., Stoneman, R. J., and Marsh, S. P., 1984, An assessment of the mineral resource potential of the San Isabel National Forest, south-central Colorado: U.S. Geological Survey Bulletin 1638, p. 40–42.

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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 McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and 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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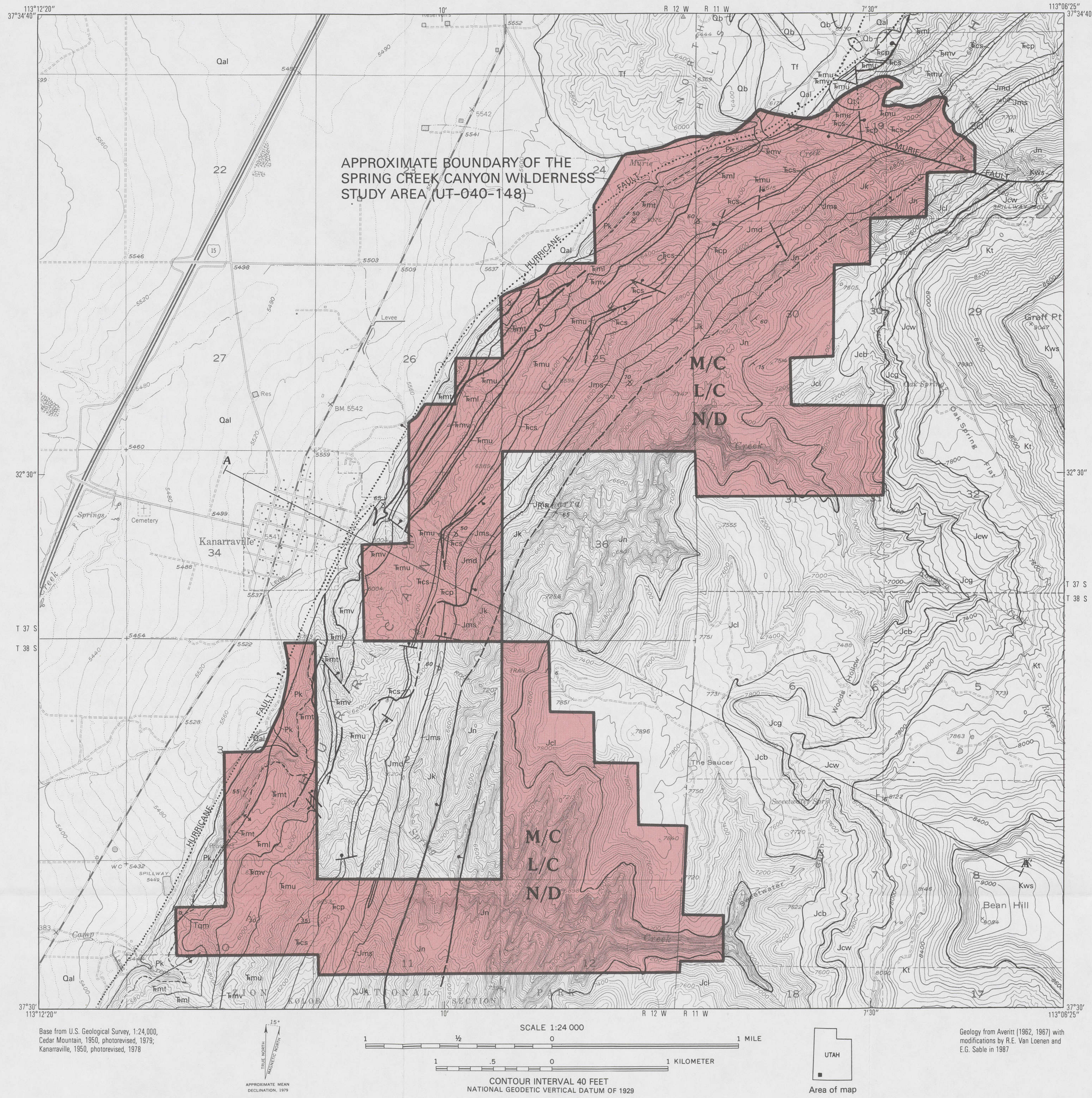
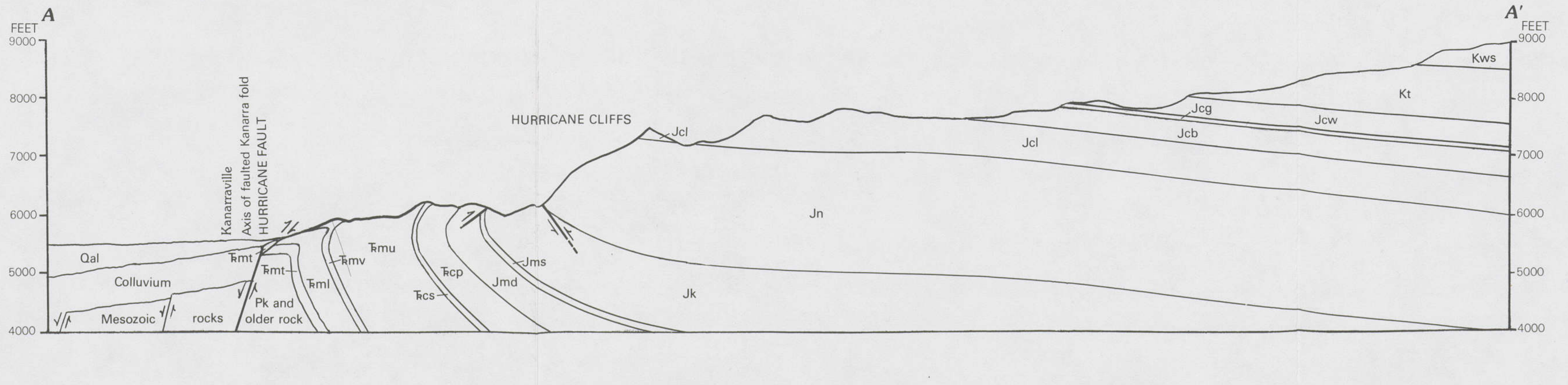


Base from U.S. Geological Survey, 1:24,000,
Cedar Mountain, 1950, photorevised, 1979;
Kanarraville, 1950, photorevised, 1978

Geology from Averitt (1962, 1967) with
modifications by R.E. Van Loenen and
E.G. Sable in 1987



EXPLANATION OF RESOURCE POTENTIAL

🟥 M/C	Geologic terrane having moderate energy resource potential for oil and gas, with certainty level C—Applies to entire study area
L/C	Geologic terrane having low resource potential for all metals including copper, silver, uranium, and geothermal sources, with certainty level C—Applies to entire study area
N/D	Geologic terrane having no resource potential for coal and gypsum, with certainty level D—Applies to entire study area

CORRELATION OF MAP UNITS

Unit			
Qal			QUATERNARY
Qt			
Qb			
Tf			TERTIARY
Tqm			
Unconformity			
Kws	Upper Cretaceous		CRETACEOUS
Kt			
Unconformity			
Jcw	Middle Jurassic		JURASSIC
Jcg			
Jcb			
Jcl			
Jn	Lower Jurassic		
Jk			
Jms			
Jmd			
Ꞓcp	Upper Triassic		TRIASSIC
Ꞓcs			
Ꞓmu	Middle(?) and Lower Triassic		
Ꞓmv			
Ꞓml			
Ꞓmt			
Unconformity			
Pk	Lower Permian		PERMIAN

LIST OF MAP UNITS

Qal	**Alluvium (Quaternary)**
Qt	**Talus (Quaternary)**
Qb	**Basalt (Quaternary)**
Tf	**Fanglomerate deposits (Tertiary)**
Tqm	**Quartz monzonite (Tertiary)**
Kws	**Wahweap and Straight Cliffs Sandstones (Upper Cretaceous)**
Kt	**Tropic Shale (Upper Cretaceous)**
	Carmel Formation of San Rafael Group (Middle Jurassic)
Jcw	**Winsor Member**
Jcg	**Gypsiferous member**
Jcb	**Banded member**
Jcl	**Limestone member**
	Glen Canyon Group (Lower Jurassic)
Jn	**Navajo Sandstone**
Jk	**Kayenta Formation**
	Moenave Formation
Jms	**Springdale Sandstone Member**
Jmd	**Dinosaur Canyon Member**
	Chinle Formation (Upper Triassic)
Ꞓcp	**Petrified Forest Member**
Ꞓcs	**Shinarump Member**
	Moenkopi Formation (Middle? and Lower Triassic)
Ꞓmu	**Includes upper red member, Shnabkaib Member, and middle red member**
Ꞓmv	**Virgin Limestone member**
Ꞓml	**Lower red member**
Ꞓmt	**Timpoweap Member**
Pk	**Kaibab Limestone (Lower Permian)**

Contact—Dashed where approximately located

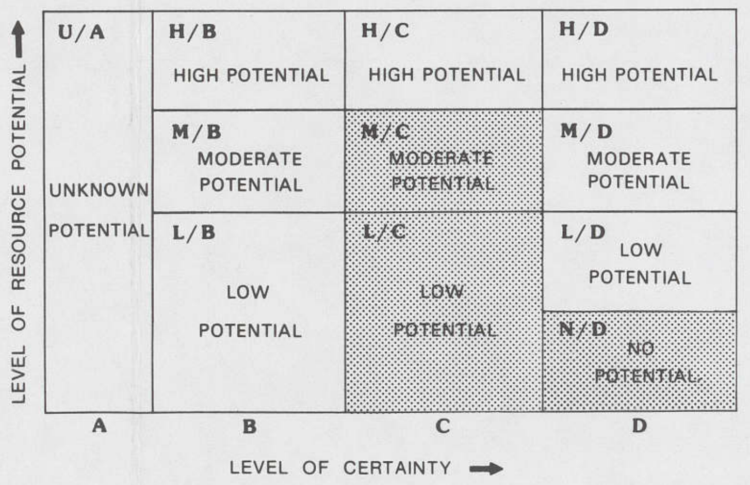
Fault—Dashed where approximately located; dotted where concealed. Bar and ball on downthrown block

Anticline

Strike and dip of bedding

Inclined

50 **Overturned**



LEVELS OF RESOURCE POTENTIAL

H High mineral resource potential
M Moderate mineral resource potential
L Low mineral resource potential
U Unknown mineral resource potential
N No known mineral resource potential

LEVELS OF CERTAINTY

A Available data not adequate
B Data indicate geologic environment and suggest level of resource potential
C Data indicate geologic environment, give good indication of level of resource potential, but do not establish activity of resource-forming processes
D Data clearly define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Diagram showing relationships between levels of mineral resource potential and levels of certainty. Shading shows levels that apply to this study area

MAP SHOWING MINERAL RESOURCE POTENTIAL AND GEOLOGY OF THE SPRING CREEK CANYON WILDERNESS STUDY AREA, IRON COUNTY, UTAH