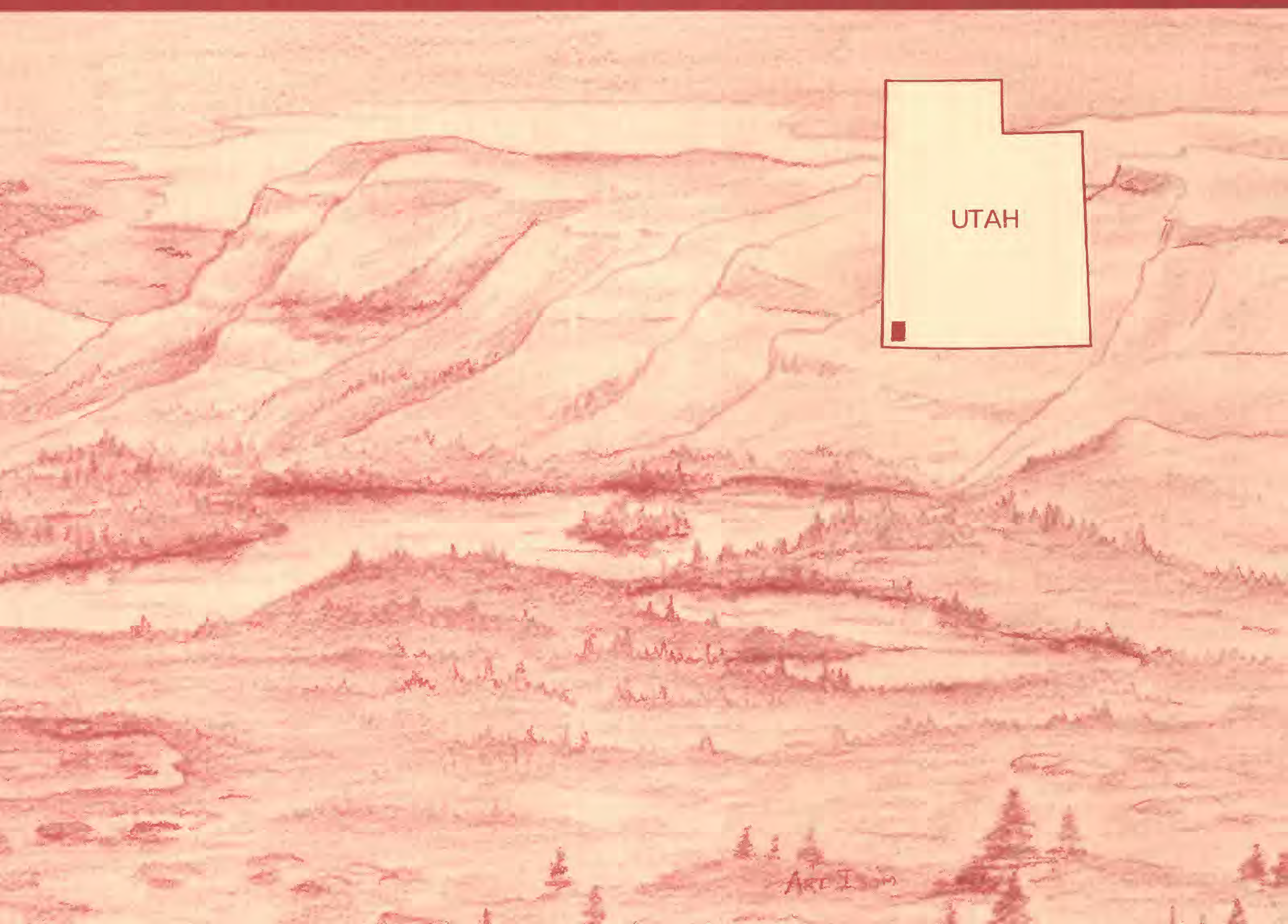
Mineral Resources of the Red Mountain Wilderness Study Area, Washington County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1746–D



Chapter D

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U.S. GEOLOGICAL SURVEY BULLETIN 1746

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—SOUTHWESTERN UTAH

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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Dallas L. Peck, Director

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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 part of the Red Mountain Wilderness Study Area (UT–040–132), Washington County, Utah.

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PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Red Mountain Wilderness Study Area, Washington County, Utah

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ABSTRACT

The U.S. Bureau of Mines and the U.S. Geological Survey studied 17,450 acres of the Red Mountain Wilderness Study Area (UT–040–132) Washington County, Utah, during spring 1986, to determine their identified resources and mineral resource potential. There are no mines, prospects, or mineralized areas; however, inferred subeconomic resources of common-variety building stone and silica sand are present at the surface. The resource potential for metallic minerals and for oil and gas is low (fig. 1). The energy resource potential for high-temperature geothermal sources in the eastern part of the study area is moderate, whereas the entire study area has high potential for low-temperature geothermal sources. There is no energy resource potential for coal.

SUMMARY

Character and Setting

The Red Mountain Wilderness Study Area (UT–040–132) is in southwestern Utah, about 8 mi (miles) northwest of St. George (fig. 2). The Shivwits Indian Reservation lies just south and southwest of the study area, and Snow Canyon State Park bounds the area on the east. The Santa Clara River flows southward along the west side of the study area. Easy access is provided to all sides of the study area via graded and paved roads.

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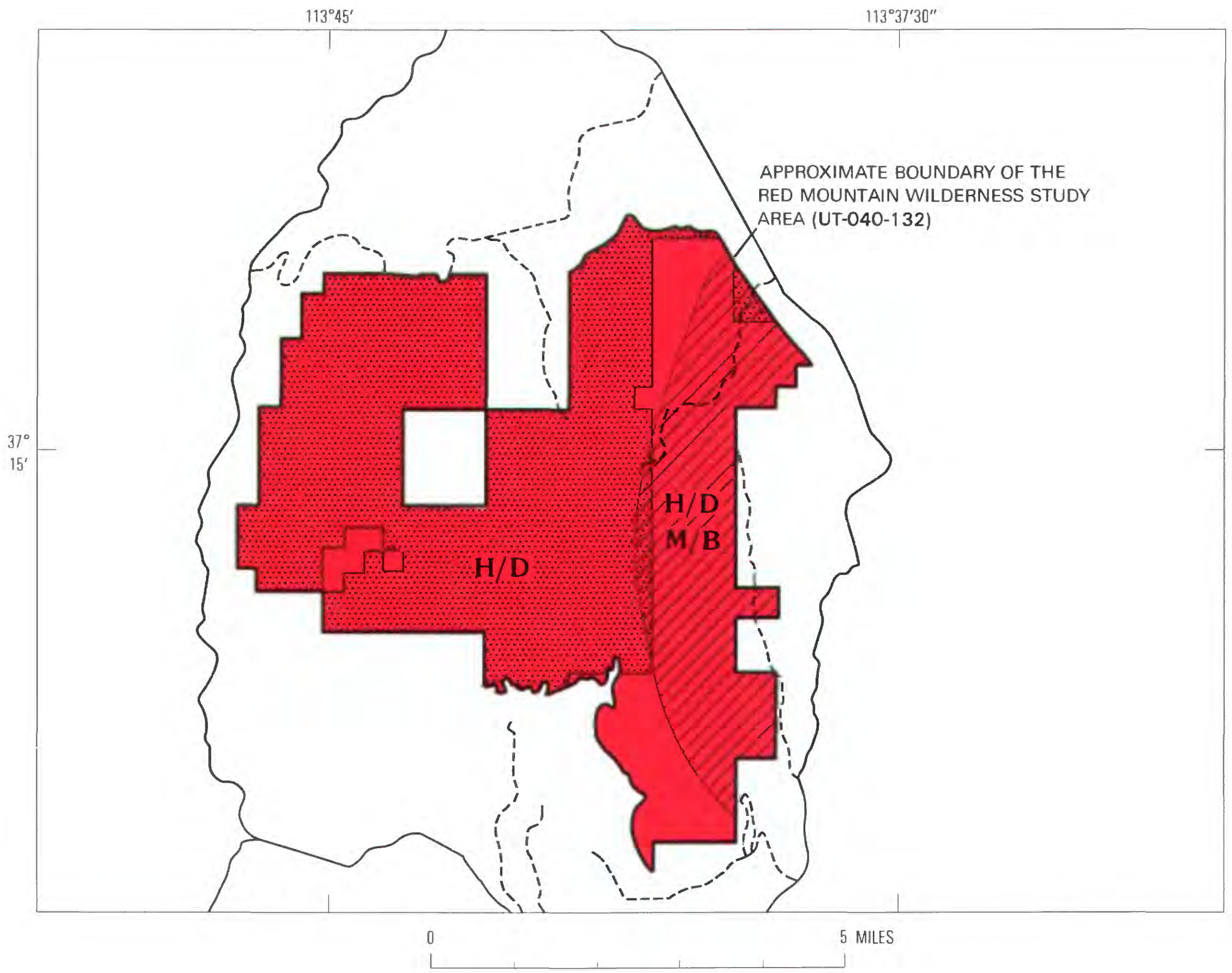
The Red Mountains are a high sandstone plateau that merges to the north with an extensive field of basalt flows and is bounded on the east, south, and west by cliffs 800–1,600 ft (feet) high. The elevation of the study area ranges from 3,240 ft near the base of the cliff northeast of Ivins to 5,570 ft on the plateau northwest of Snow Canyon.

The rocks present in the Red Mountain Wilderness Study Area and vicinity are chiefly clastic rocks of Mesozoic age (see geologic time chart in Appendix), Quaternary basalt and basaltic andesite flows, and an extensive cover of Quaternary surficial deposits. The Mesozoic rocks dip generally north-northeastward at low angles, thus the oldest units are exposed in the south and the youngest in the north. The Navajo Sandstone of Triassic(?) and Jurassic age is virtually the only rock unit present within the wilderness study area proper. The north-trending Gunlock fault cuts across part of the extreme western edge of the study area.

Analysis of geophysical data indicates that the study area overlies an east-west-trending regional gravity gradient. The gradient generally decreases in field values from south to north, and has been inferred to be a result of large-scale emplacement of granitic rock beneath the Great Basin to the north, and (or) a northward deepening of the surface of dense Paleozoic carbonate rocks and the underlying Pre-cambrian crystalline basement. The study area also overlies a regional aeromagnetic gradient that is interpreted as a reflection of the northward deepening of the basement surface. No aeromagnetic anomalies occur over either the Hurricane fault or the Virgin anticline (figs. 3 and 4), suggesting that the Hurricane fault, a high-angle structure at



EXPLANATION OF MINERAL AND ENERGY RESOURCE POTENTIAL

[Entire study area has low resource potential for (1) silver, copper, uranium, vanadium, and gold, with certainty level B, (2) all other metallic minerals, with certainty level C, and (3) oil and gas, with certainty level B. Entire study area has no energy resource potential for coal, with certainty level D]

H/D **Geologic terrane having high energy resource potential for low-temperature geothermal sources, with certainty level D—**Applies to entire study area

M/B **Geologic terrane having moderate energy resource potential for high-temperature geothermal sources, with certainty level B—**Applies to eastern part of study area (patterned)

Certainty levels

B **Data indicate geologic environment and suggest level of resource potential**

C **Data indicate geologic environment and 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 study area**

Oil and gas leases—Information from the U.S. Bureau of Land Management as of 1985

Paved road

Graded road

Figure 1. Summary map showing mineral and energy resource potential and oil and gas leases within the Red Mountain Wilderness Study Area, Washington County, Utah.

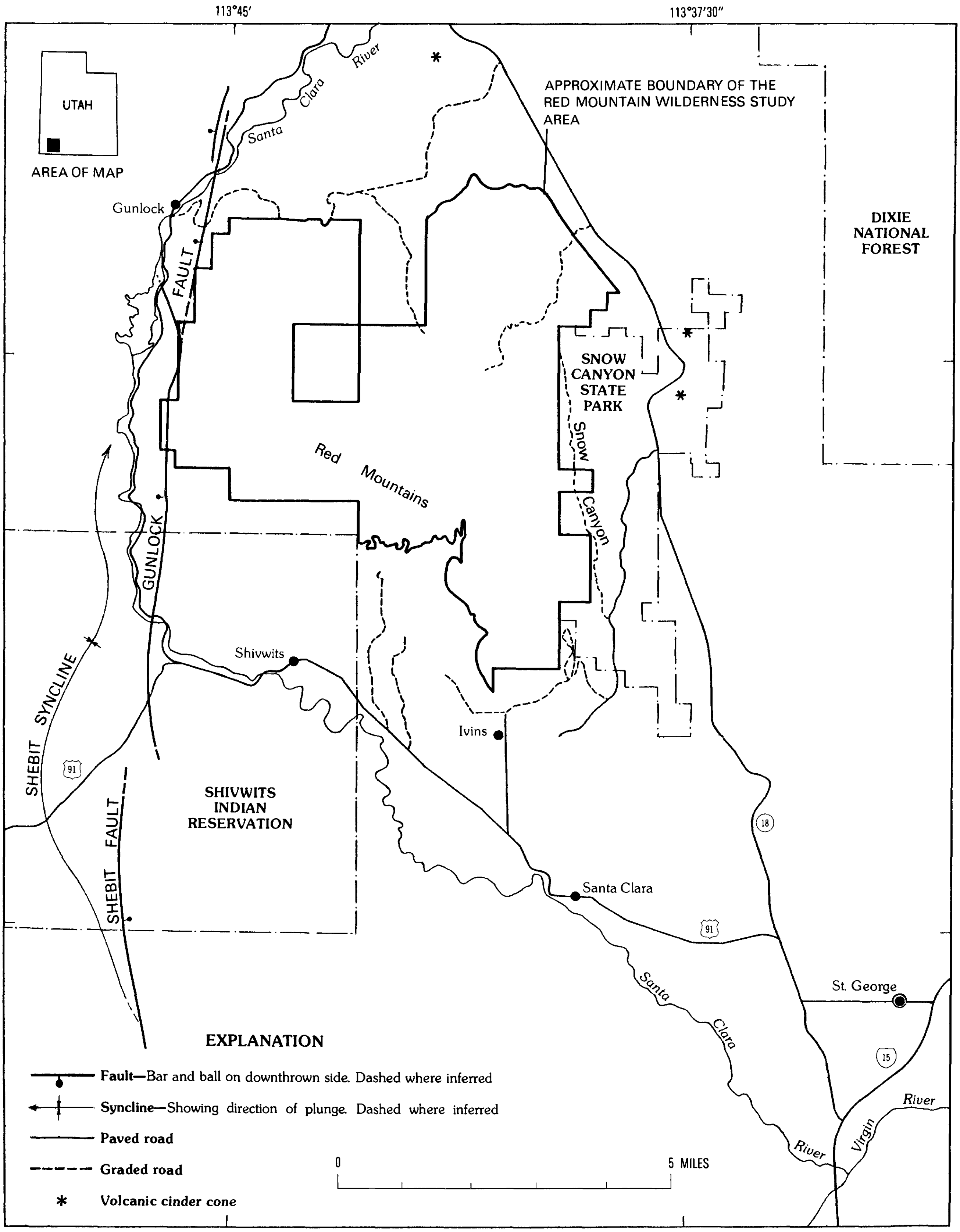


Figure 2. Index map of the Red Mountain Wilderness Study Area, Washington County, Utah. Structural data modified from Cook (1960). Note: "Red Mountains" is the name of the topographic feature.

the surface, may flatten at depth and that the Virgin anticline may be detached from the basement.

Identified Resources and Resource Potential

There is no record of mining or prospecting in the Red Mountain Wilderness Study Area. Silver reportedly was mined from the Springdale Sandstone Member of the Moenave Formation in the Santa Clara mining district, described as being 10 mi west of St. George, but there is no record of ore shipments from this district. As of August 1985, approximately 10,640 acres of the study area were under lease for oil and gas (fig. 1); however, no evidence of drilling or past exploration activity was seen during field investigation of the study area. Common varieties of building stone and silica sand are inferred subeconomic resources in the study area; however, the low unit values of these commodities require a local market to be economically viable.

No occurrences of mineralized rock were seen in the study area, and local anomalous concentrations of metallic elements within the study area are most likely associated with manganese oxide nodules. The Springdale Sandstone Member is present beneath the study area at depths ranging from about 600 ft at the south to more than 3,000 ft at the north. The lack of observable mineralized rock in outcrops of the Springdale and the absence of recorded ore production from the Santa Clara mining district suggest that the mineral resource potential for undiscovered silver, copper, uranium, vanadium, and gold resources (metals produced in the nearby Silver Reef mining district) is low in the study area. The mineral resource potential for undiscovered resources of any other metals in the study area is low.

Oil and gas have been produced from upper Paleozoic and Lower Triassic rocks at two fields about 25 mi east and northeast of the study area, east of the Hurricane fault. These rocks are probably present beneath the study area, but no favorable structural or stratigraphic traps have been identified in the study area, and no definite shows of oil have been reported from test wells drilled west of the Hurricane fault. Aeromagnetic data, which suggest that the Hurricane fault flattens at depth and that the Virgin anticline is detached from the basement, imply that structural and stratigraphic sequences at depth may be different from those present in the upper few thousand feet of the crust in and around the study area. Because currently available data are inadequate to evaluate this implication, a low energy resource potential for undiscovered oil and gas is assigned to the study area.

There are no hot springs in or near the study area; however, the presence of young-appearing volcanic cinder cones 1.5–2.0 mi to the east suggests that the energy resource potential for high-temperature geothermal sources associated with basaltic igneous systems is moderate in the eastern part of the study area. The energy resource potential for undiscovered low-temperature geothermal sources (less than 194 °F at depths less than 0.6 mi) for the entire study area is high as the study area is in a region having terrestrial heat flow of about 1.5–2.5 heat flow units (one heat flow unit yields a geothermal gradient of about 15 °F per 1,000 ft).

Coal, ranging in rank from lignitic to bituminous, is present in Upper Cretaceous rocks north and east of the study area, but there are no Upper Cretaceous rocks within the study area. Mesozoic and Paleozoic rocks beneath the study area are not known to contain coal in the region. Thus, the area has no energy resource potential for undiscovered coal.

INTRODUCTION

The USBM (U.S. Bureau of Mines) and the USGS (U.S. Geological Survey) studied 17,450 acres of the Red Mountain Wilderness Study Area (UT–040–132) in Washington County, Utah, as requested by the BLM (U.S. Bureau of Land Management). In this report the area studied is referred to as the "wilderness study area" or simply the "study area." The Red Mountain Wilderness Study Area is in southwestern Utah, about 8 mi northwest of St. George (fig. 2). The smaller communities of Ivins and Gunlock are less than a mile to the south and northwest, respectively. The Shivwits Indian Reservation lies just south and southwest of the study area, and Snow Canyon State Park bounds the study area on the east. Easy access is provided to all sides of the study area via graded roads, paved county roads, U.S. Highway 91, and by Utah Highway 18.

The Red Mountains are a high sandstone plateau that merges to the north with an extensive field of basalt flows and is bounded on the east, south, and west by cliffs 800–1,600 ft high (pl. 1). The elevation of the study area ranges from 3,240 ft near the base of the cliff northeast of Ivins to 5,570 ft on the plateau northwest of Snow Canyon.

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 sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the Appendix. The potential for undiscovered resources is studied by the USGS.

Investigations by the U.S. Bureau of Mines

USBM personnel reviewed various sources of minerals information including published and unpublished literature. Mining claim and oil and gas lease information was obtained from the BLM state office in Salt Lake City, Utah. USBM field studies in April and May 1986 included searching for mines and prospects both inside and as far as 1 mi outside the study area. Sandstone beds were sampled to determine their suitability for specific industrial uses; a total of 17 samples was taken. Additional information is available from USBM, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

The study area lies within the area mapped by photogeology and in reconnaissance at scale 1:125,000 for the geologic map of Washington County (Cook, 1960). More detailed geologic mapping of the southern part of the study area at scale 1:62,500 has been done by W. Kenneth Hamblin of Brigham Young University (St. George 15-minute quadrangle, unpub. data). The western border of the study area has been mapped at scales 1:24,000 and 1:48,000 by Hintze (1985, 1986). Geologic mapping for this mineral resource assessment of the study area was done by B.B. Houser at scale 1:24,000 during April and May 1986. Exposures were examined for signs of mineralized rock, and rock samples were collected for petrographic study. The geochemical study was done in 1986 by J.L. Jones and J.E. Kilburn; stream-sediment samples and heavy-mineral concentrates of stream sediments were collected at 37 sites, and rock samples were collected at 26 sites (Detra and others, 1988). Collection of new gravity data and interpretation of gravity and aeromagnetic data were by H.R. Blank, Jr., and interpretation of available radiometric data was by J.S. Duval.

APPRAISAL OF IDENTIFIED RESOURCES

By Robert H. Wood II U.S. Bureau of Mines

There is no record of mining or prospecting in the Red Mountain Wilderness Study Area. The Santa Clara mining district, organized in 1880, was reported to be 10 mi west of St. George, Utah (possibly a mile or two south of the study area), and to be producing from the same stratigraphic unit (Springdale Sandstone Member of the Moenave Formation) as the Silver Reef mining district about 15 mi east of the study area (Butler and others, 1920, p. 594). No shipments of ore have been reported from the Santa Clara district.

Oil and Gas

As of August 1985, approximately 10,640 acres of the Red Mountain study area were under lease for oil and gas (fig. 1) (Wood, 1987, fig. 3). No evidence of drilling or past exploration activity was seen during USBM field reconnaissance. Oil and gas is not an identified resource in the study area.

The nearest oil and gas fields, the Anderson Junction and Virgin fields, are approximately 25 mi northeast and 25 mi east, respectively, of the study area. The Anderson Junction field is now abandoned. Oil production from the Pennsylvanian Callville Limestone in the Anderson Junction field was associated with a fault and fold intersection. Oil shows in this field were reported in the Permian Kaibab Limestone, Toroweap Formation, and Coconino Sandstone and in the Mississippian Redwall Limestone. Oil production in the Virgin field is along the nose of an anticline in the basal member of the Moenkopi Formation of Triassic age. Oil shows also were reported in the Coconino Sandstone and the Callville Limestone. (See Oakes and others, 1981, p. 13–18, 54–56.)

Silver

Silver has been mined from the Springdale Sandstone Member in the Silver Reef and Santa Clara mining districts (Hess, 1933, p. 454). The Springdale is not exposed in the study area, but it is closest to the surface (500–1,000 ft) on the southern side of the area. The Springdale is covered by as much as 2,500 ft of Navajo Sandstone and 1,200 ft of Kayenta Formation throughout the rest of the study area.

Industrial Rocks and Minerals

Inferred subeconomic resources of common varieties of building stone and silica sand occur in the study area. According to Cook (1960, p. 112), "Silica sand has been produced intermittently from a deposit between St. George and Veyo." This deposit was not found during the USBM's field study, but is most likely in the Navajo Sandstone or sand dunes made up of weathered Navajo. Samples taken by the USBM in and near the study area show that the silica content in the Navajo Sandstone ranges from 87.84 percent to 94.70 percent (Wood, 1987, table 2). These percentages are below the minimum specifications of 95.00 percent suggested for the manufacturing of glass (Buie and Robinson, 1958, table 1), and therefore suggest that the Navajo Sandstone within the study area is not suitable for glass manufacture. Near the contact of the Navajo with the overlying Temple Cap Sandstone just north of the study area (sample 436VEY86, pl. 1), the Navajo is cemented with silica and, thus, may contain more than 95.00 percent silica. Occurrences of silica-cemented Navajo are apt to be thin and local, however.

All of the industrial rocks present in the study area have low unit values and require local markets to be economically viable; demand for these resources from the study area in the near future is unlikely.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By B.B. Houser, Janet L. Jones, James E. Kilburn, and H.R. Blank, Jr. U.S. Geological Survey

K.L. Cook University of Utah

Geology

Geologic Setting

The rocks present in the Red Mountain Wilderness Study Area and vicinity are chiefly clastic rocks of Mesozoic age, Quaternary basalt and basaltic andesite flows, and an extensive cover of Quaternary surficial deposits (pl. 1). The Mesozoic rocks dip generally north-northeastward at low angles, thus the oldest units are exposed in the south and the youngest in the north. The Navajo Sandstone of Triassic(?) and Jurassic age is virtually the only rock unit exposed within the wilderness study area proper. The north-trending Gunlock fault cuts across part of the extreme western edge of the study area.

Stratigraphy

The Upper Triassic Petrified Forest Member of the Chinle Formation (Wilson and Stewart, 1967) and the Dinosaur Canyon and Springdale Sandstone (Silver Reef Sandstone of Proctor, 1953) Members of the Upper Triassic(?) Moenave Formation (Harshbarger and others, 1957) are exposed south of the study area. The overlying Kayenta Formation of Late Triassic(?) age (Averitt and others, 1955) is the oldest unit present in the study area, and is exposed along the base of the cliff that bounds much of the study area on the south. These units (Chinle, Moenave, and Kayenta) form a sedimentary sequence of mudstone and sandstone that is in large part fluvial. Petrified wood and detrital carbonaceous material are common in the Springdale. Contacts between the Chinle, Moenave, and Kayenta are disconformities or minor erosional unconformities marked by fluvial channels and clay-pebble conglomerate lenses. The contact of the Kayenta with the overlying Navajo Sandstone is gradational and intertonguing over a vertical interval of about 50–75 ft, and records a change from deposition on coastal salt flats (upper part of the Kayenta) to deposition of eolian sand dunes (Navajo).

The Triassic(?) and Jurassic Navajo Sandstone is exposed over all of the study area except for small areas of basalt flows in canyons at the eastern and northwestern boundaries, and except for exposures of the Kayenta Formation along the base of the cliffs at the south. The Navajo Sandstone is about 2,000–2,500 ft thick at the Red Mountains (Hintze, 1986), and is characterized by large-scale eolian crossbedding, strong jointing, a tendency to develop smoothly sculptured vertical cliffs, and vividly contrasting reddish-orange and white color.

The Middle Jurassic Temple Cap Sandstone and Carmel Formation, the Upper Cretaceous Dakota Conglomerate, and the Upper(?) Cretaceous Iron Springs Formation are exposed to the northwest and northeast of the study area. The youngest rocks in and around the study area are Quaternary surficial materials and basalt flows. The sources of the basalt flows were fissures and cones north and northeast of the study area (fig. 2). Flows west of the study area have been dated at 1.6±0.1 Ma (million years ago) (Hintze, 1986) and 1.1±0.1 Ma (sample no. SG–70, Best and others, 1980). Flows east of the study area in Snow Canyon may be only a few thousand years old.

The surface of much of the Navajo Sandstone on the Red Mountains is covered by a blanket of residual and reworked sand ranging from a few inches to as much as several tens of feet thick.

Structure

The study area lies at the western edge of the 25-mi-wide transition zone that separates relatively undeformed rocks of the Colorado Plateau on the east from the block-faulted terrane of the Basin and Range province on the west. It is in the trough of the broad, shallow, northeast-plunging Pine Valley syncline (fig. 3) (Cook 1960). Reversals of dip in poorly exposed rocks south of the study area suggest the presence of minor folding, but no folding is evident in the Navajo Sandstone within the study area.

The north-trending Gunlock fault passes through the extreme western edge of the study area. The Gunlock fault is the northern segment of the Grandwash fault, one of the major block faults that mark the boundary between the Colorado Plateau and the Basin and Range province. Cook (1960) estimated the displacement of the fault (downthrown side on the west) to be about 4,000 ft near the town of Gunlock. The only effect of the fault seen in the rocks of the study area is a sheared and leached zone about 500 ft wide in the Navajo Sandstone adjacent to the fault.

Geochemistry

Methods

The geochemical survey of the study area included the collection of stream-sediment samples, the collection of rock samples near the stream-sediment sample sites, and the derivation of heavy-mineral concentrates (hereafter referred to as concentrates) from the stream-sediment samples. Stream sediments and concentrates were collected from active alluvium in first-order streams (unbranched) and second-order streams (below the junction of the first-order streams as determined from 1:24,000-scale maps). Rock samples were taken from unaltered outcrops to provide background information for geochemical values.

These sample media were chosen because they best reflect the chemistry of rock material eroded from the drainage basin upstream from the sample site, as well as from the site itself. Concentrates may contain minerals that result from ore-forming processes in addition to detrital heavy minerals common to sedimentary rocks. The selective concentration of heavy minerals permits determination of some elements that are not easily detected in bulk stream-sediment samples. Stream sediments and rocks provide information that helps identify areas that contain unusually high concentrations of elements that may have been derived from mineral deposits. These samples also help to identify rock types upstream.

Both stream sediments and concentrates were collected at 37 sites, and rocks were collected at 26 sites. These sample sites are located both within and outside of the study area (pl. 1). Stream sediments were sieved to minus-80 mesh and then pulverized to fine powder for analysis. To obtain concentrates, bulk stream-sediment samples were sieved to minus-10 mesh and then panned to eliminate most of the quartz, feldspar, clays, and organic material. The remaining lightweight minerals were removed by heavy-liquid separation (bromoform, specific gravity 2.8) and discarded. The heavy minerals were magnetically separated into three fractions—magnetic, slightly magnetic, and nonmagnetic. The nonmagnetic fraction was ground to a fine powder before analysis. The rock samples were crushed and then pulverized to a fine powder for analysis. Splits of the pulverized samples were analyzed for 31 elements by six-step, optical emission, semiquantitative spectrography (Grimes and Marranzino, 1968). Detailed sampling procedures and sample preparation and analytical techniques are given in Detra and others (1988).

Anomalous elemental concentrations obtained from analysis of the three sample types were used to delineate possible mineral deposits. Values were determined to be anomalous by comparison with background values of the study area and vicinity and with crustal abundance (Rose and others, 1979). Background values were developed by calculating the mean of each element and then applying two standard deviations to the mean to yield a minimum threshold value. This value was then compared with the average crustal abundance of each element and with data given in the literature for similar material. From this procedure, tentative anomalous values were determined.

Results

Concentrates, stream sediments, and rocks were all useful in locating anomalous concentrations of elements throughout the study area. Sites containing anomalous concentrations of barium (greater than 10,000 ppm) in concentrates were scattered throughout the map area, with a slight concentration in the northeast region. Barite, confirmed by microscopic inspection and X-ray diffraction, was abundant in all of the samples containing anomalous barium and is assumed to be the major source of this element. High concentrations of strontium occurred in the concentrates at two of the sites anomalous in barium. Strontium is commonly associated with barium and this association was confirmed using a laser microprobe, which detected strontium within the crystal lattice of the barite. Also, tin was notably high in the concentrates with respect to background at four widely separated sites. The mineral source of the weak tin anomalies was not identified.

Anomalous concentrations of tungsten, arsenic, and antimony were found in a stream-sediment sample (no. 106, pl. 1) and a rock sample (no. 111, pl. 1) taken from a drainage in the north-central part of the map area (pl. 1). This suite of elements is associated with the manganese oxide nodules found in the drainage. Spectrographic analysis of a manganese oxide nodule found at the rock sample site confirmed the association of the anomalous elements with the manganese oxide. Semiquantitative emission spectrographic analysis of this nodule revealed anomalous tungsten (greater than 10,000 ppm), arsenic (700 ppm), and antimony (2,000 ppm) as well as high amounts of copper, cobalt, molybdenum, and barium. No anomalous values were found in concentrate samples from this drainage, but in this sample medium the slightly magnetic manganese oxide would be removed during preparation. Other rock samples from the drainage not coated with the manganese oxide also were not anomalous in these elements. The source of the high elemental concentrations is assumed, therefore, to be due strictly to the manganese oxide.

X-ray diffraction and scanning electron microprobe analyses identified the manganese oxide nodule as hollandite, a barium-rich manganese oxide. Manganese oxide minerals, in general, are known for their scavenging abilities and almost certainly enrich normal background concentrations for certain elements. The majority of the anomalous elements previously mentioned could have been accumulated in this manner. At greater than 10,000 ppm, however, tungsten is anomalous even in manganese oxide. Tungsten is rare in the Earth's crust and, in general, the content of tungsten in common rock-forming minerals is low (Hobbs and Elliot, 1973). Although tungsten enrichment may occasionally occur in ferruginous sandstone, no tungsten was found in any rock sample that was not associated with a manganese oxide coating. As the tungsten was not found to be originating in the sandstone of the area, it must have accumulated in the hollandite along the route traversed by the ground water. As no further follow-up studies were done in this area, the inferred source of the metals (tungsten in particular) is strictly conjectural.

Geophysics

Regional Bouguer gravity and aeromagnetic anomaly data in the Red Mountain Wilderness Study Area and vicinity and limited aeroradiometric data provide insight and constraints on structural and lithologic interpretations that may affect the assessment of mineral resource potential. The gravity anomalies chiefly reflect regional structural and compositional trends and do not provide evidence for any mineral deposits or occurrences in the study area. Interpretations of aeromagnetic anomalies, which suggest that the Hurricane fault flattens at depth and that the Virgin anticline is detached from the basement, may have important implications for future asssessment of oil and gas resource potential as more data become available.

Gravity Data

The Bouguer gravity anomaly map (fig. 3) was prepared from gravity observations at 48 stations established in conjunction with this study and at more than 300 stations established previously. Principal facts for the older stations are available from the National Center for Geophysical and Solar-Terrestrial Data (Boulder, CO 80301), and from K.L. Cook (Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112). All readings were reduced to complete Bouguer anomaly values at a standard density of 2.67 g/cm^3 (grams per cubic centimeter) following routine procedures (see Cordell and others, 1982, for equations used). Terrain corrections were made from digital topography out to a distance of 100 mi from each station; no corrections were made manually.

The gravity relief is approximately 60–65 mGals (milligals), mostly expressed as a general decrease in field values from south to north, with contours trending more or less east-west across the map area in a broad arcuate pattern (fig. 3). The Red Mountain Wilderness Study Area lies directly astride the steepest part of this gradient. The same gradient extends west to the Sierra Nevada and east into the Colorado Plateau. Locally it is strongly perturbed and almost everywhere it is nonuniform, consisting of two or more parallel "steps" in the field level. Eaton and others (1978) have pointed out that the gradient coincides with the southern limit of voluminous silicic volcanism as well as with a sharp change in regional elevation. Analysis of transverse profiles in the Basin and Range province of Nevada led them to interpret the gradient as the signature of a density discontinuity largely involving crustal rocks, rather than mantle rocks. They speculated that the gradient results from large-scale emplacement of silicic intrusive rock beneath the Great Basin. In southwestern Utah the gradient also coincides with a northward deepening of the surface of dense Paleozoic carbonate rocks and the underlying Precambrian crystalline basement. Large volumes of silicic rock have intruded Mesozoic and younger strata in the region of low Bouguer anomaly values north of the study area.

The lowest Bouguer gravity values occur in the Pine Valley Mountains north of the study area (fig. 3), where the regional gradient appears to flatten. These mountains are composed chiefly of quartz monzonite porphyry of the 3,000-ft-thick Pine Valley sill and consanguineous extrusive rocks. The form of the intrusion, which should be denser than the surrounding rocks, is not depicted by the gravity contours, perhaps because of its limited depth and the relatively wide station spacing.

Aeromagnetic Data

The aeromagnetic map (fig. 4) was produced from total-intensity data obtained from a survey carried out by Scintrex Mineral Surveys, Inc., under the direction of the USGS, and subsequently published as part of the aeromagnetic map of Utah (Zietz and others, 1976). Flight traverses were oriented north-south and spaced 2 mi apart at a barometric elevation of 9,000 ft above sea level. The main field of the Earth was removed prior to contouring.

The aeromagnetic map shows some features in common with those of the gravity map (fig. 3) but in other respects differs significantly. Sedimentary rocks of

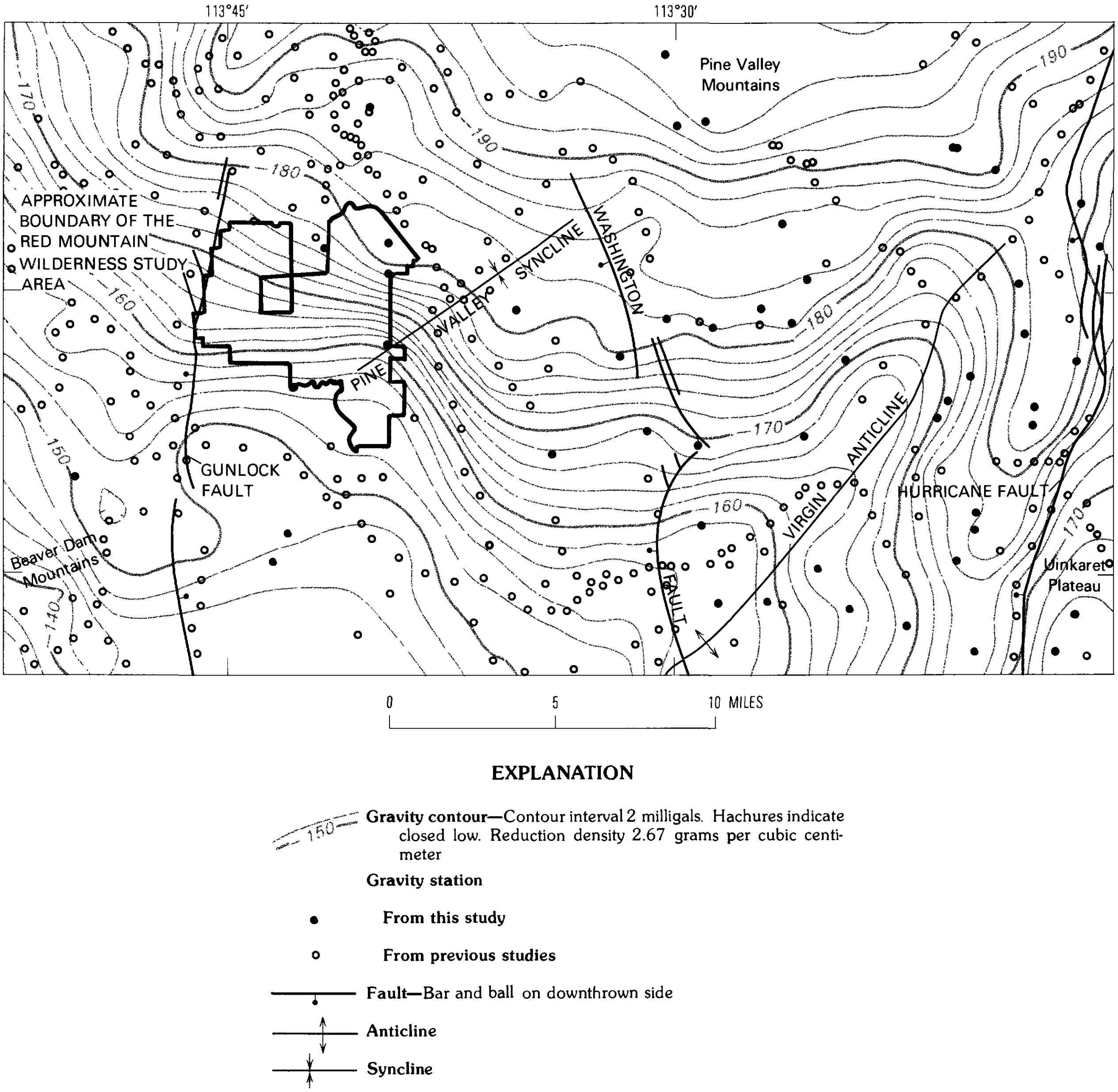


Figure 3. Complete Bouguer gravity anomaly contours of the Red Mountain Wilderness Study Area and vicinity, Washington County, Utah. Structural data modified from Cook (1960).

the Colorado Plateau and transition zone successions are effectively transparent to the magnetic probe, which "sees" through them at this flight elevation to the much more strongly magnetized crystalline basement. Besides the basement rocks, the only other sources of aeromagnetic anomalies are igneous rocks of Cenozoic age.

The regional north-south aeromagnetic gradient in the southern part of the map area (fig. 4) is interpreted as a reflection of the northward deepening of the basement surface. The strong aeromagnetic high in the southwestern corner is associated with a granitic intrusion exposed in the Precambrian core of the Beaver Dam Mountains. The high in the southeastern corner of the map area (Uinkaret Plateau) is considered to be the expression of a concealed basement uplift. There is no indication that the source of the Uinkaret Plateau anomaly is offset by the Hurricane fault, as the aeromagnetic contours (fig. 4) pass through the map trace of the fault without apparent disturbance. This relation suggests that the Hurricane fault, a high-angle structure at the surface, flattens with depth. Similarly, no aeromagnetic anomaly occurs over the Virgin anticline, suggesting that the anticline does not have a core of magnetic rock and may be detached from the basement.

The anomaly field in the northern half of the map area is a broad depression, locally perturbed by large

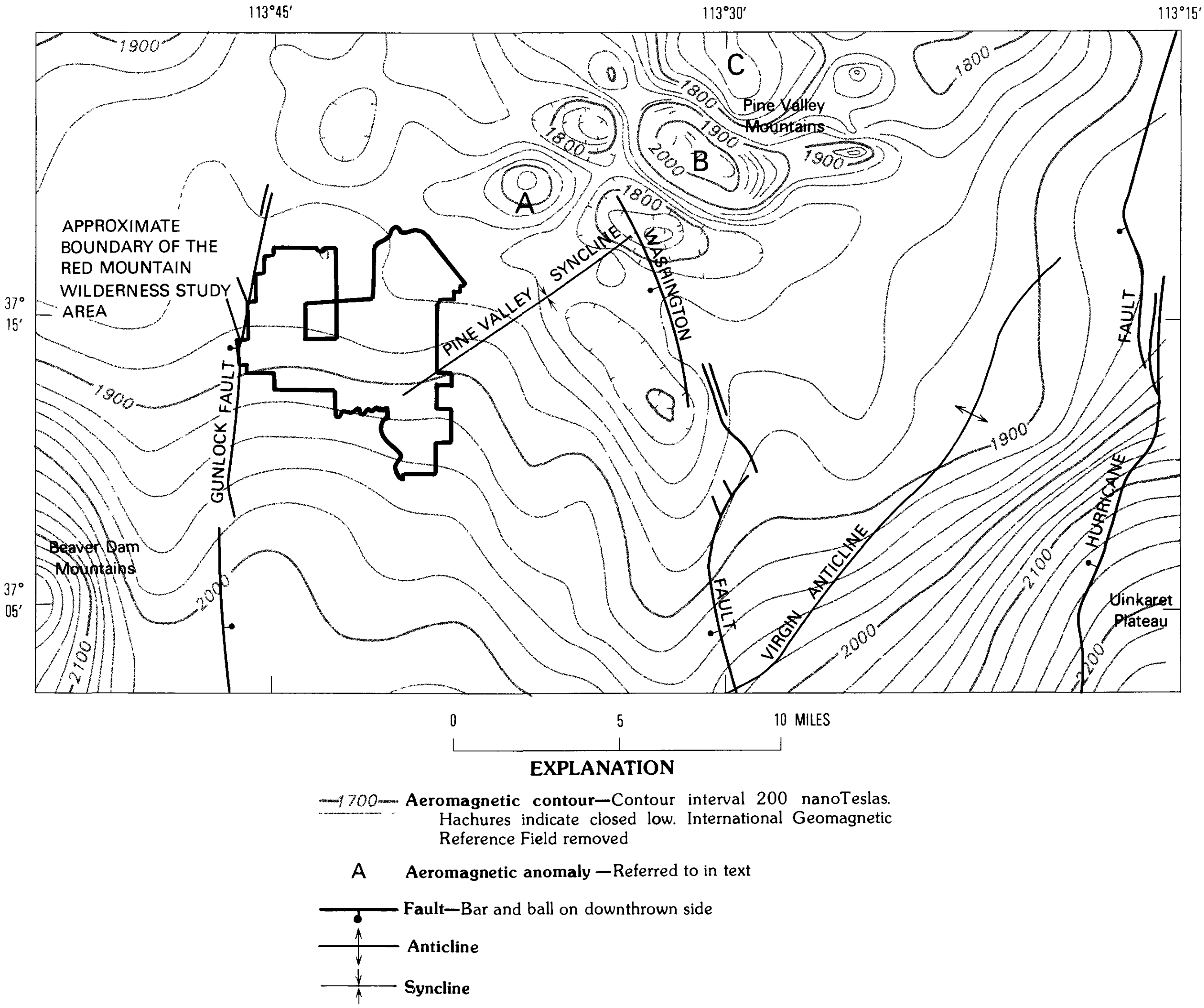


Figure 4. Residual total-intensity aeromagnetic contours of the Red Mountain Wilderness Study Area and vicinity, Washington County, Utah. Structural data modified from Cook (1960).

thicknesses of basalt, as at A, and of quartz monzonite, as at B (fig. 4). An aeromagnetic low (C) occurs where the thickness of the Pine Valley quartz monzonite sill has been greatly reduced by erosion (Cook, 1960).

Aeroradiometric Data

Limited aeroradiometric data are available for the study area as a result of the NURE (National Uranium Resource Evaluation) program. In southwestern Utah these data were collected along east-west traverses spaced 3 mi apart at a nominal elevation of 400 ft above terrain. The data have been examined by J.S. Duval (USGS, written commun., 1987), who reports that the Red Mountain Wilderness Study Area has overall low radioactivity with concentrations of 0.1–1.2 percent K (potassium), 0.1–1.0 ppm eU (equivalent uranium), and 1–4 ppm eTh (equivalent thorium). No radioactivity anomalies were found within or adjacent to the wilderness study area at the flight spacing of 3 mi.

Mineral and Energy Resource Potential

Metals

No mines, prospects, or evidence of mineralized rock were found in the study area or in the vicinity of the outcrop belt of the Springdale Sandstone Member south of the study area. No mineralized rock was seen in the sheared and leached zone associated with the Gunlock fault at the western edge of the study area.

A scintillometer, carried throughout the geologic investigation, indicated no radiation values above background levels, although geochemical sampling indicated that uranium is locally present in low concentrations. Other elements locally present in amounts ranging from detectable to high are antimony, arsenic, barium, strontium, thallium, thorium, tin, tungsten, manganese, copper, cobalt, and molybdenum (USBM sample nos. 9, 13 (see Wood, 1987) and USGS sample nos. 106, 111 (pl. 1)). These metal concentrations are associated with manganese oxide coatings and nodules, and are tentatively attributed to the scavenging effect of manganese oxide (Wood, 1987; Detra and others, 1988).

The boundary of the Santa Clara mining district is not precisely defined, but it was probably about a mile or two south of the study area. It was reported to have been centered on the Springdale Sandstone Member of the Moenave Formation (Butler and others, 1920). This is the same host rock as the sandstone-hosted silver deposit at the Silver Reef mining district 15 mi east of the study area (Proctor, 1953, 1986), which has produced silver, copper, uranium, vanadium, and gold. No shipments of ore were reported from the Santa Clara district and, although the Springdale south of the study area has the same general lithology as it does in the Silver Reef mining district, no mineralized zones are apparent. A USBM sample which contained 0.4 ppm silver (Wood, 1987) was collected just south of the study area from a stream that has its drainage basin in the Navajo Sandstone and Kayenta Formation, not in the Springdale.

The Springdale Sandstone Member appears to be as suitable a host rock for the tabular sandstone-uranium-type ore-deposit model (silver in this case) (Finch, 1982) in exposures south of the Red Mountains as it is in the Silver Reef mining district 15 mi to the east. The lack of observable mineralized rock in the Springdale in outcrop south of the area, however, in combination with the absence of recorded production from the Santa Clara district, suggests that there is low mineral resource potential for sandstone-hosted silver, copper, uranium, vanadium, and gold deposits in the study area, with certainty level B. The mineral resource potential for deposits of any other metals in the study area is low, with certainty level C.

Oil and Gas

Molenaar and Sandberg (1983) assigned a low resource potential for oil and gas to the part of southwestern Utah, west of the Hurricane fault, that includes the study area. Oil and gas have been produced from upper Paleozoic and Lower Triassic rocks east of the Hurricane fault (fig. 3) at two fields about 25 mi east and northeast of the study area. The geologic map of Washington County (Cook, 1960) indicates that these rocks are probably present beneath the study area, but no favorable structural or stratigraphic traps have been identified within the area. Aeromagnetic data, which suggest that the Hurricane fault flattens at depth and that the Virgin anticline is detached from the basement, imply that structural and stratigraphic sequences at depth may be different from those present in the upper few thousand feet of the crust in and near the study area. Currently available data are inadequate to evaluate the importance of this implication to the assessment of the oil and gas resources of the study area.

No conclusive shows of oil have been reported from test wells drilled west of the Hurricane fault in Washington County (Cook, 1960, p. 112). Molenaar and Sandberg (1983) suggested the possibility that long-distance eastward petroleum migration may be the cause of the apparent absence of oil and gas in this region of southwestern Utah. In agreement with this assessment, the energy resource potential for oil and gas is rated as low in the study area, with certainty level B.

Geothermal Sources

There are no hot springs in or near the study area; however, the presence of young-appearing volcanic cinder cones 1.5–2.0 mi to the east of the study area suggests that the energy resource potential for high-temperature geothermal sources associated with basaltic igneous systems is moderate, with certainty level B, in the eastern part of the study area. The energy resource potential for low-temperature geothermal sources (less than 194 °F at depths generally less than 0.6 mi) for the entire study area is high, with certainty level D, as the study area is in a region having terrestrial heat flow between 1.5 and 2.5 HFU (heat flow units) (Sass and Lachenbruch, 1979) and a mean annual temperature of about 60 °F. (1.0 HFU yields a temperature gradient of about 15 °F per 1,000-ft depth). These parameters indicate that at a depth of 0.6 mi beneath the study area, temperatures on the order of 130–180 °F will be encountered.

Coal

Coal, ranging in rank from lignitic to bituminous, is present in Upper Cretaceous rocks north and east of the study area (Gregory, 1950; Averitt, 1962). Upper Cretaceous rocks do not occur in the study area and other Mesozoic and Paleozoic rocks beneath the study area are not known to contain coal in the region. Thus, the study area has no energy resource potential for coal, with certainty level D.

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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.

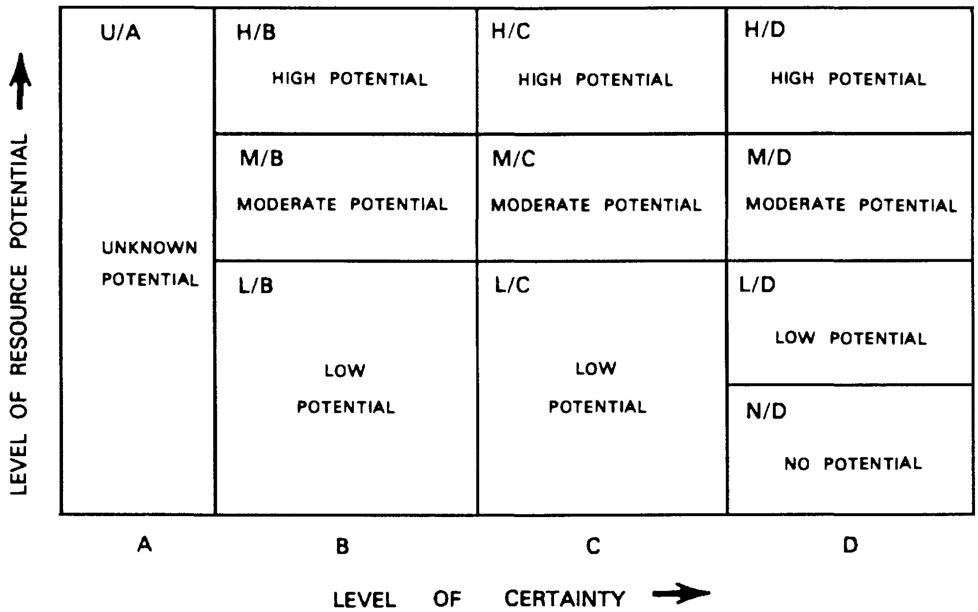
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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