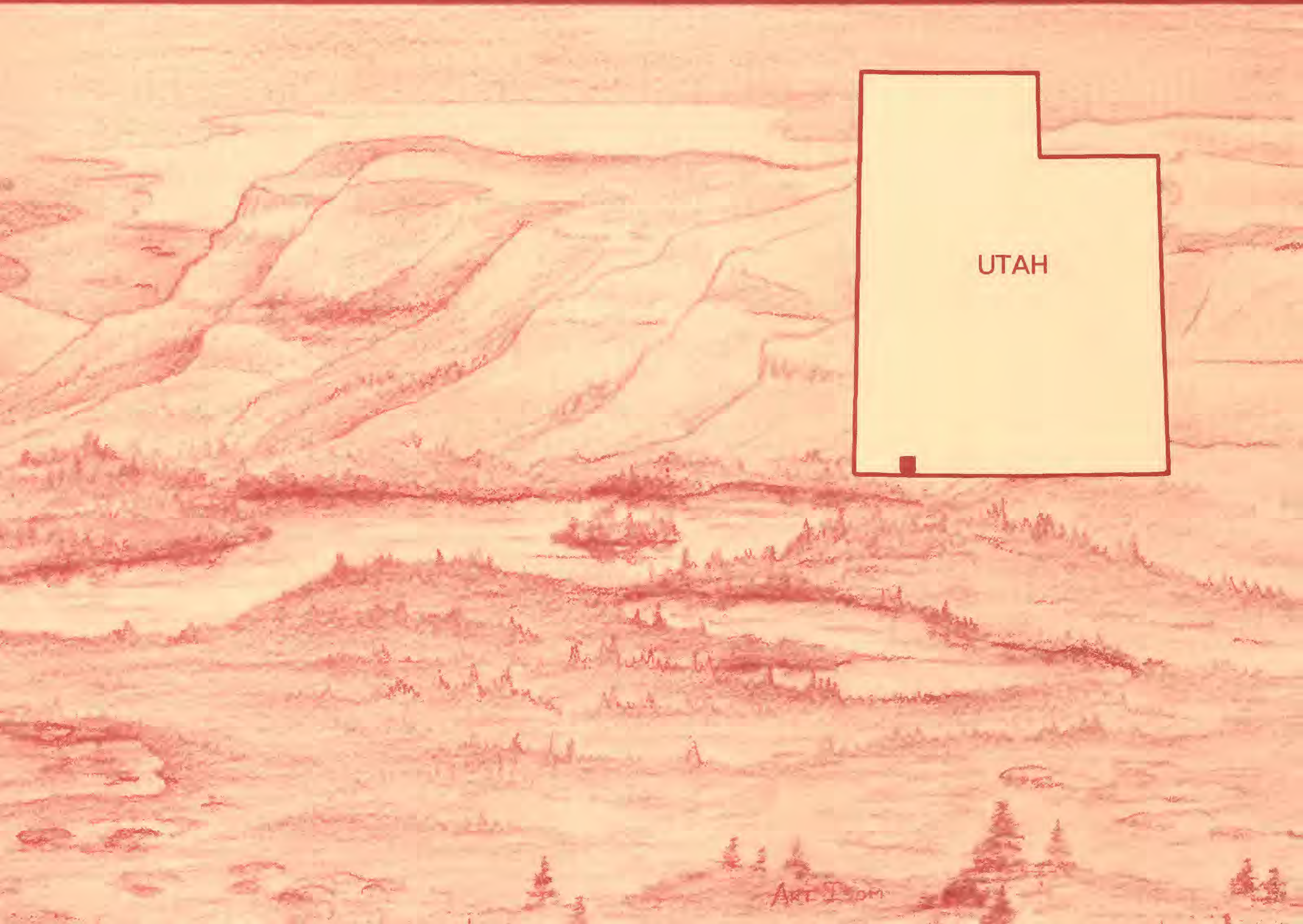
Mineral Resources of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1746–A



CHAPTER A

Mineral Resources of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—SOUTHWESTERN UTAH

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

U. S. GEOLOGICAL SURVEY

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 a part of the Canaan Mountain (UT–040–143) and all of The Watchman (UT–040–149) Wilderness Study Areas, Washington and Kane Counties, Utah.

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PLATE

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1. Mineral resource potential and geologic map of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah

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Mineral Resources of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah

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ABSTRACT

Canaan Mountain (UT–040–143) and The Watchman (UT–040–149) Wilderness Study Areas are in southwestern Utah along the boundary of Zion National Park. At the request of the U.S. Bureau of Land Management (BLM), 32,800 acres of the Canaan Mountain Wilderness Study Area in Washington and Kane Counties and the 600-acre The Watchman Wilderness Study Area in Washington County, near the main entrance to Zion National Park, were studied for this report. In this report, these areas are referred to as "study areas." The mineral resource potential of the study areas was evaluated in 1985 and 1986 by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). No identified resources occur in the study areas. The study areas have a moderate energy resource potential for undiscovered oil and gas, as indicated by their favorable geologic setting, and a low resource potential for undiscovered copper, gold, lead, silver, zinc, manganese, uranium, coal, and geothermal energy resources.

SUMMARY

Character and Setting

Canaan Mountain and The Watchman Wilderness Study Areas are about midway between St. George and Cedar City, Utah, about 20 mi (miles) east of Interstate Highway 15. This region is best known for Zion National Park. The small towns of Virgin, Rockville, and Springdale along Utah State Highway 9 and Hildale and Colorado City near Utah State Highway 59 and Arizona State Highway 389 are near the study areas.

The Canaan Mountain Wilderness Study Area is comprised of scenic plateaus and canyon lands that border Zion National Park. The Watchman Wilderness Study Area is largely an area of surficial rock debris on the western side of Johnson Mountain and The Watchman, which are prominent sandstone buttes east of the study area in Zion National Park. The study areas are easily accessible by secondary roads that approach their boundaries. Several trails suitable for hiking cross the Canaan Mountain Wilderness Study Area. Secondary roads branching off State Highway 9 provide access to The Watchman Wilderness Study Area and to trail heads leading into the northern parts of the Canaan Mountain Wilderness Study Area. Access to the southern and eastern parts of Canaan Mountain Wilderness Study Area is from secondary roads leading off Utah State Highway 59 and Arizona State Highway 389 (fig. 1).

Mining has played little or no role in the development of this area. The region was settled for agriculture, and water was obtained from the Virgin River system. Discovery of oil in the nearby Virgin oil field has stimulated exploration interest in the region since 1907, although overall oil production has been generally unprofitable. Currently the main activities of this region are those centered around Zion National Park and some small-scale farming and ranching.

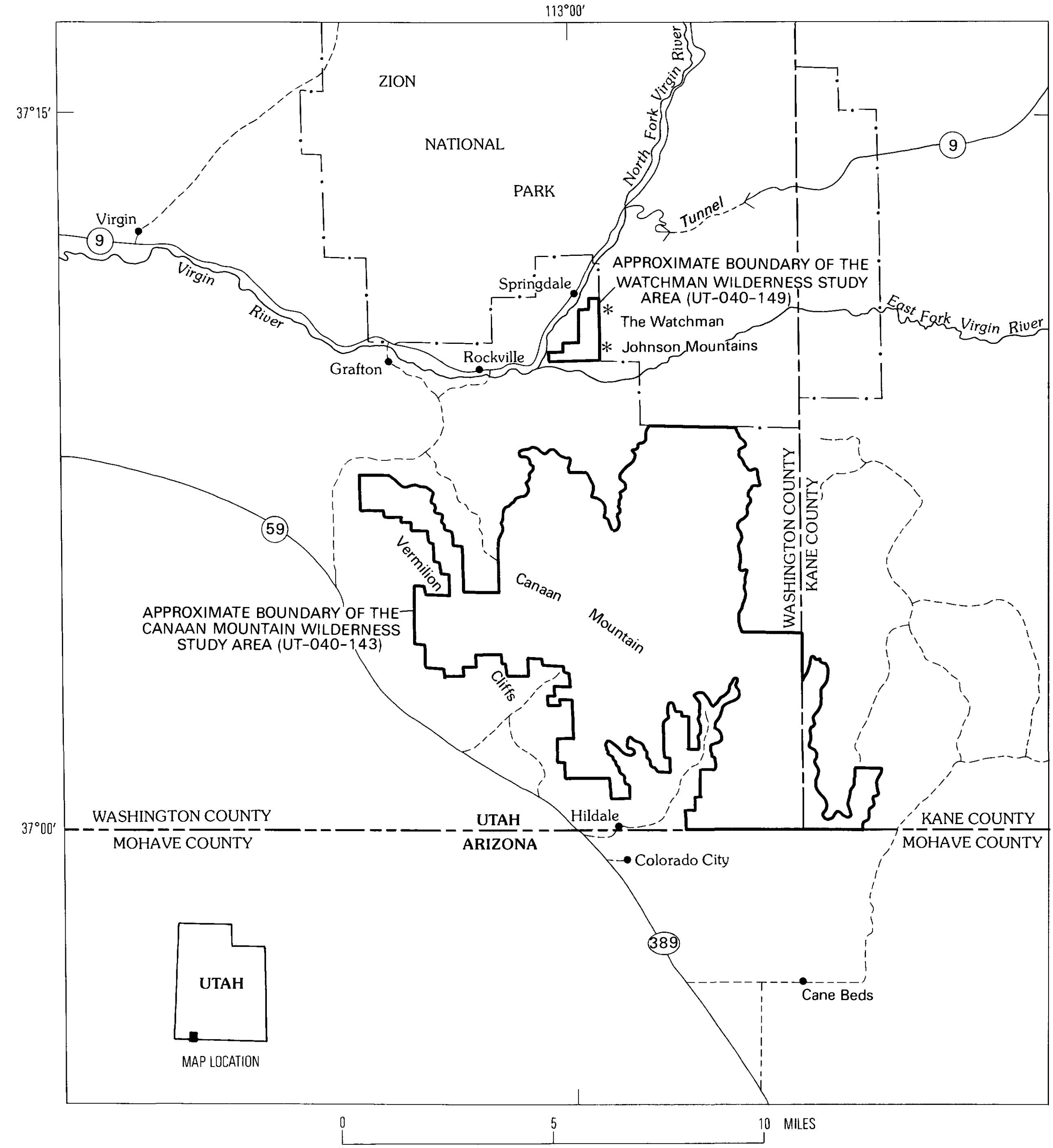


Figure 1. Index map showing location of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah.

The study areas are in the southwest margin of the Colorado Plateau physiographic province, a region of relatively flat-lying rock strata. About 3,900 ft (feet) of sedimentary rocks of early to middle Mesozoic age (Triassic and Jurassic) (see geologic time chart in Appendix) are exposed in and near the study areas. More than 5,000 ft of older sedimentary strata of Paleozoic and early Mesozoic ages occur in the subsurface. The youngest rock unit in the study areas is the Navajo Sandstone of Early Jurassic age. The lowermost 1,600 ft of this rock unit is exposed bedrock covering nearly 80 percent of the land surface in the Canaan Mountain Wilderness Study Area. It occurs in spectacular, nearly vertical canyon walls and on the upland "slickrock" surfaces of the plateaus. The Navajo is of eolian origin; it ranges from brown to light gray, and medium to very large scale sand-dune crossbedding is a prominent feature. The Navajo Sandstone is underlain by about 1,000 ft of slope- and cliff-forming rocks of the Lower Jurassic Kayenta and

Moenave Formations. Rock of these units, due to its pinkish and reddish colors, forms the distinctive "vermilion cliffs" in the region. The lowermost rock unit exposed in the study areas is the Upper Triassic Chinle Formation. The topography formed by this rock unit is one of landslides and badlands, in contrast to the cliff-forming rock units above. Parts of the western boundaries of the study areas are within the failed slopes of the Chinle Formation.

The Canaan Mountain Wilderness Study Area contains a few minor, northerly trending faults and a system of abundant vertical joints in the Navajo Sandstone. The regional dip of the strata in the study areas is about 1.5° to the northeast.

Identified Resources

No resources were identified in the Canaan Mountain or The Watchman Wilderness Study Areas.

There are 54 unpatented mining claims located in and near the northwestern part of the Canaan Mountain Wilderness Study Area. These claims were for precious metals that reportedly occur there in the Petrified Forest Member of the Chinle Formation. Our studies did not confirm the presence of gold, although silver, platinum, and palladium were detected at very low levels in samples taken from these claims. Economic recovery of metals from such low-grade rock is not feasible now or in the foreseeable future.

A uranium prospect was reported to exist near the Canaan Mountain Wilderness Study Area in Horse Valley Canyon; however, it could not be located. No anomalous radioactivity was found in the area of the reported prospect.

Nearly all of the Canaan Mountain Wilderness Study Area was under lease for oil and gas in 1984, although no drilling or other exploration activity has been carried out on the leases. By January 1987, most of the leases were dropped or canceled, and the land is no longer open for leasing.

Sand and gravel and clay deposits occur in the study areas; however, they have no unique qualities that make them more valuable than the vast quantities of similar material in surrounding areas.

Potential for Undiscovered Resources

Canaan Mountain and The Watchman Wilderness Study Areas have a moderate energy resource potential for oil and gas (fig. 2). The geologic setting of the study areas is similar to that present in the nearby Virgin oil field. The Virgin field, about 10 mi northwest of the study areas (fig. 3), has produced about 200,000 barrels of oil from structural and stratigraphic traps in the Lower Triassic Timpoweap Member of the Moenkopi Formation of Early and Middle(?) Triassic age and from the Kaibab Limestone of Early Permian age. These rock units are present more than a thousand feet beneath the study areas but have not been tested by drilling.

The resource potential for copper, gold, lead, silver, zinc, manganese, uranium, coal, and geothermal energy in the study areas is low. Special consideration was given to members of two formations present in the study areas that are known to contain uranium in other parts of Utah. The Springdale Sandstone Member of the Moenave Formation contains uranium, which reportedly has been produced from the Silver Reef district. The Silver Reef district, known primarily for its rich silver ore, is about 20 mi west of the study areas. The Petrified Forest and the Shinarump Members of the Chinle Formation contain rich deposits of uranium throughout the central part of the Colorado Plateau. No anomalous radioactivity was found in either the Springdale Sandstone Member or the Chinle Formation in the study areas. Two localities in sandstone of the Chinle, near the northwest part of the Canaan Mountain Wilderness Study Area, were slightly radioactive. The absence or low level of radioactivity in outcrops, the dearth of elements commonly associated with sandstone-hosted uranium deposits, and the overall radioactivity determined by an aeroradiometric survey indicate a low energy resource potential for uranium deposits.

Trace amounts of copper, gold, lead, silver, and zinc are known to occur in some areas in the Chinle Formation, but these metals at these low concentrations cannot be mined profitably. The host rock unit which contains ore in the Silver Reef district is present in the study areas, but no evidence was found to suggest that similar mineralization has occurred in the study areas.

Manganese-rich limestone nodules are common in the middle part of the Petrified Forest Member of the Chinle Formation. The distribution of the nodules, however, is sparse and they make up only a very small part of the member. The study areas have a low resource potential for manganese.

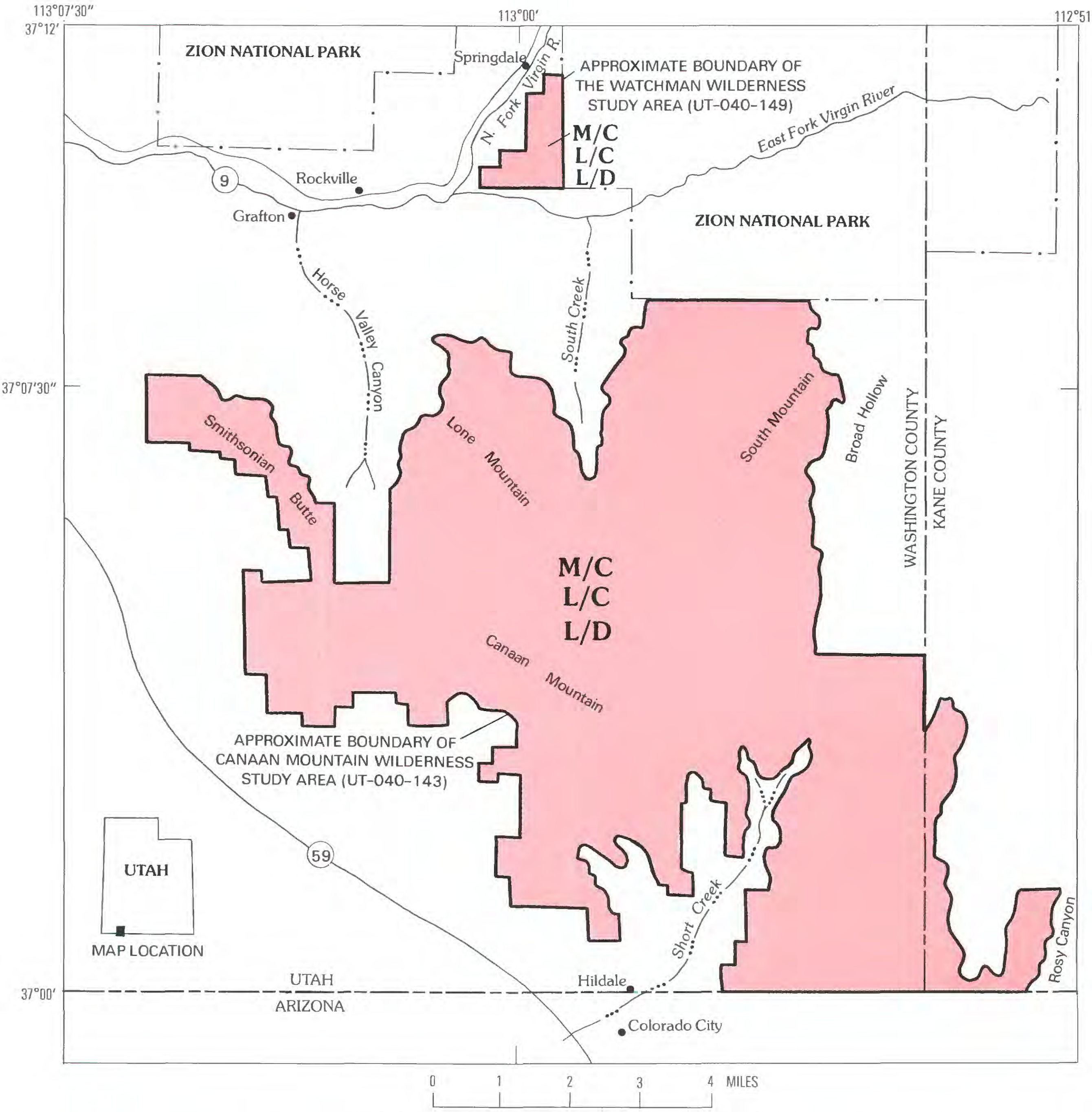
The geologic setting of the study areas is not favorable for the occurrence of coal; the energy resource potential for coal is low.

The study areas are in terrane defined as having low heat flow; they have low energy resource potential for geothermal energy.

INTRODUCTION

The Canaan Mountain and The Watchman Wilderness Study Areas are grouped in this report because of their proximity and their similar geologic settings. This report covers 32,800 acres of the 47,170-acre Canaan Mountain Wilderness Study Area in Washington and Kane Counties and the 600-acre The Watchman Wilderness Study Area in Washington County about 2 mi to the north. Study of these areas was requested by the BLM, and the areas studied are referred to in this report as the "study areas." These study areas are two of twelve wilderness study areas that border Zion National Park.

The study areas are in southwestern Utah, about 20 mi east of Interstate Highway 15 (fig. 1), near the main entrance to Zion National Park. The Watchman Wilderness Study Area is about 0.5 mi southeast of the town of Springdale and near the confluence of the North and East Forks of the Virgin River, about 1 mi south of



EXPLANATION OF RESOURCE POTENTIAL

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

L/C Geologic terrane having low resource potential for copper, gold, lead, silver, zinc, uranium, and geothermal energy, with certainty level C—Applies to all of each area

L/D Geologic terrane having low resource potential for coal and manganese, with certainty level D—Applies to all of each area

Levels of certainty

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 the area

Figure 2. Summary map showing mineral resource potential of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah.

the entry of Utah State Highway 9 into Zion National Park. This study area shares a common boundary for about 1.5 mi along its east side with the park. The Watchman Wilderness Study Area is an area of mostly surficial rock debris on the west side of Johnson Mountain and The Watchman, both of which are sandstone buttes located in Zion National Park.

The Canaan Mountain Wilderness Study Area shares part of the northern part of its boundary with Zion National Park, and the Arizona-Utah state line is the southern part of the boundary. The remaining parts of the boundary are defined by a combination of land nets and topography. Rosy Canyon and Broad Hollow roughly define the eastern part of the boundary, Short Creek the southern part, and Horse Valley Wash and South Creek the northern part (see fig. 2). South of the Arizona-Utah state line and adjoining the Canaan Mountain Wilderness Study Area is the Cottonwood Point Wilderness.

The study areas are along the southwest margin of the Colorado Plateau physiographic province. Topography consists of colorful mesas and plateaus carved from nearly flat-lying sedimentary rock. This region of Utah, an area that extends south into northwestern Arizona (the Arizona Strip), is referred to as the Grand Staircase. The landforms consist of a series of plateaus or bedrock terraces separated by cliffs. Canaan Mountain Wilderness Study Area is on one terrace or "step" in the staircase, lying below the White Cliffs and above the "vermilion cliffs". The terrain is deeply dissected by streams that are part of the Virgin River drainage system. The mountains or plateaus in the Canaan Mountain Wilderness Study Area are more than 3,500 ft above the Virgin River at Grafton, Utah. The Vermilion Cliffs escarpment, a prominent landmark of southwestern Utah, rises nearly 2,000 ft above Hildale, Utah, to the top of Canaan Mountain in the southern part of the study area.

The mesas and plateaus and the massive precipitous cliffs are formed mostly of the Navajo Sandstone; the most noteworthy features in the Canaan Mountain Wilderness Study Area are Smithsonian Butte and Lone, South, and Canaan Mountains (fig. 2). Large areas of "slickrock" (barren, flat-lying rock surfaces) broken by joints, natural arches, and pinnacles are common on the plateaus. These landforms are similar to, although not as spectacular as those in the Navajo Sandstone in Zion National Park.

The study areas have a desert climate but receive enough precipitation to support ponderosa pine, Douglas fir, and aspen at higher altitudes, and sagebrush, maple, and pinon pine on the lower slopes. Agriculture is important in the area; however, irrigation is essential. Principal sources of revenue are from the tourist trade and farming and livestock operations. The amenities provided in the region, especially the relatively warm winter climate, are appealing, and large areas of land adjoining the southwestern part of the Canaan Mountain Wilderness Study Area are beginning to be developed. Except for stock grazing and wood cutting, there is little evidence of man's past activity within the study areas.

There is no surface evidence of mining or exploration in the study areas, although there are mining claims in the northwestern part of the Canaan Mountain Wilderness Study Area. Most of the Canaan Mountain Wilderness Study Area was leased for oil and gas in 1984, but little is under lease at the present time. The presence of the nearby Virgin oil field undoubtedly has generated interest in oil exploration in the region, and silver and uranium mining in the Silver Reef district generated prospecting excitement in the region for many years.

Private land adjoins the northern and southern parts of The Watchman Wilderness Study Area; public access is from Zion National Park on the east or across BLM lands on the west. The northern parts of the Canaan Mountain Wilderness Study Area are accessible from State Highway 9 near Rockville; a secondary road crosses the Virgin River and follows Horse Valley Wash and South Creek. Roads leading into both of these canyons are on private lands and currently (1986) are behind locked gates. Main hiking trails leading into the Canaan Mountain Wilderness Study Area begin in these canyons. Access to the western and southern parts of the Canaan Mountain Wilderness Study Area is from Utah State Highway 59 and secondary roads branching off to the east from the highway. The eastern part is accessible by taking one of a number of unimproved roads east of Arizona State Highway 389 and northeast of Cane Beds (fig. 1). These roads cross areas of active windblown sand, and travel on them can be difficult at times. Some hiking trails exist within the Canaan Mountain Wilderness Study Area. These trails follow early-day stock trails and logging roads and are shown on recent U.S. Geological Survey topographic maps.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources are classified according to the system of the 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), which is also shown in the Appendix. Undiscovered resources are studied by the USGS.

Investigations by the U.S. Bureau of Mines

Appraisal of identified resources in the Canaan Mountain and The Watchman Wilderness Study Areas included field work and literature searches by the USBM. Prior to the field investigations, various sources of minerals information, which included published and unpublished literature and USBM files, were reviewed. BLM files were reviewed for mining claims and oil and gas, coal, and geothermal lease information. BLM personnel, National Park Service personnel at Zion National Park, and local residents were interviewed regarding minerals information in and near the study areas.

Field investigations, conducted in June 1985 and October 1986, consisted of searching for mines and prospects, examining and sampling unpatented mining claims in and near the study areas, sampling outcrops, and sampling sediments from streams draining favorable formations. Twenty-one samples were taken from the Canaan Mountain Wilderness Study Area: 12 stream sediment, 8 outcrop, and 1 panned concentrate (Kreidler, 1986). The outcrop, panned-concentrate, and 2 stream-sediment samples were analyzed for gold, silver, platinum, and palladium by fire-assay, and the panned-concentrate and 11 stream-sediment samples were analyzed for uranium by fluorometry. All samples were analyzed for 40 elements by semiquantitative optical emission spectroscopy (Kreidler, 1986). Three outcrop samples were collected from the Chinle and Moenave Formations in The Watchman Wilderness Study Area. These samples were analyzed for gold, silver, and copper by atomic absorption spectrometry, uranium by fluorometry, vanadium by inductively coupled plasma analysis, and 31 elements by optical emission spectrography. Whole-rock analyses were run to determine the bulk composition of the samples. (See Zelten, 1987.) A gamma-ray spectrometer was carried on field traverses through the areas. No radioactivity above background levels was detected.

Investigations by the U.S. Geological Survey

The assessment of the potential for undiscovered resources in Canaan Mountain and The Watchman Wilderness Study Areas is based largely on the knowledge of the geology and geologic setting and on geophysical data and results from geochemical sampling. Field work for these studies was done in parts of the months of May and September of 1985 and June and September of 1986. A new geologic map was prepared by E.G. Sable at 1:24,000 scale from data obtained by field work and color aerial photographs and reduced to 1:50,000 scale for this report. A contour map (fig. 4) of the top of the Moenave Formation was made for parts of the study areas for use as an aid in assessing possible structures that might serve as reservoirs for oil and gas. Geophysical studies herein interpreted by H.R. Blank, Jr., included gravity, aeromagnetic, and aeroradiometric surveys. Two hundred and twenty-six gravity stations were established and data obtained from them were used in this report. Seventy-four stream-sediment samples and 45 rock samples from the Canaan Mountain Wilderness Study Area were collected and analyzed. Nine stream-sediment and two rock samples were collected and analyzed from The Watchman Wilderness Study Area. Analytical data and sample locations are given by Adrian and others (in press).

Information used in establishing oil and gas potential is taken largely from Ryder (1983) and Molenaar and Sandberg (1983). Other sources of data used in this report are from Heyl (1978), who described the Silver Reef deposit, and Bahr (1963), who described the Virgin oil field. Energy resource evaluations were prepared for the study areas by Oakes and others (1981) and for the region by the U.S. Department of Energy (1979). Pertinent literature on the geology of this general region includes a comprehensive report on the Zion National Park region (Gregory, 1950); a detailed analysis of the Moenkopi Formation (McKee, 1954); discussion of Triassic and Jurassic rocks (Wilson and Stewart, 1967); review and integration of temporal and spatial relationships of the Navajo Sandstone and other Jurassic rocks (Peterson and Pipiringos, 1979); overall geologic perspective with diagrammatic illustrations of geologic history and portrayal of the stratigraphic column in southwestern Utah (Hintze, 1973); and a recent report on the geologic history and evolution of land forms in Zion National Park (Hamilton, 1984).

APPRAISAL OF IDENTIFIED RESOURCES

By Terry J. Kreidler and Jeanne E. Zelten
U.S. Bureau of Mines

Mining Activity

There are no mines, prospects, or identified mineral resources in the study areas and the areas are not included in any mining district.

The nearest mining district is the Silver Reef (Harrisburg) district, about 20 mi to the west of the study areas. Between 1875 and 1910, over 7 million oz (ounces) of silver worth nearly $8 million (at 1910 prices) and small amounts of associated copper, uranium, and vanadium, were produced from the Springdale Sandstone Member of the Lower Triassic Moenave Formation. In 1950, 8.68 tons of ore averaging 0.56 percent uranium was shipped (Gregory, 1950, p. 188).

The only mining activity near the study areas, as of August 1985, was a uranium prospect reported by Oakes and others (1981, p. 150) in sec. 36, T. 42 S., R. 11 W., just outside the Canaan Mountain Wilderness Study Area, but it was not located. In the 1950's, uranium occurrences in the Petrified Forest Member of the Chinle Formation were prospected 6–8 mi south of the Canaan Mountain Wilderness Study Area, and some ore reportedly was shipped (Baillieul and Zollinger, 1982, p. C–90), although no records were found to support this. As of July 1985, there were 54 unpatented mining claims staked in and near the Canaan Mountain Wilderness Study Area for precious metals (Kreidler, 1986, pl. 1). There are no mining claims or mineral leases in The Watchman Wilderness Study Area (Zelten, 1987).

Oil and Gas

As of September 1984, over half of the Canaan Mountain Wilderness Study Area was under oil and gas leases (fig. 3). As of August 1985, there had been no drilling or other exploration activity on the leases (Gordon Cormier, BLM District Geologist, St. George, Utah, oral commun., August 8, 1985). As of January 1987, there were no leases in The Watchman Wilderness Study Area, and most of the leases in the Canaan Mountain Wilderness Study Area were canceled; the land is no longer open for leasing. Leases shown on figure 3, taken from BLM plats and current as of September 1984, depict recent company interest but may not all be valid at this time.

The Virgin oil field (fig. 3), about 10 mi northwest of the study areas, was an intermittent, low-volume producer between 1907 and 1970, although production costs generally exceeded profits. Total production during this period was 201,127 barrels of oil (Stowe, 1972, p. 23). The producing zone is at depths between 424 and 750 ft. Similar rock units probably exist beneath the study areas, but nearby exploration wells were dry and are abandoned. No drilling has been done within the study areas.

Results of Investigation

Precious Metals

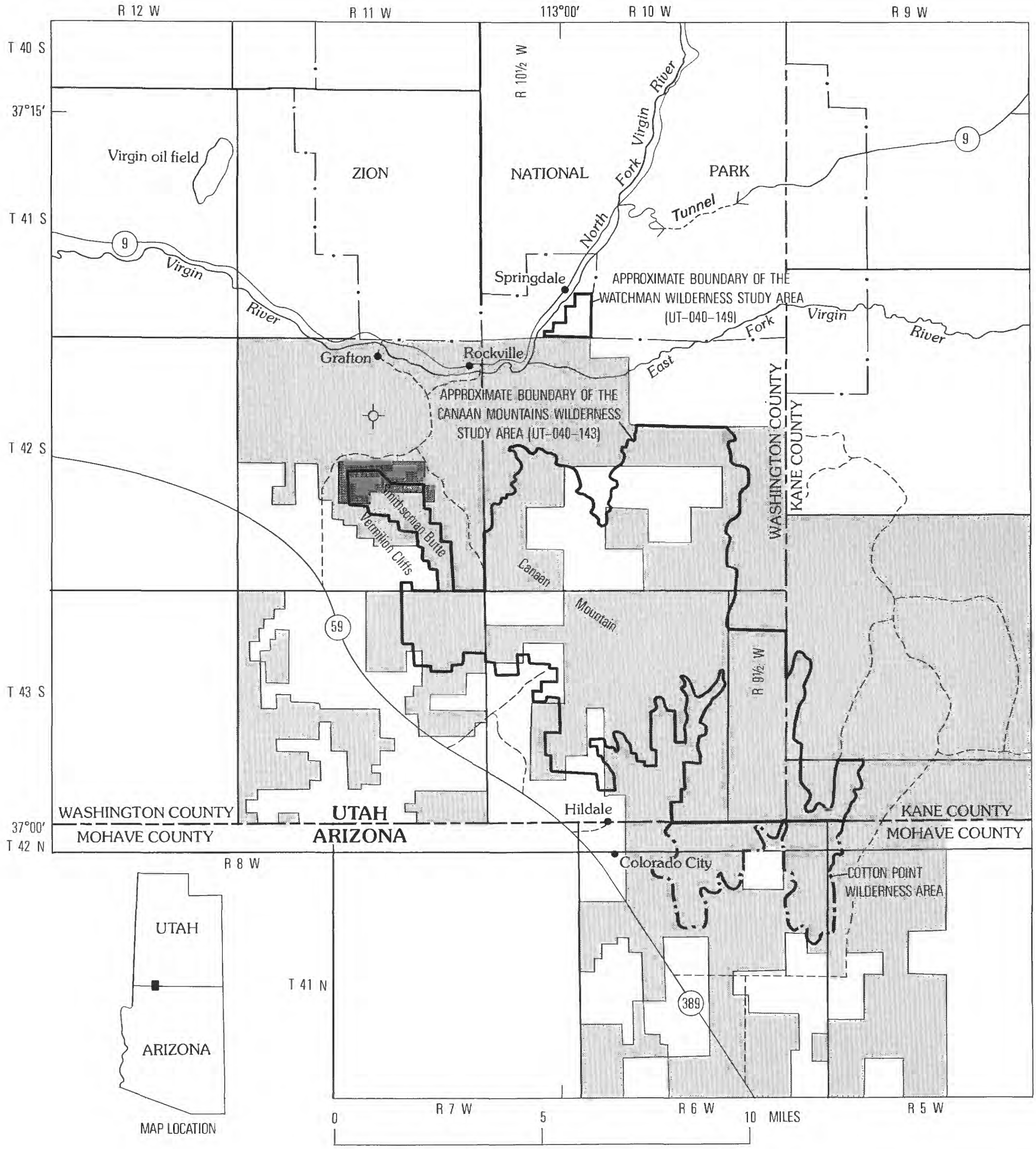
For many years, small amounts of gold and other precious metals have been known to occur in the variegated clay of the Petrified Forest Member of the Chinle Formation (Gregory, 1950). All attempts at economic recovery have met with failure due to low levels of and the extremely fine size of the metal particles (Lawson, 1913, p. 447). The source of the metals is not known. According to the claim holder of a block of claims that covers the Petrified Forest Member along the northern boundary of the Canaan Mountain Wilderness Study Area north of Smithsonian Butte, the area contains recoverable amounts of gold, silver, platinum-group minerals, and other rare metals. However, the 11 samples collected by the USBM from these claims and other outcrops of the Petrified Forest Member do not contain any detectable gold, and only 1 sample contained silver above the detection limit of 0.002 oz/st (ounces per short ton) (Kreidler, 1986). Sample 6 contained platinum (0.001 oz/st) and samples 3, 5, 6, and 13 contained palladium (0.001 oz/st) (Kreidler, 1986). Economic recovery of such low-grade material is not feasible now or in the foreseeable future. Analysis of samples from the Chinle and Moenave Formations in The Watchman Wilderness Study Area showed no indications of economic concentrations of metals (Zelten, 1987).

Uranium

The Colorado Plateau has been one of the major uranium-producing areas in the United States since the late 1940's, with most of the important deposits occurring in sandstone, conglomerate, and mudstone of the Upper Triassic Chinle and Upper Jurassic Morrison Formations. Minor amounts of uranium have also been mined from rocks of Permian, Cretaceous, and Eocene ages. Several miles south of the study areas, uranium occurs in and reportedly has been produced from the Petrified Forest Member of the Chinle Formation, and, to the west, uranium was produced at Silver Reef from the Moenave Formation.

A uranium prospect reportedly near the Canaan Mountain Wilderness Study Area boundary in sec. 36, T. 42 S., R. 11 W. and last worked in 1958 (Oakes and others, 1981, p. 150), could not be located during the USBM field investigation. The host rock may be the Lower Jurassic Moenave Formation (D.W.J. Brine, BLM, St. George, Utah, written commun., 1985). (Brine, however, did not visit the prospect.) All outcrops near the reported prospect site were examined with a total-count scintillometer for anomalous radioactivity, but none was found. Outcrops of the Moenave and the Shinarump and Petrified Forest Members of the Chinle in both study areas were also checked for anomalous radioactivity, with negative results. Radioactivity in the study areas did not exceed background, which averaged 30–50 cps (counts per second).

The average uranium content of the 12 stream-sediment samples from the Canaan Mountain Wilderness Study Area is 2.6 ppm (parts per million)



EXPLANATION

Oil and gas leases—Information from the Bureau of Land Management; current as of September 1984

Unpatented mining claims

Approximate location of four dry oil and gas wells

Zion National Park boundary

State road

Unimproved road

Figure 3. Map showing oil and gas leases and unpatented mining claims in and near the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah.

uranium (range, 0.85–6.9 ppm) (Kreidler, 1986), which falls in the range of average uranium content in sandstone (0.45–3.2 ppm) and is less than the average content in shale (4 ppm) (Levinson, 1980, p. 885–886). Samples of the Moenave and Chinle Formations from The Watchman Wilderness Study Area contained no detectable uranium (Zelten, 1987).

Industrial Rocks and Minerals

The Navajo Sandstone, which underlies most of the study areas, could be utilized for several industrial applications such as foundry, fracturing, and abrasive sand. Within the study areas, however, the Navajo does not have any unique characteristics that would make it more valuable than similar sandstone deposits that cover much of the Colorado Plateau. Similarly, the deposits of sand and gravel and clay within the study areas might have value as local construction materials; however, they too can be easily acquired outside the study areas.

Collectible Commodities

Petrified wood is scattered throughout the Petrified Forest Member in the Canaan Mountain Wilderness Study Area and probably is present at depth beneath The Watchman Wilderness Study Area. Some of the wood is brightly colored, but it occurs predominantly in shades of gray; no collecting sites are known in the study areas. Minor bleaching of Navajo Sandstone has occurred along some fractures, resulting in brightly colored sand which may be used for sand painting and other decorative purposes; however, larger deposits near Kanab, Utah, can probably supply all future needs. Although picture stone has been seen in the Canaan Mountain Wilderness Study Area, the deposits are too small for any type of development (Helmut Doelling, Utah Geological and Mineral Survey, Salt Lake City, written commun., July 1987). Iron concretions, commonly called "ironstone," are ubiquitous in the Navajo Sandstone, and, although they occur in the study areas, they are easily accessible and available throughout the southwest.

Conclusions

Although minor amounts of platinum and palladium were detected in one and four samples, respectively, from near the Canaan Mountain Wilderness Study Area, the grades are too low to be of commercial interest, and development is not economically feasible now or in the foreseeable future.

No uranium occurrences were found in the study areas in either the Chinle or Moenave Formations.

The deposits of sandstone, sand and gravel, and clay in the study areas have no unique qualities to make them more valuable than the vast quantities in the surrounding area.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

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Geology

Geologic Setting

The Canaan Mountain and The Watchman Wilderness Study Areas adjoin Zion National Park in the westernmost part of the Colorado Plateau, a region consisting of gently dipping rock strata which are interrupted by relatively minor faults and sharp flexures. About 3,900 ft of sedimentary rocks of early to middle Mesozoic age (Triassic and Jurassic) are exposed in and peripheral to the study areas (pl. 1). Older sedimentary strata of Paleozoic and early Mesozoic ages, more than 5,000 ft thick, occur in the subsurface. Younger rocks of middle and late Mesozoic and early Cenozoic ages, which were probably more than 4,500 ft thick, are now eroded from the study areas; they included clastic rocks (sandstone, siltstone, and shale), carbonate rocks (limestone and dolomite), and minor evaporite beds (gypsum) deposited in both marine and continental environments.

Information on Paleozoic rocks in the subsurface beneath the study areas is extrapolated here from the rocks exposed in the Grand Canyon and Zion National Park regions and from a well record at Pintura, 22 mi northwest of the areas (Cary, 1963). The Paleozoic rocks include, in ascending order, more than 2,500 ft of clastic and carbonate rocks of Cambrian and Devonian ages; the Redwall Limestone (Mississippian), about 800 ft thick; the Callville Limestone (Pennsylvanian), 600–800 ft thick; and units of Early Permian age, the Pakoon Limestone (740 ft thick), the Coconino and Queantoweap Sandstones (1,340 ft thick), the Toroweap Formation (545 ft thick), and the Kaibab Limestone (about 260 ft thick). All of the Lower Permian rocks are considered to be possible oil and natural gas reservoir rocks. Information on strata of Early Triassic age in the subsurface are extrapolated from nearby areas (E.G. Sable, unpub. mapping, 1986) and include about 400 ft of the Timpoweap, lower red, and Virgin Limestone Members of the Moenkopi Formation, of which the Timpoweap Member is a possible reservoir rock. The middle and upper red members and Shnabkaib Member of the Moenkopi Formation are also present in the subsurface of the study areas but crop out nearby and are shown on the geologic map (pl. 1). The middle red member of the Moenkopi (T̄R mm), more than 250 ft thick, is a slope-forming unit of reddish-brown siltstone, shale, minor thin sandstone beds, and minor gypsum, deposited on fluvial flood plains under arid conditions. This is succeeded by the Shnabkaib Member (T̄R ms), about 260 ft of slope-forming reddish siltstone and sandstone with interbedded gypsum and gypsiferous shale, deposited along a low arid coastal plain. The overlying upper red member (T̄R mm) about 250 ft thick, indicates a resumption of clastic red-bed deposits with an upward increase in sandstone beds, forming steep slopes and, locally, cliffs. The oldest bedrock unit exposed in the Canaan Mountain and The Watchman Wilderness Study Areas is the Chinle Formation (pl. 1); the youngest units are, respectively, the Moenave Formation and the Navajo Sandstone.

The Chinle Formation consists of the Shinarump Member (T̄R cs) and the overlying Petrified Forest Member (T̄R cp). The Shinarump, 80–140 ft thick, is a cliff-forming unit of gray, crossbedded sandstone and conglomerate and minor gray and greenish shale deposited in channels and on flood plains by high energy streams. Conglomerate contains chert and quartzite pebbles and cobbles and silicified wood fragments. The Petrified Forest Member, 240–280 ft thick, forms slopes and badlands. It is mostly variegated (grayish, reddish, purplish, and brownish) clay shale and a fairly persistent stream-channel-fill sandstone unit about in the middle of the member. The member contains volcanically derived clay minerals, and when wet it is slippery, swells, and contributes to slope failure of overlying units. Sandstone units in the Chinle Formation contain uranium minerals in many areas of the southwestern United States.

The Moenave Formation (Jm), about 450 ft thick, consists of three members. They are, in ascending order, the Dinosaur Canyon, Whitmore Point, and Springdale Sandstone Members, consisting respectively of slope-forming reddish siltstone and shale and minor thin sandstone beds, grayish to reddish siltstone and shale, and cliff-forming, pinkish, crossbedded sandstone containing clayey "rip-up" clasts. All rock types represent continental fluvial and lacustrine deposition. The Springdale Sandstone Member hosts the ore deposits in the Silver Reef district near Leeds, Utah.

The Kayenta Formation (Jk), 550–720 ft thick, is composed of slope- to cliff-forming, upward-coarsening, reddish to reddish-orange silty shale, siltstone, and sandstone of fluvial flood-plain origin. The unit appears to generally thicken eastward in the mapped area.

The Navajo Sandstone (Jn), of which an incomplete thickness of about 1,600 ft is exposed in the Canaan Mountain Wilderness Study Area, is as much as 2,220 ft thick a short distance north in Zion National Park. The Navajo is exposed in spectacular, nearly vertical canyon walls and on upland surfaces of Canaan and South Mountains. It is a fine- to medium-grained, well-sorted sandstone which exhibits medium to very large scale sand-dune crossbedding. It is locally stained by iron- and manganese-oxides. The Navajo can be roughly subdivided into a lower brown unit having beds of moderate thickness (about 2–5 ft), a middle pinkish and gray unit, and an upper nearly white unit; the latter two have thick sets of crossbedding. The boundaries of these units do not, however, coincide with bedding, and the colors are probably due to post-depositional factors such as ground-water staining or bleaching agents or relationships to ancient land surfaces where color changes were caused by ground-water chemical constituents and position of the water table. The Navajo is an excellent aquifer. With its spectacular crossbedding features and linear joint patterns, the Navajo provides the most scenic characteristics of the bedrock formations in Zion National Park and adjoining areas. It was deposited in an extensive desert "sand sea" consisting of sand dunes that encroached southward from highlands north of the study areas about 180 million years ago.

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 of Early Jurassic age on the basis of palynomorphs in the Moenave. This usage is recognized in the present report.

In the Canaan Mountain and The Watchman Wilderness Study Areas, a gap in the rock record from about 180 million years ago to perhaps 2 million years ago is mostly the result of Cenozoic erosion. Continental deposits of late Cenozoic age, which cover bedrock in many parts of the area, were then deposited by stream, mass-movement, and eolian processes which are still active. These late Tertiary(?) and Quaternary units and morphological features, such as stream terraces and erosional surfaces, are scattered throughout much of the mapped area.

Weakly to moderately carbonate-cemented, brownish conglomerate and gravel (QTg) occur in high stream-terrace remnants as much as 150 ft or more above the Virgin River. Some exposures have been and are currently quarried for gravel outside the study areas.

Deposits due to downhill mass movement of rock and soil (landslide deposits) (QTm) may be as much as several hundred feet thick in places. They are particularly conspicuous between South Mountain and Horse Valley Wash and in The Watchman Wilderness Study Area where they cover most of the bedrock (pl. 1). Landslide debris remnants also occur in many places at considerable distances from the slopes where they originated. The deposits are a debris of unsorted rock and soil which represents slide, slump, flow, and creep processes. Most of them are relatively unconsolidated, but some well-cemented debris remnants at high altitudes were seen in The Watchman Wilderness Study Area. The landslide deposits contain immense slide blocks of relatively undeformed rock, mostly Navajo Sandstone, as much as 1,500 ft in diameter and 200 or more feet thick. Movement of many landslide deposits, such as those along South Creek, apparently has been initiated on or in the underlying Petrified Forest Member of the Chinle Formation, which has acted as the lubricating lower surface of the slide masses when the member was uncovered by erosion. The boundaries of many of the landslide deposits are difficult to delineate because parts of the Petrified Forest Member have also been involved in the movements as evidenced by steeply dipping beds of that unit. The largest landslide deposits are along a belt of mass movement features which extend 10 mi north-northwest of the Canaan Mountain Wilderness Study Area into Zion National Park. This belt generally parallels the fault trends in Zion National park, suggesting that seismic activity may have initiated the landslides.

Sand, silt, and clay (QTs), the products of mostly eolian, alluvial, and weathering processes, overlie bedrock in many parts of the mapped area. They are estimated to be inches to many tens of feet thick. Their upper surfaces are relatively smooth, planar to gently curving, and appear to support a more mature vegetation cover than on younger surficial units or surfaces. In the lowlands southwest of Smithsonian Butte, the surfaces of this unit seem to represent surfaces of inactive alluvial fans and pediments. On Canaan and South Mountains, the deposits occur as remnants of sheet and dune sand and locally as a thin veneer of sand and silt overlying the landslide deposits along the west side of South Creek. Age of these deposits is not known; they may be early Quaternary and (or) possibly late Tertiary in age. Their surfaces reflect remnants of an ancient topography which antedated the Quaternary canyon- and arroyo-cutting processes in this region.

Eolian sand and silt (Qs), all of probable Quaternary age, occur as small dune deposits, sheets, and sand aprons below bedrock cliffs. These include active currently developing deposits as well as older more stabilized sand.

Units mapped as colluvium (Qc) consist of locally derived, unsorted silt, sand, and granule- to boulder-size rock fragments. They are relatively young and include products of creep, flow, rock fall, and small landslides.

Alluvium (Qac) mapped along the larger streams, such as the Virgin River, is composed of silt, sand, and fine to coarse gravel. It ranges from material on present flood plains and bars to material in terraces as high as about 20 ft above present stream levels. Colluvium along the bases of adjoining hills is mapped with stream alluvium. Alluvium also occurs in fan deposits, plateau-side terraces, and in mixed alluvium-colluvium-eolian deposits along minor ephemeral streams.

Structure

Bedrock structure in the Canaan Mountain and The Watchman Wilderness Study Areas is relatively simple and consists of a homocline having a gentle northeast dip averaging about 1.5°, as indicated by structure contours drawn on the Springdale Sandstone Member of the Moenave Formation in the western, southern, and central parts of the mapped area (fig. 4). This regional dip is interrupted by a few steeply dipping, north-northeast- and north-northwest-trending normal faults having displacements of less than 300 ft. A local steepening of dip to about 2° occurs along the upper part of South Creek and is probably related to minor faulting in that vicinity.

Numerous nearly vertical linear fractures (joints) are prominently expressed in the Navajo Sandstone (pl. 1). Some of these may be expressions of faults, but the generally homogeneous nature of that unit makes interpretations of faulting within it uncertain. Regional joint trends are south-southeast, but anomalous radial and arcuate joint patterns are conspicuous between Short Creek and Cottonwood Canyon in the southeastern part of the Canaan Mountain Wilderness Study Area. These patterns may result from (1) fracturing due to development of a local stress field between the two faults in that area, (2) local domal uplift, or (3) an older stress field preceding that which resulted in the regional joint trends.

Geochemistry

A reconnaissance geochemical survey was conducted in the Canaan Mountain Wilderness Study Area in the summer of 1985. Minus-80-mesh stream sediments, heavy-mineral concentrates derived from stream sediments, and rocks were selected as the sample media in this study. Seventy-four sites were sampled for stream sediments and heavy-mineral concentrates and 45 sites were sampled for rocks.

The stream-sediment samples were collected from the active alluvium in the stream channel. Each sample was composited from several localities along a channel

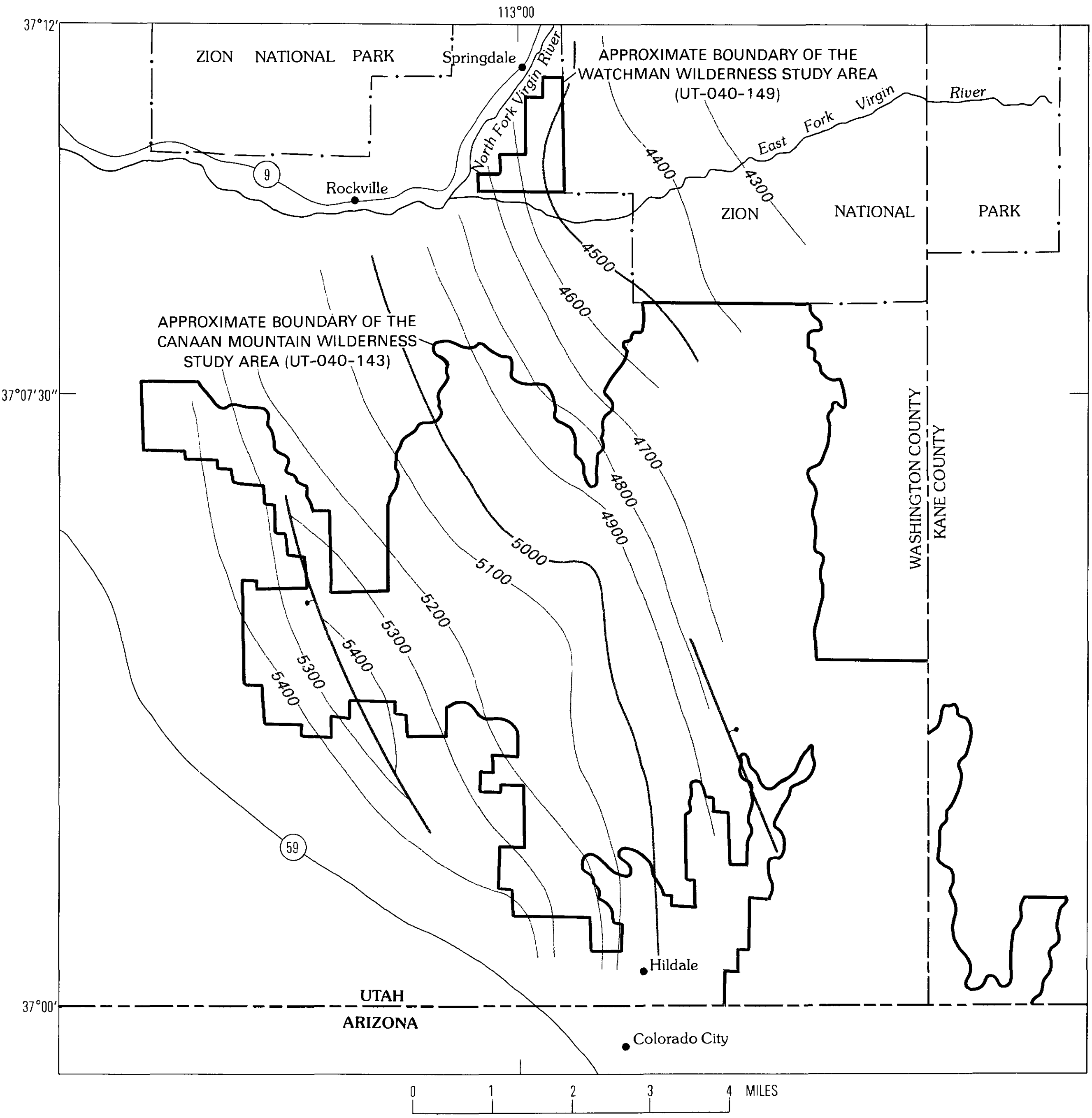

Figure 4. Structure contour map of parts of the Canaan Mountain and The Watchman Wilderness Study Areas, Washington and Kane Counties, Utah. Contours drawn on top of the Moenave Formation; datum is mean sea level; contour interval 100 feet; faults have ball and bar on downthrown side.

length of approximately 50 ft. The stream sediments were sieved through an 80-mesh screen and pulverized before analysis. The heavy-mineral concentrates were sieved through a 10-mesh screen and then panned until most of the quartz, feldspar, clay-size material, and organic matter were removed. The remaining light minerals were separated from the heavy minerals with a heavy liquid (bromoform, specific gravity 2.8). The magnetite and ilmenite were removed from the material of specific gravity greater than 2.8 with an electromagnet. The concentrates were ground to a fine powder before analysis.

Stream sediments represent a composite of the rock and soil exposed upstream from the sample locality. The heavy-mineral concentrate may represent a concentration of ore-forming and ore-related minerals and heavy accessory minerals that permit determination of some elements that are not easily detected in bulk stream sediments.

Rock samples were collected and analyzed from outcrops that appeared to be mineralized. Rock which appeared fresh and unaltered was also collected to provide information on geochemical background values. The rocks were crushed and pulverized before analysis.

The samples were analyzed in the USGS laboratories by one or a combination of the following methods: uranium and thorium by delayed neutron activation; arsenic, bismuth, cadmium, zinc, mercury, and gold by atomic absorption spectrometry; 31 elements by direct-current arc-emission spectrography; and 40 elements by inductively coupled plasma (ICP) atomic-emission spectroscopy. All sample localities, analytical data, analysts, and a description of methods used are included in Adrian and others (in press).

The geochemical analyses did not reveal any rock units in the study areas that might contain mineral resources. Special attention was given to two formations that underlie the study areas and crop out along the western parts of the study areas. These are the Moenave Formation, which has produced silver and uranium from deposits about 20 mi west of the study areas, and the Chinle Formation, which is known for rich uranium deposits in the central part of the Colorado Plateau.

A partial suite of elements that was looked for in samples from the study areas and that is commonly associated with uranium in roll-front deposits in the Colorado Plateau include vanadium, molybdenum, copper, and, although it is less common, silver. Only silver was found in anomalous amounts in the sampled media in the study areas. Low levels of silver detected in three stream-sediment samples along the west side of the Canaan Mountain Wilderness Study Area were probably derived from shale in the Chinle. This shale also contains trace amounts of antimony, arsenic, and zinc (Adrian and others, in press), elements not normally associated with uranium and silver in roll-type sandstone deposits. The presence of silver and its association with these elements does not indicate uranium in roll-type sandstone mineralization but rather background values for the Chinle Formation.

Barium, strontium, and manganese in stream sediments were derived from manganese-rich limestone nodules, some of which were analyzed (Adrian and others, in press); the nodules are common in shale of the Chinle Formation.

Geophysics

Regional aeromagnetic and gravity data for the Canaan Mountain and The Watchman Wilderness Study Areas and vicinity were examined for evidence of structure and lithology that might relate to evaluation of mineral resource potential. The only aeromagnetic data available for the area north of lat 37° N. were obtained in conjunction with the National Uranium Resource Evaluation (NURE) program. NURE traverses in this region were flown 3 mi apart on east-west headings about 400 ft above the terrain. South of lat 37° N. (the Utah-Arizona border), data are available from a survey flown by the University of Arizona (Sauck and Sumner, 1970) along east-west flight lines spaced 3 mi apart at a constant barometric altitude of 9,000 ft above sea level. Gravity data consist of observations at 226 stations, 144 of which were obtained from U.S. Defense Mapping Agency files (through the National Center for Geophysical and Solar-Terrestrial Data, Boulder CO 80303) and the remainder from new work done for the present project by H.R. Blank and J.A. Sampson of the USGS.

The International Geomagnetic Reference Field (IGRF) has been removed from both aeromagnetic data sets and the two have been merged at the 9,000-ft elevation (about 1,500 ft above the highest terrain) to produce a residual total-intensity anomaly map (fig. 5). Only two sources of magnetic anomalies are known to be present in the map area: Cenozoic basaltic lava flows and their associated vents a few miles west and northwest of the study areas, and Precambrian crystalline basement, which is everywhere at depths of 1.3 mi or more beneath the nearly flat-lying and magnetically "transparent" sedimentary rock strata. Because of the wide aeromagnetic traverse spacing and the drape-to-level upward-continuation process, the configurations of shallow-source anomalies on the map are likely to be distorted relative to their true configurations at the level of observation; moreover, the magnetic signatures of sub-horizontal sheets are commonly below the detection threshold if their thicknesses are greatly exceeded by terrain clearance. Consequently the map does not faithfully record the distribution of basalt flows, even though these rocks may be strongly polarized. Two local magnetic highs (+50 nT and –40 nT maximum amplitude; nT, nanoTesla), 4–5 mi northwest of the Canaan Mountain Wilderness Study Area, probably represent some combination of lava-flow and vent-rock signatures. The remaining field disturbances seen on the map occur over nonvolcanic terrane and arise from sources in the underlying basement. They represent intrabasement magnetization contrasts and (or) topographic relief on the basement surface.

The principal basement magnetic anomaly is a northeast-trending, broad magnetic high in the northwest part of the map area (fig. 5) that includes the two magnetic highs mentioned previously and another magnetic high (150 nT maximum aplitude). Its actual regional trend is north to northeast, generally parallel to the Sevier fault, which is a few miles east of the map area.

No major faults having these trends have been mapped within the study areas, and there is no reason to suspect that the steep gradient bounding the anomaly on the east is produced by a fault involving sedimentary rocks; instead, the gradient probably reflects intrabasement differences in lithologies. The apex of this broad anomaly is the intense magnetic high centered about 5 mi north-northeast of The Watchman Wilderness Study Area. Analysis using a NURE profile suggests a source depth of about 2 mi, and, thus, the feature is probably due to a strongly magnetic body within the basement complex.

Gravity data have been reduced to Bouguer anomaly values for a density of 2.67 g/cm^3 (grams per cubic centimeter) and computer-terrain-corrected out to a radius of 100 mi, following standard USGS procedures (Cordell and others, 1982). The resulting complete Bouguer anomaly map is shown in figure 6. The anomaly pattern of this map is dominated by northwest-southeast-trending contours of a major gradient that extends as an essentially continuous feature from northern Arizona and southwestern Utah into southern Nevada and California. In southern Nevada, the gradient corresponds to northerly increases in average regional altitude and in depth to Precambrian basement. This gradient is diminished but not eliminated by use of a lower Bouguer reduction density or isostatic corrections. Analyses of profiles across the gradient in southern Nevada by Eaton and others (1978) led them to infer that the source of the density discontinuity is mostly or wholly within the crust, and they postulated that it represents the southern limit of voluminous mid-crustal granitic intrusions of Mesozoic and Cenozoic age in the Great Basin. However, the regional gradient is unbroken by the Basin and Range-Colorado Plateau transition in Utah, and evidence of large-scale plutonism in the study areas is lacking.

Local anomalies superposed on the gradient in the Canaan Mountain Wilderness Study Area are of shallow origin. To some extent, the isogals mirror the topography, reflecting the low density of clastic rocks with respect to the reduction density. For example, the gravity low associated with Canaan Mountain, entirely within the Canaan Mountain Wilderness Study Area boundary, is the result of readings at four stations whose elevations are 1,000–2,000 ft higher than those of neighboring stations. The difference in elevation represents almost the full thickness of the Navajo Sandstone, whose bulk density is probably close to 2.3 g/cm^3 rather than 2.67 g/cm^3, thus readily accounting for the anomaly. The gravity low in the northeastern corner of the map may be due to high topography between the two forks of the Virgin River. A weak gravity low 5 mi northwest of The Watchman Wilderness Study Area is associated with a scoria cone.

In contrast to the role of magnetic and gravity data in constraining models of the regional geologic framework, the principal utility of NURE aeroradiometric data is in direct mineral resource prospecting. The NURE profiles over Canaan Mountain and The Watchman Wilderness Study Areas have been examined by J.S. Duval of the USGS. He reports (written commun., 1987) that the study areas have low overall radioactivity, with concentrations of 1.0–2.0 percent potassium, 0.5–3.0 ppm eU (equivalent uranium), and 0–8 ppm eTh (equivalent thorium); no significant anomalies occur within or near the study areas. Much of the data over the study areas were recorded at an altitude exceeding 600 ft above ground, which is about the limit for effective gamma-ray detection.

Mineral and Energy Resources

Oil and Gas Occurrences

Although Utah's oil and gas production comes primarily from the thrust belt of north-central Utah, the Paradox Basin of southeastern Utah, and the Uinta Basin of northeastern Utah, only a few small fields that have had production or are currently producing oil and gas exist outside these three principal areas. The only producing field in southwestern Utah is the Upper Valley field near Escalante, Utah, about 75 mi northeast of the study areas. The abandoned Anderson Junction and Virgin fields are west of Zion Park, 20 and 10 mi, respectively, northwest of the study areas.

Due to the proximity of the Virgin field to the study areas and its geologic setting, which is similar to that of the study areas, the attributes of this field are used in the evaluation of oil and gas potential for the study areas. Oily tar that occurs in seeps in the vicinity of the Virgin field and several other localities nearby (used as lubricants by Indians and pioneer settlers) prompted exploration for oil and gas, and the first well drilled there in 1907 opened the Virgin field. Since 1907, more than 150 wells have been drilled in and near the Virgin field, the latest being in 1986. Some of the wells produced as much as 30 barrels of oil per day (BOPD), but most of them yielded only 1–4 BOPD from shallow wells ranging from 500 to 800 ft deep. Total production from the Virgin field has been slightly over 200,000 barrels of asphalt-paraffin base oil. Most wells produced little or no gas.

The reservoir rocks in the Virgin field are lime-matrix conglomerate in the upper part of the Kaibab Limestone and arenaceous limestone of the Timpoweap Member of the Moenkopi Formation. These formations are separated by an unconformity. Oil in the Virgin field apparently accumulated in a structural low on the nose of a very gently plunging, broad anticline. Differences in the physical properties of oil from well to well may indicate

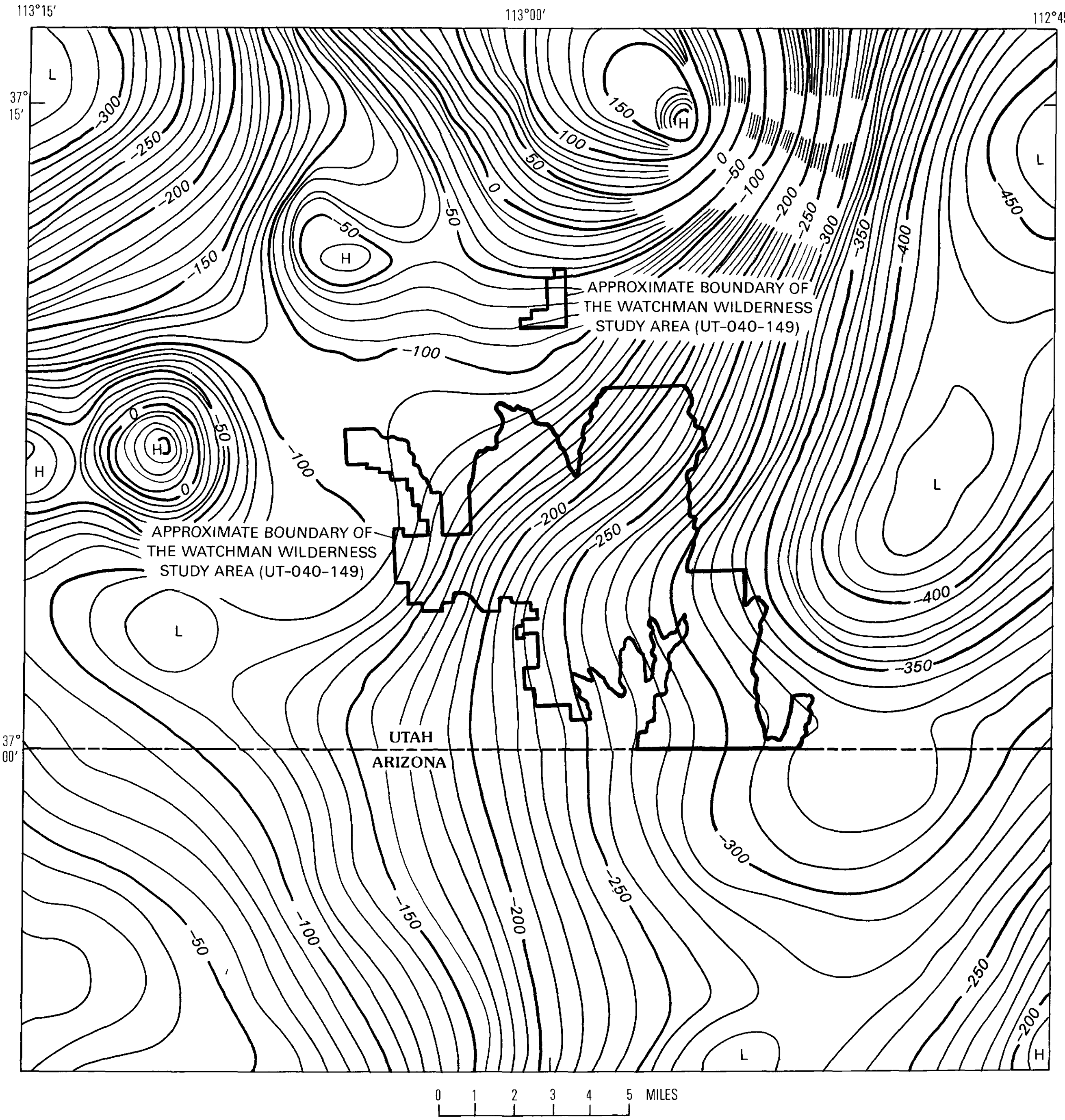

Figure 5. Residual total-intensity aeromagnetic map of the Canaan Mountain and The Watchman Wilderness Study Areas and vicinity, Utah and Arizona. Magnetic contour interval 10 nT (nanoTeslas); flight-line spacing, 3 mi; north of lat 37°N., survey flown 400 ft above terrain; south of lat 37°N., survey flown at 9,000 ft barometric; level of observation 9,000 ft above sea level; International Geomagnetic Reference Field removed; datum arbitrarily adjusted for merger of surveys in Utah and Arizona; H, magnetic high; L, magnetic low.

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 Timpoweap, Kaibab, and the Toroweap. The well was considered dry and was abandoned (P. Carter, BLM, Cedar City, Utah, written commun., 1987).

Other structural highs near the study areas have been tested for oil but none successfully. Four wells were drilled, one as recently as 1985, on the Grafton anticline,

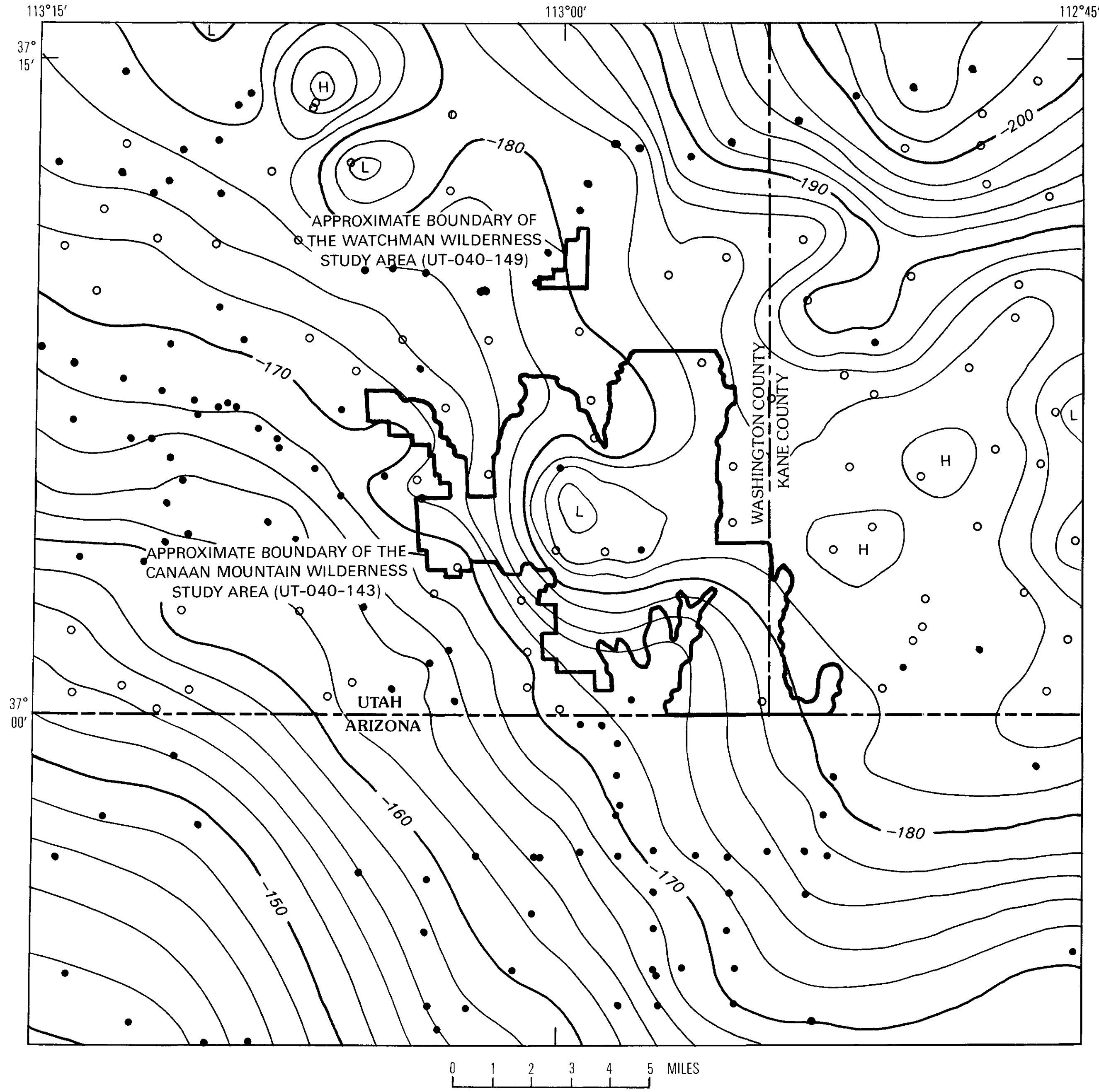

Figure 6. Complete Bouguer gravity anomaly map of the Canaan Mountain and The Watchman Wilderness Study Areas and vicinity, Utah and Arizona. Contour interval 2 mGal; gravity stations indicated by open dots (this study) and solid dots (U.S. Defense Mapping Agency data); L, gravity low; H, gravity high.

located north of Smithsonian Butte about 1 mi south of Grafton (fig. 3). Commercial quantities of oil were not found in any of the wells, although traces of oil were found in samples of the Timpoweap Member taken from the well drilled in 1985 (C. Brandt, Utah Geological and Mineral Survey, written commun., 1987).

The prominent Virgin anticline (not to be confused with the Virgin oil field), about 15 mi southwest of the study areas, has been drilled into, but no oil was found.

South of the study areas, 19 wells were drilled in northern Arizona, and all were dry; however, oil shows were reported in 13 of the wells in the Kaibab Limestone, Timpoweap Member, and Redwall Limestone (Ryder, 1983).

About 15 mi east of the Canaan Mountain Wilderness Study Area, strata adjacent to the Sevier fault have been tested in 5 drill holes. Traces of oil were found but no production was established (C. Brandt, Utah

Geological and Mineral Survey, written commun., 1987). In addition to the pervasiveness of oil traces found by drilling in the region, oil impregnated rock and oily tar deposits on the surface are common locally near the study areas. These deposits occur west of the study areas along the Hurricane fault and in the La Verkin, Virgin, and Short Creek Valleys (Gregory, 1950).

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

Potential for Oil and Gas Resources

Canaan Mountain and The Watchman Wilderness Study Areas have a moderate energy resource potential for the occurrence of oil and gas at certainty level C, on the basis of their structural and stratigraphic setting, results of exploration in the region, and their proximity to the Virgin oil field. This assessment concurs with the rating given the areas by Molenaar and Sandberg (1983).

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

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

The many signs of oil in the region, such as surface seeps and traces of oil in several favorable formations encountered in drill holes, and the presence of the nearby Virgin oil field, whose geologic setting is similar to that of the study areas, may suggest more than moderate resource potential for the occurrence of oil and gas beneath the study areas. However, the available reservoir rocks in the region have been and 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. A well drilled west of Zion National Park in 1986 contained massive amounts of water in the Timpoweap, Kaibab, and Toroweap, all potential reservoir rocks (P. Carter, BLM, Cedar City, Utah, written commun., 1987). Drilling records from a well drilled in the Anderson Junction field, about 15 mi northwest of the study areas, showed fresh water flowing in the Callville Limestone and Redwall Limestone (Giardina, 1979).

The study areas have been assigned a moderate energy resource potential for oil and gas, with a C level of certainty. The surface geologic setting of the study areas is well known, but there are no subsurface data. Exploration drilling would be required to identify petroleum occurrences, but no drilling has been done within the study areas.

Base and Precious Metals

Canaan Mountain and The Watchman Wilderness Study Areas have a low mineral resource potential for copper, gold, lead, silver, and zinc, with certainty level C. The geologic setting of the study areas consists of a relatively flat-lying sequence of exposed Triassic and Jurassic sedimentary rocks, the bulk being of eolian origin. These rocks, in the absence of igneous activity, are for the most part unfavorable for hosting mineral resources other than the roll-front sandstone-hosted uranium deposits of the Colorado Plateau (see section entitled "Uranium").

A deposit, probably of the roll-front sandstone-hosted uranium type, occurs in the Springdale Sandstone Member of the Moenave Formation in the Silver Reef district about 20 mi west of the study areas. This district, discovered in 1869, was mined for silver until about 1910 when the rich ore was mined out. The Springdale Sandstone was host to rich silver ore that contained microscopic-size silver halide minerals along with minor amounts of copper, uranium, and vanadium. During the early 1950's, uranium was mined from the district. The origin of the Silver Reef deposits is thought to be analogous to the sandstone-hosted uranium deposits of the Colorado Plateau (Heyl, 1978). The deposit is unique in that the enrichment is in silver rather than uranium. Criteria used to characterize roll-type sandstone-hosted uranium deposits also apply to Silver Reef-type deposits.

Because of the Silver Reef deposit, the host Springdale Sandstone Member was given special attention in the study areas. The Springdale underlies both study areas, and it is exposed along the western half of the Canaan Mountain Wilderness Study Area and through the central part of The Watchman Wilderness Study Area. The unit forms brick-red ledges, and any signs of alteration or bleaching, characteristics of sandstone host rock in the Silver Reef district, are conspicuous. In the Silver Reef district, the Springdale is mostly bleached from red to light gray. Nothing unusual was noted in the appearance of the sandstone in the study areas, nor were anomalous concentrations of any elements (specifically uranium, silver, copper, vanadium, and molybdenum) found in samples taken from the unit. No associated radioactivity was found in the sandstone. Although the Springdale Sandstone Member is exposed in only a very small part of the study areas, most of the unit is overlain by as much as 2,300 ft of the Kayenta Formation and the Navajo Sandstone. If a Silver Reef-type deposit exists, it will probably be in the subsurface where it will be difficult to locate. Although the Springdale is exposed over many hundreds of square miles, nowhere outside the Silver Reef district is it known to contain concentrations of metals.

The Chinle Formation has long been known to contain traces of base (copper, lead, and zinc) and precious (gold and silver) metals, although little is known about the nature of their occurrence. These metals may have been introduced from tuffaceous components that make up the Petrified Forest Member of the Chinle. Metals derived from the Chinle in the Silver Reef district may have been remobilized during diagenesis and concentrated in organic-rich sandstone of the Springdale Sandstone Member.

Manganese-rich limestone nodules are common in the middle part of the Petrified Forest Member of the Chinle Formation. Manganite (MnO) is the principal manganese mineral and it makes up about 5 percent of the nodules; barite is also common. The distribution of nodules, however, is sparse and they make up only a very small part of the member. Similar but somewhat richer nodules were mined in the early 1900's for their manganese content from the Chinle Formation in Kane County, east of the study areas (Helmut Doelling, Utah Geological and Mineral Survey, written commun., 1987). The study areas have a low resource potential for manganese, with a D level of certainty.

Low levels of gold are present in the Chinle Formation in eastern Kane County (Helmut Doelling, Utah Geological and Mineral Survey, written commun., 1987; Bush and Lane, 1982). Attempts made to recover gold from the lower part of the Petrified Forest Member in Kane County have apparently been unsuccessful. Gold was not detected in any samples of the Chinle Formation collected within the study areas.

Coal

The mineral resource potential for coal is low in the Canaan Mountain and The Watchman Wilderness Study Areas, at certainty level D.

Utah contains many rich coal fields, mainly in the eastern and southern parts of the state. Coal fields near the study areas in southwestern Utah are the Harmony, Kolob, and Alton. The Kolob coal field is about 15 mi northeast of the study areas. Commercial-grade coal in these coal fields and all other coal fields throughout Utah occurs in rocks of mostly Cretaceous age, but minor amounts of coal occurs in rocks of early Tertiary age.

Coal occurs locally in thin beds in Kane County in the Chinle Formation of Late Triassic age; however, it is low rank (Helmut Doelling, Utah Geological and Mineral Survey, written commun., 1987). The Chinle Formation underlies the study areas at depths of as much as 2,500 ft except near the western borders of the study areas, where it crops out. Coal seams were not found nor are they known to occur in any exposures of the Chinle Formation in or near the study areas. Cretaceous and Tertiary rocks, coal-bearing in many parts of Kane County, are not present in the study areas. The presence of any coal in the Chinle, let alone commercial quantities, is highly unlikely; the resource potential is therefore low. This assessment is made with a certainty level of D because the geologic setting is well known and favorable conditions do not exist in the study areas.

Uranium

Canaan Mountain and The Watchman Wilderness Study Areas have a low mineral resource potential for uranium, at certainty level C. There are major uranium deposits in the southeastern quarter of Utah, but the principal host rock (Morrison Formation of Late Jurassic age) is not present in the study areas. The Colorado Plateau is rich in uranium, especially in northwestern New Mexico and southeastern Utah. The Morrison Formation is thought to contain 80 percent of the potential uranium resources in that region (U.S. Department of Energy, 1979). Significant deposits of uranium also occur in the Chinle Formation of southeast Utah and in the breccia pipes of northern Arizona.

Southwestern Utah has not been a major producer of uranium, although some has been mined locally near the study areas. Abandoned uranium mines are in the Silver Reef district, where uranium was produced from the Springdale Sandstone Member of the Moenave Formation, and about 15 mi to the northeast in the Orderville Canyon area, where uranium was mined from the Dakota Sandstone of Late Cretaceous age. If uranium occurs in the study areas, the most likely geologic environment and types of deposits would be (1) peneconcordant, sandstone-hosted deposits in the Moenave and Chinle Formations (the Morrison and Dakota are not present here), and (2) vein-type deposits occurring in breccia pipes.

The Springdale Member contains uranium in the deposits at Silver Reef; however, no evidence for uranium enrichment in the Springdale was found in the study areas, nor is the Springdale known to contain mineral resources other than those at Silver Reef.

The Chinle Formation contains rich uranium deposits in much of the central part of the Colorado Plateau. During the Triassic Period, an environment of high-energy deposition of coarse sand and gravel trapped carbonaceous material that later served as a reductant for depositing uranium. The Chinle Formation is poorly exposed along the western parts of the study areas. The lower member of the Chinle, the Shinarump, is a resistant ledge-forming unit containing 80–140 ft of sandstone and conglomerate that are apparently devoid of significant amounts of uranium minerals. Modern stream sediments derived in part from the Chinle Formation and samples collected from outcrops of the formation do not contain anomalous amounts of uranium. Radioactivity measured on the ground at outcrops was generally low; however, in the SW¼ of sec. 24 in a creek bottom in Horse Valley Wash (east of Smithsonian Butte; pl. 1), anomalous radioactivity (500 counts per second) was detected at a spring. This anomaly is near the top of the Shinarump Member, and prospect pits, a few feet above, may have been dug in an attempt to locate the source of this anomaly. Rock samples from the spring and prospect pits do not contain anomalous amounts of uranium. Apparently, the spring water is carrying a radioactive daughter product from some undetermined source. This anomaly is about 1 mi outside the Canaan Mountain Wilderness Study Area. A sandstone unit near the middle of the Petrified Forest Member of the Chinle Formation is slightly radioactive in exposures at the base of Smithsonian Butte. This sandstone unit contains petrified wood fragments. The uranium content of two samples was 9 and 12 ppm uranium, amounts not considered anomalous for sandstone in this unit. The mineral resource potential for uranium in the Chinle Formation in the study areas is low, with a certainty level of C.

The geologic setting of the study areas may be favorable for the occurrence of breccia pipes that contain uranium, but the likelihood of them being discovered is practically nil. Breccia pipes are common in northern Arizona just south of the study areas. Hundreds of pipes have been identified there and some contain commercial quantities of uranium. Mineralized pipes were originally mined for copper, but in the early 1950's they were recognized to have significant uranium content. The pipes have since been exploited for uranium, and current exploration continues for others that may contain high-grade uranium ore. These pipes appear to have formed when overlying sedimentary rock strata collapsed into caverns that formed in the Mississippian Redwall Limestone, providing channelways for fluids that, in some areas, carried and deposited copper, uranium, and other elements within and adjacent to the breccia in the pipes. The uppermost formation involved in pipe development is the Upper Triassic Chinle Formation (Wenrich, 1985). Most pipes are discovered by their surface expression in formations exposed by erosion. Because the Chinle, for the most part, lies beneath a considerable thickness of sedimentary rocks in the study areas, pipes, if they do exist, will be difficult to locate. The Redwall Limestone, which apparently controls pipe development, thickens from southeast to northwest across northwest Arizona. In the Grand Canyon region, an area of prolific pipe development, the Redwall ranges from 550 to 700 ft thick (Wenrich, 1985). Beneath the study areas the Redwall is believed to be approximately 800 ft thick, a seemingly favorable setting for pipe development, but, because the host rock units are at depth, it is unknown if pipes formed and mineralization occurred. The study areas therefore have low potential for uranium in breccia pipes.

The mineral resource potential for uranium in the Canaan Mountain and The Watchman Wilderness Study Areas is low on the basis of the geologic setting, the results of the geochemical investigations, and the overall low radioactivity detected by the aeroradiometric survey. This assignment is made with a C level of certainty.

Geothermal Energy Sources

Canaan Mountain and The Watchman Wilderness Study Areas have a low energy resource potential for geothermal energy, with a C level of certainty. The study areas are along the western edge of the Colorado Plateau province, a relatively stable province characterized by low heat flow. By comparison, the adjoining Basin and Range province is tectonically active and has a high heat flow. The study areas are about 10 mi east of thermal springs that discharge warm water (106 °Fahrenheit, 41 °Celsius) into the Virgin River near Hurricane, Utah. These springs are along and are probably controlled by the Hurricane fault zone. The Hurricane fault zone is a major structure that is along the transition zone between the Colorado Plateau and the Basin and Range province, an area characterized by relatively high heat flow. The study areas are east of this zone where heat flow drops. Warm springs do not occur in the study areas and no other evidence was found to indicate more than a low potential for geothermal energy sources in the study areas.

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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

LEVEL OF RESOURCE POTENTIAL ↑

U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL
A	B	C	D

LEVEL 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.

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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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