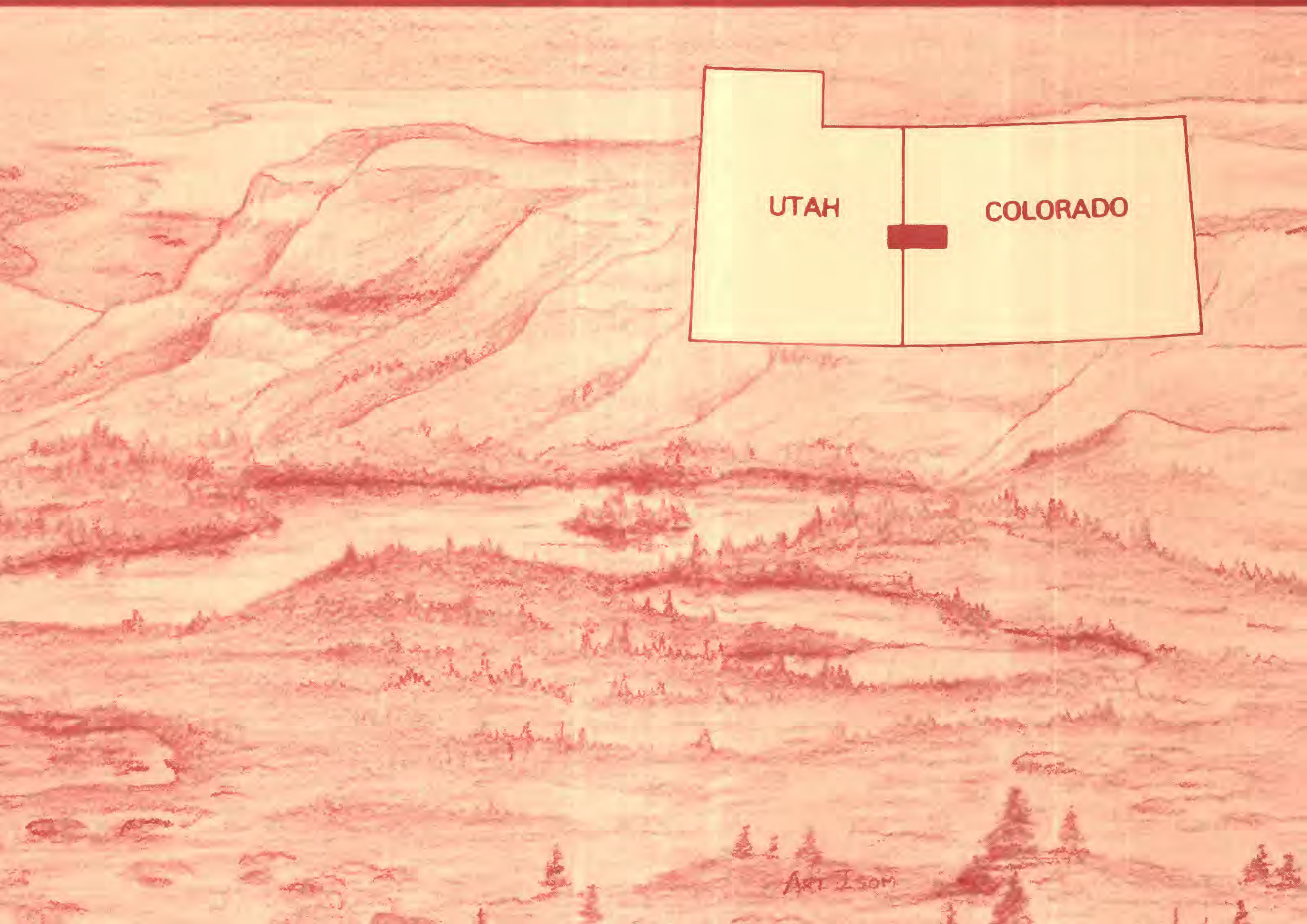
Mineral Resources of the Black Ridge Canyons Wilderness Study Area, Mesa County, Colorado, and Grand County, Utah, and Westwater Canyon Wilderness Study Area, Grand County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1736–C



Chapter C

Mineral Resources of the Black Ridge Canyons Wilderness Study Area, Mesa County, Colorado, and Grand County, Utah, and Westwater Canyon Wilderness Study Area, Grand County, Utah

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
GRAND JUNCTION REGION, COLORADO

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U. S. GEOLOGICAL SURVEY
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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Black Ridge Canyons (CO–070–113/113A; UT–060–116/117) Wilderness Study Area, Mesa County, Colorado, and Grand County, Utah, and the Westwater Canyon (UT–060–118) Wilderness Study Area, Grand County, Utah.

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PLATE

[Plate is in pocket]

FIGURES

TABLE

Mineral Resources of the Black Ridge Canyons Wilderness Study Area, Mesa County, Colorado, and Grand County, Utah, and the Westwater Canyon Wilderness Study Area, Grand County, Utah

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SUMMARY

Abstract

In 1986 the U.S. Bureau of Mines and the U.S. Geological Survey conducted studies to appraise the identified mineral resources (known) and assess the mineral resource potential (undiscovered) of 73,937 acres of the Black Ridge Canyons (CO–070–113/113A; UT–060–116/117) and 31,160 acres of the Westwater Canyon (UT–060–118) Wilderness Study Areas in western Colorado and eastern Utah. Subeconomic placer gold deposits were identified along the Colorado River at the Pussycat claims in the Westwater Canyon study area. Identified resources of dimension stone occur in the west-central part of the Black Ridge Canyons Wilderness Study Area. Subeconomic sand, gravel, stone, and rock resources occur within the Black Ridge Canyons study area, but sufficient quantities are available elsewhere to satisfy current needs. There is a high mineral resource potential for placer gold adjacent to the Colorado River and in terrace deposits above it in both study areas. There is a moderate resource potential for gold, silver, copper, and barite in vein deposits in the southern part of the Westwater Canyon Wilderness Study Area. There is also a moderate resource potential for uranium occurrences in the Morrison Formation in the southeastern part of Black Ridge Canyons Wilderness Study Area, but no resource potential for this type of uranium occurrence due to complete erosion of the Morrison Formation in the Westwater Canyon Wilderness Study Area. There is a low resource potential for gold, silver, mercury, copper, and uranium in the Chinle Formation in both study areas, and for chromium, nickel, and cobalt resources in Precambrian (Proterozoic; see geologic time chart in appendix) rocks in both study areas. Geological, geochemical, and geophysical studies indicate a low energy resource potential for undiscovered oil, natural gas, carbon dioxide, and geothermal energy in both study areas, and a low mineral resource potential for the above-mentioned mineral resources for both study areas where not specified differently. There is a low resource potential for coal in the Black Ridge Canyons Study Area, and no potential for coal in the Westwater Canyon Study Area.

Character and Setting

The wilderness study areas are located west of Grand Junction, Colo., on the northern and western flanks of the Uncompahgre Plateau (fig. 1). The study areas comprise 105,417 acres of desert canyons and mesas along the Colorado River in Mesa County, Colo., and Grand County, Utah. The entire area is underlain by over a thousand feet of nearly flat-lying Mesozoic (see geologic time chart in appendix) sedimentary rocks of the Chinle, Wingate, Kayenta, Entrada, Wanakah, Morrison, and Dakota Formations overlying Precambrian igneous and metamorphic rocks. The study areas are transected by several west-northwest-trending normal faults and down-warped rocks.

Identified Resources and Mineral Resource Potential

There has been modest production of some commodities within the study areas. During the 1950's and 1960's, 7,000 short tons of flagstone were produced from a

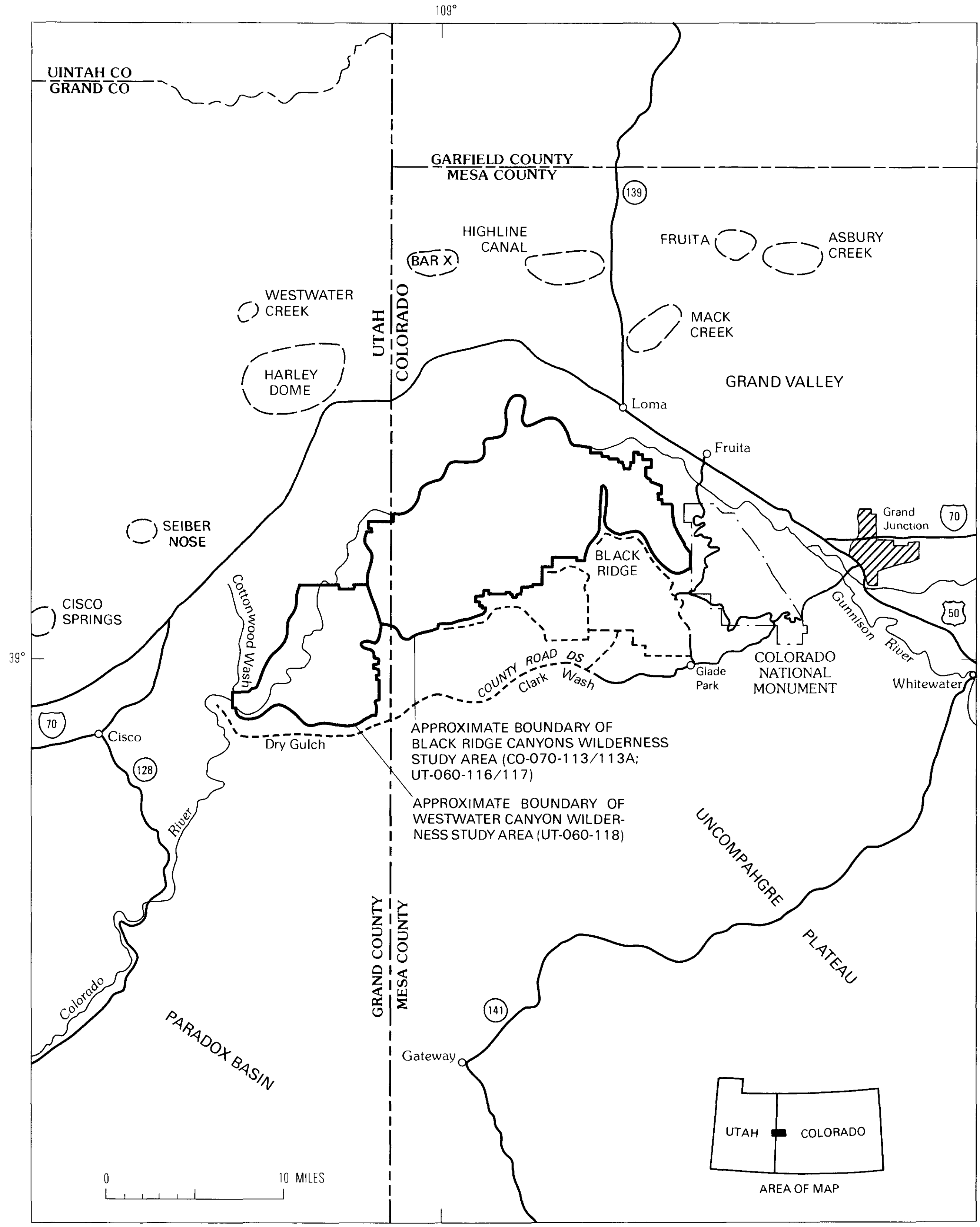

Figure 1. Index map showing location of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas, Grand County, Utah, and Mesa County, Colorado. Oil and gas fields are outlined by long-dashed lines.

quarry in the Kayenta Formation near Long Mesa, in the western part of the Black Ridge Canyons Wilderness Study Area (fig. 2). This same time period witnessed modest production of uranium from the Edna mine in the Salt Wash Member of the Morrison Formation in Devils Canyon, in the eastern part of the same study area. Placer gold was produced from the Pussycat claims near Snyder Mesa in the Westwater Canyon Wilderness Study Area.

Exploration for a variety of commodities has occurred throughout the study areas. A short adit exists in the Chinle Formation in Devils Canyon in the Black Ridge Canyons Wilderness Study Area. Trace amounts of copper occur in this adit, but there is no known production. Small prospect pits for copper, gold, and silver occur in Precambrian rocks at several locations along the Colorado River, and along the Dry Gulch fault zone, in and near the Westwater Canyon Wilderness Study Area. There are placer gold claims along the Colorado River in both study areas, and oil and gas leases are held in the western part of the Westwater Canyon Wilderness Study Area.

Geophysical surveys conducted in the study areas show that the gravity and magnetic anomalies have their origin in the Precambrian crystalline rocks beneath the Mesozoic sedimentary rocks. A diorite pluton observed in outcrop is further delineated by geophysical data in the east-central part of the Westwater Canyon Wilderness Study Area. These data coupled with other geophysical data suggest that a thrust fault of Precambrian rocks over Paleozoic sedimentary rocks may exist beneath the southwest corner of the Westwater Canyon Wilderness Study Area.

Geochemical sampling conducted in the study areas confirmed the presence of placer gold along the Colorado River in both study areas, and revealed altered rocks at the contact of the Triassic Chinle Formation with the underlying Precambrian rocks in the western part of the Black Ridge Canyons Wilderness Study Area. Elevated concentrations of copper, lead, silver, barium, arsenic, and molybdenum at this altered zone are believed to have been leached from the Precambrian rocks. Anomalous amounts of gold, silver, copper, and barite were detected in veins in Precambrian rocks in the southern part of the Westwater Canyon Wilderness Study Area, and elevated concentrations of these same metals were detected in other fractures in the Precambrian rocks of Westwater Canyon.

Within the study areas there is an identified subeconomic resource with reserves of 24 oz of placer gold at the Pussycat claims in the Westwater Canyon Wilderness Study Area, and an identified resource with reserves of 9,000 short tons of dimension stone in the Black Ridge Canyons Wilderness Study Area (fig. 2 and pl. 1). Subeconomic sand, gravel, and stone and rock resources occur in both study areas. There is a high mineral resource potential for placer gold adjacent to the Colorado River and in terrace deposits above it in both study areas.

Uranium deposits found in the Salt Wash Member of the Morrison Formation occur in carbonaceous, high energy fluvial, channel sandstones located along axes of depositional thickening, near local redox boundaries between oxidizing and reducing environments, and adjacent to humate-generating "favorable gray mudstones." This combination of factors occurs in the southeast part of the Black Ridge Canyons Wilderness Study Area where there is a moderate mineral resource potential for uranium in the Morrison Formation around Devils Canyon. In the rest of the Black Ridge Canyons study area the Morrison Formation has been removed by erosion, or this combination of favorable factors does not exist and the potential is regarded as low. There is no potential for uranium in the Morrison Formation in the Westwater Canyon Wilderness Study Area because the formation has been completely removed by erosion.

Geochemical sampling of prospect pits by the U.S. Bureau of Mines reveals gold, silver, and copper anomalies in barite veins in Precambrian rocks in the Dry Gulch fault zone. These veins trend northeastward into the southern part of the Westwater Canyon study area, disappearing beneath Mesozoic sedimentary rocks and cropping out further into the study area in Star Canyon. There is a moderate potential for gold, silver, copper, and barite resources in vein deposits in Star Canyon in the southern part of the Westwater Canyon Wilderness Study Area. Other prospect pits and altered fractures in Precambrian rocks of Westwater Canyon were checked, but their potential for mineral resources of gold, silver, copper, and barite is low. The Westwater Canyon and Black Ridge Canyons Wilderness Study Areas have a low resource potential for chromium, nickel, and cobalt in Precambrian ultramafic rocks, based on geochemical data. There are occurrences of gold, mercury, and uranium in members of the Chinle Formation that occur well outside the study areas, but those rocks containing these commodities do not exist within the study areas. Copper and silver occasionally occur in the Chinle Formation as well. The mineral resource potential for gold, mercury, copper, silver, and uranium deposits in the Chinle Formation is low for both study areas.

Oil and gas occur near the study areas in the Paleozoic and Mesozoic rocks of basins adjacent to the Uncompahgre Plateau. Source rocks for hydrocarbons are not known to exist in the study areas, and reservoir rocks lie exposed at the surface or have been removed completely by erosion. West of the study areas Precambrian crystalline rocks are known to be thrust over possible petroleum-bearing Paleozoic rocks, but it is not known if this occurs beneath the western part of the Westwater Canyon Wilderness Study Area. Both study areas have a low energy resource potential for oil, gas, and carbon dioxide. Formations known to contain coal in other parts of Colorado crop out in one part of the Black Ridge Canyons study area, but do not exist in the Westwater Canyon study area. The Black Ridge Canyons study area has a low resource potential for coal while the Westwater Canyon study area has no potential. Springs and seeps exist in both study areas but there are no warm or hot springs. The potential for geothermal energy resources is low. The potential for the occurrence of the above-mentioned mineral and energy resources is low for both study areas where not specified differently.

INTRODUCTION

At the request of the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey

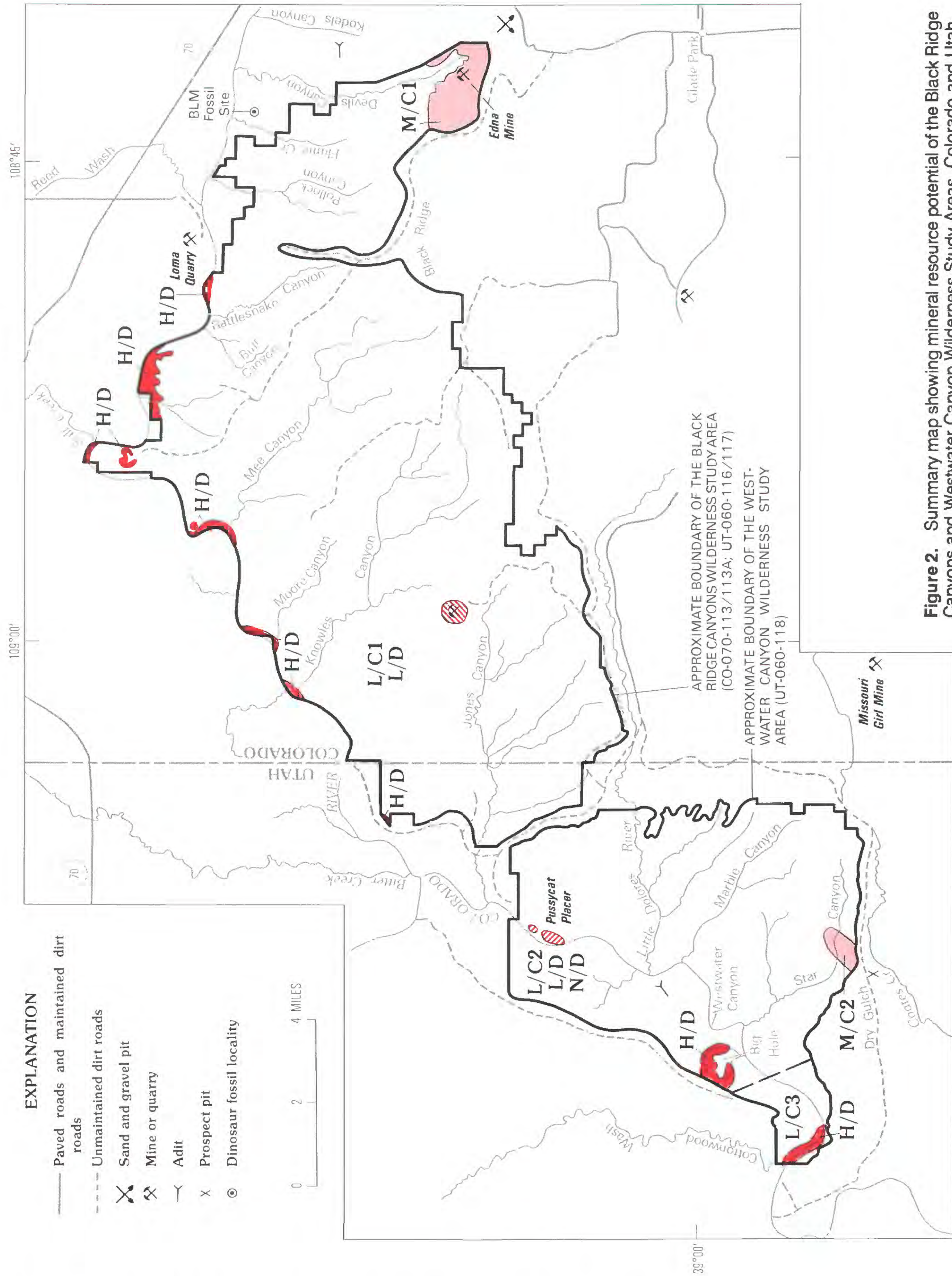

Figure 2. Summary map showing mineral resource potential of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas, Colorado and Utah.

EXPLANATION OF MINERAL RESOURCE POTENTIAL

	Area of identified dimension stone resource
	Area of identified subeconomic placer gold, sand, and gravel resource
H/D	Geologic terrane having high mineral resource potential for placer gold, with certainty level D
M/C1	Geologic terrane having moderate mineral resource potential for uranium in the Morrison Formation, with certainty level C
M/C2	Geologic terrane having moderate mineral resource potential for gold, silver, copper, and barite in vein deposits, with certainty level C
L/C1	Geologic terrane having low mineral resource potential for uranium, gold, mercury, copper, and silver in sedimentary rocks, for gold, silver, copper, and barite in vein deposits, for chromium, nickel, and cobalt in ultramafic rocks, and for geothermal energy and coal, with certainty level C
L/C2	Geologic terrane having low mineral resource potential for gold, mercury, copper, and silver in sedimentary rocks, for gold, silver, copper, and barite in vein deposits, for chromium, nickel, and cobalt in ultramafic rocks, and for geothermal energy, with certainty level C
L/C3	Geologic terrane having low mineral resource potential for geothermal energy, oil, gas, and carbon dioxide, with certainty level C
L/D	Geologic terrane having low mineral resource potential for oil, gas, and carbon dioxide, with certainty level D
N/D	Geologic terrane having no mineral resource potential for uranium in the Morrison Formation or for coal, with certainty level D

(USGS) and the U.S. Bureau of Mines (USBM) studied the Black Ridge Canyons (CO–070–113/113A; UT–060–116/117; 73,937 acres) and Westwater Canyon (UT–060–118; 31,160 acres) Wilderness Study Areas. They are on the northern and western flanks of the Uncompahgre Plateau (fig. 1) west of Grand Junction, in Mesa County, Colo., and Grand County, Utah. The Black Ridge Canyons Wilderness Study Area is bordered on the east by the Colorado National Monument, on the north and northwest by the Colorado River; the southwest part, which is in Utah, adjoins the Westwater Canyon Wilderness Study Area. The Westwater Canyon Wilderness Study Area's southern boundary is along Dry Gulch and Coates Creek, and its eastern boundary is about 1 mile west of the Colorado-Utah border. In this report the areas studied are referred to as "the wilderness study areas," or simply the "study areas."

The study areas are in rugged desert terrain characterized by deep canyons and high mesas where cliff walls frequently overhang, and arches and pinnacles abound. Elevation ranges from 4,152 ft at the Colorado River near Cottonwood Wash to 6,890 ft at the top of Black Ridge. Access to the wilderness study areas is provided by the Colorado River and by dirt roads. An unimproved access road extends 9–10 mi northwest along the southern boundary of the Black Ridge Canyons Wilderness Study Area from Colorado National Monument. County road DS extends 22 mi west of Glade Park along the southern boundary of the Westwater Canyon Wilderness Study Area to the Colorado River.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study areas 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 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 of this report. The potential for undiscovered resources is studied by the USGS. This report, using more data and covering a larger area, supplements and refines an earlier report by the USGS (Toth and others, 1983) on the mineral resource potential of the Black Ridge Canyons Wilderness Study Area.

Investigations by the U.S. Bureau of Mines

The USBM appraisal consisted of a literature search for data relative to mining, minerals, and geology; discussions with those holding mining claims; examination of BLM mining claim records and contracted mineral studies; and a field investigation. The field investigation consisted of examining, mapping, and sampling mines and prospect sites in and near the study areas and a search for additional mineralized sites.

A total of 407 samples (134 from the Black Ridge Canyons study area and 273 from the Westwater Canyon study area) was collected, including chips from outcrop and mineralized rocks, and placer, stream-sediment, and panned-concentrate samples. Placer deposits were evaluated by digging test pits to bedrock (where possible), channel sampling the exposed gravels, and reducing a measured volume of placer material to a black-sand concentrate by sluicing and (or) panning.

Sample analyses were done by three laboratories. Bondar-Clegg, Inc., of Lakewood, Colo., analyzed the rock and stream-sediment samples. Copper, lead, and vanadium concentrations were determined by atomic absorption spectroscopy; tin concentrations by ion fusion; and fluorine concentrations by specific ion analysis of a potassium-hydroxide fusion. All other elements looked for were determined by neutron activation analysis. The Bureau of Mines, Western Field Operations Center laboratory in Spokane, Wash., determined the gold content of placer samples (black-sand panned concentrates) by amalgamation. The U.S.

Table 1. Summary table showing identified resources and mineral resource potential for the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas

[Resource potential: H, high; M, moderate; L, low; N, none. Levels of certainty: C, D (see Appendix for explanation)]

Commodities	Westwater Canyon Wilderness Study Area	Black Ridge Canyons Wilderness Study Area
Placer gold	Subeconomic (24 oz) H/D, Colorado River, Big Hole	H/D, Colorado River
Dimension stone		Subeconomic (9,000 tons of flagstone)
Sand and gravel	Inferred subeconomic	Inferred subeconomic
Uranium	N/D, Morrison Formation L/C, Chinle Formation	M/C, Morrison Formation, SE corner L/C, Chinle Formation
Chromium, nickel, cobalt	L/C	L/C
Gold, silver, copper, barite (vein deposits)	M/C, Star Canyon	L/C
Gold, mercury, copper, silver (sedimentary rocks)	L/C	L/C
Oil, gas, carbon dioxide	L/D, except L/C in SW corner	L/D
Geothermal energy	L/C	L/C
Coal	N/D	L/C

Geological Survey, Geologic Division, Branch of Sedimentary Processes laboratory in Golden, Colo., analyzed two samples of bentonitic material by X-ray diffraction. Analytical data are in Chatman (1987).

Investigations by the U.S. Geological Survey

Geologic maps (pl. 1) of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas were prepared by R.P. Dickerson from the following: mapping of the eastern part of the Black Ridge Canyons Wilderness Study Area (Toth and others, 1983), unpublished mapping of Westwater Canyon by J.E. Case, and new mapping of the western part of the Black Ridge Canyons Wilderness Study Area in April and May 1986 by R.P. Dickerson. Sampling for a stream-sediment geochemical survey was done in May and July 1986; geochemical data were collected and interpreted by Harlan Barton for this report. A gravity survey of the wilderness study areas was made in May 1986 by Robert Morin (1987) and added to existing gravity and aeromagnetic data of J.E. Case (Case, 1966; Case and Joesting, 1972). Interpretation of the geophysical data was done by J.E. Case for this report. Landsat Multispectral Scanner data were processed digitally to map variations in the occurrence of surface limonite and to map lineaments. These remote-sensing data were interpreted by Keenan Lee (1987).

APPRAISAL OF IDENTIFIED RESOURCES

By Mark L. Chatman U.S. Bureau of Mines

Mining Activity

Mining activity within the study areas has been minimal and is limited to a stone quarry, a gold placer along the Colorado River, a uranium prospect, and small prospects for metals. Flagstone was quarried from the Black Ridge Canyons Wilderness Study Area during the 1950's and 1960's (Schwochow, 1978). Some gold production probably took place on the Pussycat placer claims in the Westwater Canyon Wilderness Study Area (fig. 3). Initial placer work began there around the late 1800's and later work was done around the 1950's (Ray Pene, oral commun., Moab, Utah, 1986). Small prospects for metals found in both wilderness study areas were mainly for copper—none of the work resulted in any mineral production.

Current Mining Claims and Mineral Leases

In 1986, placer gold was the principal mineral of interest, as indicated by numerous unpatented placer mining claims staked in the study areas and on adjacent lands (fig. 3). One lode claim group for gold is in the Westwater Canyon Wilderness Study Area. Previously, claims were staked for uranium in the Black Ridge Canyons Wilderness Study Area. Neither study area is part of any organized mining district, but many of the claim records bear classifications "Grand River" or "Cisco" mining district. Grand River is formerly the name of the Colorado River, and Cisco is a town about 5.5 mi due west of the Westwater Canyon Wilderness Study Area (fig. 1). Several oil and gas leases were in effect in 1986 and covered about 10 percent of the Westwater Canyon Wilderness Study Area (fig. 3).

Appraisal of Sites Examined

Prospects, mining claims, and mineralized sites in and near the study areas were examined, sampled, and mapped (maps and accompanying analytical data are presented in Chatman (1987)). Gold was detected in placers in both study areas; an indicated subeconomic deposit was identified at the Pussycat claim area in the Westwater Canyon Wilderness Study Area. Lode gold was detected in silicified fractures in Precambrian rocks in the Westwater Canyon Wilderness Study Area. No additional gold resources of either placer or lode type were delineated. Flagstone reserves (see "Stone and Rock Products" below) were inferred at one quarry in the Black Ridge Canyons Wilderness Study Area; other stone occurrences cover extensive parts of both study areas, but no other resources were identified. Sand and gravel resources in the Black Ridge Canyons Wilderness Study Area, discussed in Schwochow (1978, pl. 1-d), are inferred and subeconomic. Hydrocarbons, clay, gem stones, and fossils are discussed in the literature, but were not found in the areas.

Placer Gold

Placer gold has been deposited in gravel bars and gravel terraces along the Colorado River in the study areas. The gold occurs as small, thin flakes, usually less than 0.02 in. across. Extensive areas have been staked with placer mining claims, but only one placer gold mineral patent was granted in the region—the Linn placer, adjacent to Black Ridge Canyons Wilderness Study Area (Fine, 1888). There has been little mining activity on any of these claims, except at the Pussycat placer claim group in the Westwater Canyon Wilderness Study Area, where indicated subeconomic gold resources were identified.

Pussycat Claims

Gold has been concentrated on the Pussycat claim group (fig. 3) in a narrow gravel terrace that lies on a bench of Precambrian bedrock about 100 ft east of the present Colorado River channel. This terrace contains an estimated 5,000 cu yd (cubic yards) of placer sand and gravel, with equal proportions of cobbles, pebbles, and gravel distributed mostly in two narrow zones, each averaging about 100 ft wide, 400 ft long, and 2–3 ft thick. These zones represent a former point bar preserved about 20–30 ft above current high water level. Testing by the USBM in the spring of 1986 revealed that recoverable ($1.80/cu yd at $382.62/oz, or about 0.005 oz/cu yd) fine-grain gold (less than 0.02 in.) is present, but distribution of the gold within these deposits is not uniform (Chatman, 1987). Other small, thin gravel terrace remnants exposed on the Pussycat claims contain negligible amounts of gold.

The bedrock consists of locally sheared biotite gneiss and amphibolite intruded by a granite porphyry. Small siliceous veins, usually less than 2 ft thick, crosscutting these rocks contain as much as 430 parts per billion gold. The trace amounts of gold present in these veins do not account for the quantities in the placer; virtually all the gold present, therefore, was probably derived from upstream sources in the Colorado River basin. Overburden, consisting of 1 to 5 ft of soil and talus, derived from Triassic and Jurassic sedimentary rocks to the east, may conceal some similar channel-fill placers in the area immediately east of the defined gold resources; some of these channel fills may be auriferous.

Indicated subeconomic resources in the placer deposits amount to about 24 oz of gold ($9,000 based on December 1986 price of $382.62/oz of gold), resulting in a determined average value of $1.80 per cu yd for this 5,000 cu yd deposit. The resource is partially contained in placer tailings that remain from earlier mining operations. Sample analyses indicate that higher grades are present—as much as $10.20/cu yd—suggesting that

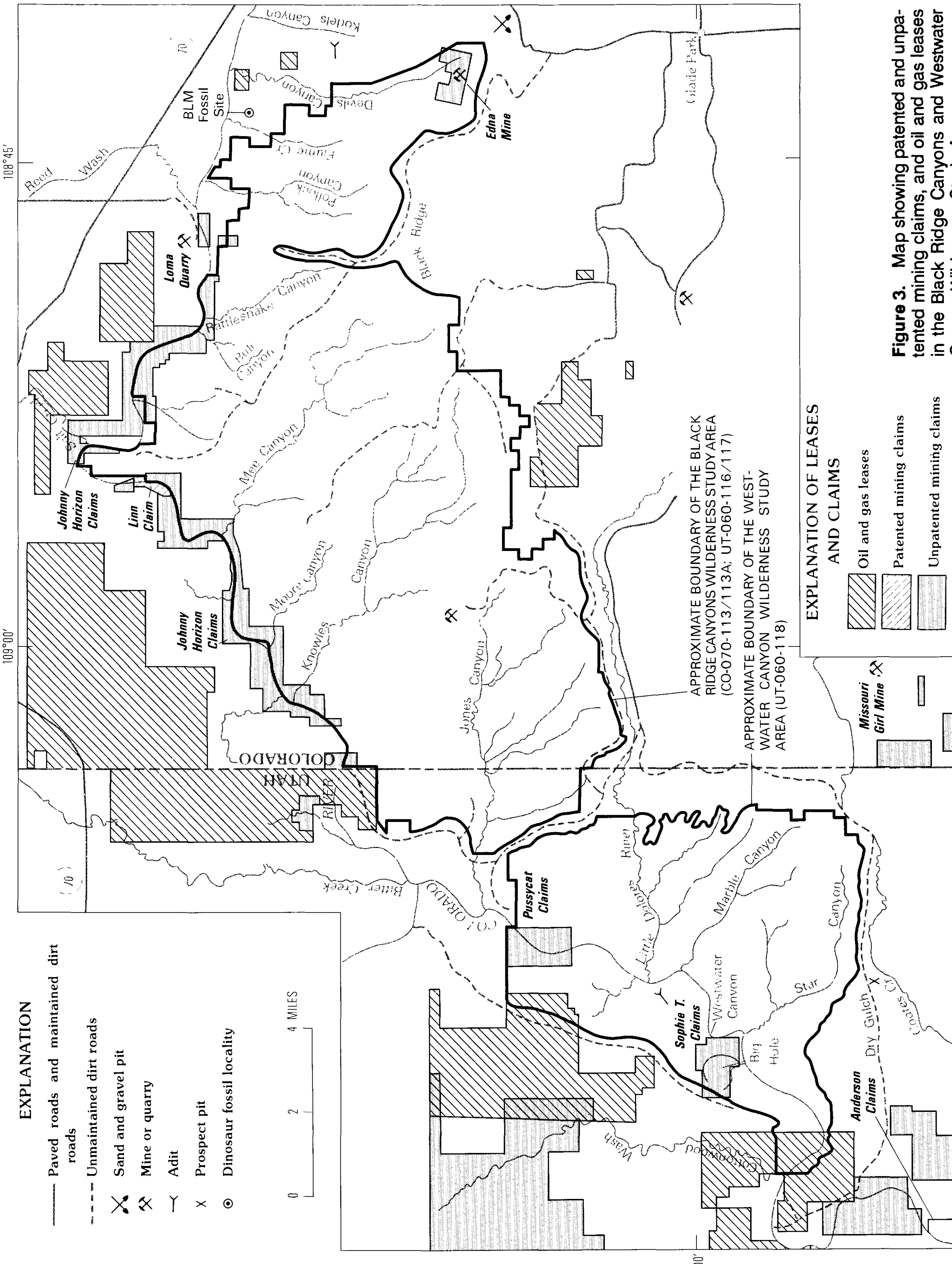

Figure 3. Map showing patented and unpatented mining claims, and oil and gas leases in the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas.

parts of the deposit could be worked economically by selective, low-capital-investment mining. A recovery test run suggests that sluicing will recover only about 59 percent of the gold. Employment of innovative methods such as flotation with the air-sparged hydrocyclone (Miller and others, 1986) in mining may improve recovery.

Other Placers

Other gravel bars occur along the Colorado River in both wilderness study areas (fig. 3); 36 of 59 samples collected from these placers contain gold, but most of the values of the contained gold are low—less than $0.50/cu yd. An accurate appraisal of these gravel bars could not be made due to the high water stage of spring runoff. At the time of the field investigation, most of the gravel bars were completely submerged, or nearly so, and could not be adequately sampled.

The Johnny Horizon placer claim group (fig. 3) includes many gravel bars of this type along the north end of the Black Ridge Canyons Wilderness Study Area. Placer samples collected there contain as much as $2.36/cu yd in gold, suggesting that economically viable sections of placer deposits might exist below the high water mark.

The Sophie T claims (fig. 3) are on small, thin gravel terraces in the Westwater Canyon Wilderness Study Area and contain small amounts of gold (generally less than $0.25/cu yd). Actual gold values on the Sophie T and other gravel terraces may be higher than samples indicate because the placers contain a high percentage of bentonitic clays and caliche. This mixture is difficult to disaggregate and it is likely that some of the gold adheres to the clay and caliche and is washed away during panning.

Placer claims were staked for gold between 1981 and 1985 on approximately 4 sq mi of land where Dry Gulch joins the Colorado River (fig. 3); some of these claims are adjacent to the Westwater Canyon Wilderness Study Area. Excavations have been made only at the Anderson claim group, most recently in the 1950's (Gerald Laughter, oral commun., Moab, Utah, 1986). No production is known from these placers, although USBM sampling at the Anderson group recovered gold. A search for possible sources of this placer gold was undertaken up Dry Gulch, along the Dry Gulch fault zone (pl. 1). Panned-concentrate, stream-sediment, and rock-chip samples were collected there; the only gold detected was trace amounts in silicified fractures. Those trace values probably do not contribute significantly to placer gold quantities present where the Dry Gulch fault zone, the Colorado River, and the staked placer claims coincide. The Dry Gulch fault zone is not considered to contain identified gold resources.

Lode Mineral Occurrences in Fractured Precambrian Rocks

No lode mineral resources were identified, although some fractures in the Precambrian rocks of both study areas contain minor concentrations of copper, gold, and silver. Excavations have been made in the Westwater Canyon Wilderness Study Area on occurrences of this type located 1,500 ft southeast of the Pussycat placer occurrences in the walls of Westwater Canyon, and on occurrences on the study area periphery along Dry Gulch (fig. 2). A similar occurrence in the Black Ridge Canyons Wilderness Study Area was prospected in Devils Canyon; another, in Kodels Canyon, is near the study area periphery (fig. 2). Occurrences are listed and analytical data are presented in Chatman (1987).

Of all these occurrences, the only ones that appear to be significant are the four silicified fractures along Dry Gulch that contain trace amounts of gold—they are partially within the Westwater Canyon Wilderness Study Area. The fractures occupy a zone about 400 ft wide and 2,400 ft long and trend north-northeast (pl. 1). The individual fractures, which are as much as 1,000 ft long and 12 ft wide, are probably related to the main part of the Dry Gulch fault zone, which lies 400–500 ft to the south. These fractures cut Precambrian biotite gneiss and amphibolite, scattered granitic dikes, and small mafic intrusive bodies. Thin barite veins (1 in. to 1 ft thick) fill short, randomly oriented fractures in the gneiss and amphibolite and locally cut the older siliceous fractures.

The barite veins, exposed in several shallow pits, contain fluorite and low concentrations of gold, silver, copper, and tungsten (pl. 1). The small size of these veins and the low metal values preclude consideration as an identified resource. Samples from the much larger silicified fracture zones, contain trace amounts of gold in 16 of 21 samples along with some anomalous barium, copper, and lead concentrations. Similar weakly mineralized fractures may be present in nearby Precambrian rocks which are covered by colluvium. Comparable gold values were detected in other, much smaller, silicified zones in Precambrian bedrock on the Pussycat claims.

Some intrusions into the Precambrian rocks of the Black Ridge Canyons study area carry weak metal concentrations (fig. 2), but none appear to contain resources: metapyroxenite in Marble Canyon carries 6 ppb (parts per billion) silver and a granitic dike in Rattlesnake Canyon carries 89 ppb gold. Silver (3 ppm or parts per million), along with 2.0 percent copper, has been reported in an aplite dike in Devils Canyon (Toth and others, 1983). Most other exposures of Precambrian rock sampled are barren, including those along the monocline and along the fault zone that disrupts Precambrian rocks between Rattlesnake Canyon and Devils Canyon; the fault trends N. 25–30° W. for over 20 mi, including a 7–8 mi stretch across the northern part of the Black Ridge Canyons Wilderness Study Area. It is the largest fault zone within the areas studied (Cashion, 1973; Schwochow, 1978; Toth and others, 1983). Samples collected along the fault zone have no significant metal concentrations, indicating that no mineralizing fluids had migrated into the study area along this fracture zone.

Weakly mineralized Precambrian fractures, with elevated copper concentrations, were prospected at the eastern end of the Dry Gulch fault zone, about 4 to 5 mi southeast of the Westwater Canyon Wilderness Study Area (pl. 1). One of the adits there is apparently part of the Missouri Girl mine (figs. 2, 3), where faulted Precambrian rocks were prospected for copper and silver as recently as 1966 (Schwochow, 1978). Production from these occurrences is unknown.

Oil and Gas

Neither study area contains identified oil and gas resources. Laramide-age folding north and west of the study areas provided traps, some of which were later filled by oil and gas from Paleozoic source rocks from below (Walton, 1956; Stone, 1977; Scanlon, 1983). Leases on extensive acreage adjacent to the study areas cover these traps (fig. 3). Oil and gas leases on about 15 percent of the Westwater Canyon Wilderness Study Area cover possible extensions of the "Greater Cisco" fields of eastern Utah (Brown and Ritzma, 1982). Drilling reportedly took place within "a quarter of a mile" of the western boundary of the Westwater Canyon Wilderness Study Area but resulted in dry holes (Oakes and others, 1982); hole locations were not determined for this study. Greater Cisco fields have yielded over 72,000 barrels of oil and 4.6 billion cu ft of gas from 1925 to 1978, in part from the Salt Wash Member of the Morrison Formation (Brown and Ritzma, 1980). The hydrocarbon source rocks of those fields were eroded from, or never deposited in, the study areas (Mahoney and Kunkel, 1963; Stearns and Jamison, 1977).

Stone and Rock Products

On the basis of USBM estimates and a calculated density of 4,200 lb/cu yd, about 7,000 short tons of Kayenta Formation flagstone have been quarried near Jones Canyon in the southern part of Black Ridge Canyons Wilderness Study Area (T. 11 S., R. 104 W.) (fig. 2). About 9,000 short tons of inferred reserves remain within the present quarry confines, provided the qualities of this stone remain consistent throughout the estimated 18-ft-thick reserve base. The exposed sandstone is pale red to buff. The flags are commonly 2 in. thick, but can range from ¼ to 3 in. Schwochow (1978) reports 1965 as the last year of quarry operations. Outcrops indicate that additional flagstone may exist south of the quarry. No additional identified stone resources were delineated in either study area.

Some rock formations that are present in both study areas have been quarried at locations outside the area boundaries. These include Kayenta Formation sandstone, extracted from the Loma quarry north of the Black Ridge Canyons Wilderness Study Area. The quarry, which supplied flagstone and curbstone, was last worked in 1962 (Schwochow, 1978). Other sources of building stone are the Wingate Sandstone, found extensively in both study areas, and Entrada Sandstone, found only in the Black Ridge Canyons Wilderness Study Area; because of distance to market and transportation costs, these are inferred as subeconomic. Both formations have been quarried at several sites within Mesa County, Colo. (Schwochow, 1978).

Precambrian granitic gneiss similar to that in both study areas is used for local road fill. The source quarry is probably one of several on Clark Wash, south of the Black Ridge Canyons Wilderness Study Area (pl. 1). Massive porphyritic Precambrian granite exposed in the bottoms of Knowles, Moore, Mee, and Rattlesnake Canyons in the Black Ridge Canyons Wilderness Study Area has ornamental qualities but its behavior in response to splitting and cutting is unknown. None has been quarried.

Cobblestones deposited along the Colorado River flood plain in the Black Ridge Canyons Wilderness Study Area constitute another possible stone resource; stone of this type has been used locally in construction of walls and foundations (Schwochow, 1978).

Sand and Gravel

Inferred subeconomic sand and gravel resources are present in the Black Ridge Canyons Wilderness Study Area (fig. 2). Sand and gravel has been deposited along the Colorado River flood plain almost continuously from Grand Junction westward to the head of Westwater Canyon, and there are several terrace gravel deposits as well along the river. Schwochow (1978) considers this entire zone underlain by resources of sand and gravel. None of this sand and gravel has been utilized, largely because the value is diminished by the distance to the Fruita-Grand Junction-Clifton, Colo., market area; transportation for hauling aggregates more than about 8 mi soon becomes cost-prohibitive (Schwochow, 1976). It is unlikely that sand and gravel within the terrace gravels identified by Schwochow (1978) are suitable for use because they have been cemented by caliche (a form of calcium carbonate), an impurity which is detrimental to the marketability of aggregate. A residual clay-and-sand mixture formed on an Entrada Sandstone bench was mined for low-grade fill material from a shallow pit less than a mile southeast of the Black Ridge Canyons Wilderness Study Area (pl. 1). Similar occurrences could exist within parts of the Black Ridge Canyons Wilderness Study Area underlain by the Entrada Sandstone, but none are known. There are few Entrada benches because the formation is usually a cliff-forming unit overlain by the Wanakah Formation.

Clay

No clay resources were identified in either study area. Butler (1914) suggested that in general, Morrison Formation clays might well be considered as a "low-grade clay" resource. There is no record of using Morrison Formation clays in the Grand Junction region as the main component of structural clay products (such as bricks); clays of the Mancos Shale apparently supply this need (Van Sant, 1959). No such common variety clays were found in the Morrison Formation of the Black Ridge Canyons Wilderness Study Area; the Morrison Formation is not present in the Westwater Canyon Wilderness Study Area.

Bentonite from the Morrison Formation has been mined from two pits about 9 mi southeast of the Black Ridge Canyons Wilderness Study Area and used as canal liner and as a brick coloration additive (Van Sant, 1959; Schwochow, 1981). No high-quality bentonites were observed in either study area. Analysis of one 24-ft-thick bentonitic horizon in the Black Ridge Canyons Wilderness Study Area shows that smectite clays (montmorillonite) comprise only about one-fourth of the bulk sample (Chatman, 1987). The calcium level is high, indicating that the material is nonswelling for industrial purposes. Quartz, a deleterious impurity in bentonites, is a major component.

Gem Stones and Fossils

Semiprecious silica gem stones reported in the vicinity of the study areas include opalized and agatized fossils, jasper, and vein opal (Sinkankas, 1959; Schwochow, 1978). No collecting localities are known within the study area boundaries, but some may occur in the uppermost part of the Morrison Formation. A locality was reported in the southwesternmost corner of the Westwater Canyon Wilderness Study Area (Dasch, 1964) but apparently its location was misplotted in the reference.

Vertebrate fossils may exist in the Morrison Formation section of the Black Ridge Canyons Wilderness Study Area, though none were found. Regionally, the Morrison Formation is one of the most prolific sources of dinosaur remains (Schwochow, 1978), and a fossil locality maintained by the BLM exists about ½ mi northeast of the Black Ridge Canyons Wilderness Study Area (fig. 2).

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

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Geology

Geologic Setting

The Black Ridge Canyons and Westwater Canyon Wilderness Study Areas are on the north and west sides of the Uncompahgre Plateau. The study areas contain igneous and metamorphic rocks of Precambrian age and flat-lying sedimentary rocks of Mesozoic age. The sedimentary rocks are folded as monoclines, or locally faulted, along northwest-trending normal faults that originate in the Precambrian basement.

The Precambrian rocks of the study areas (pl. 1) consist of Early and Middle Proterozoic age metamorphic rocks (amphibolitic gneiss, amphibolite, gneissic granodiorite, metadiorite, metapyroxenite) and quartz monzonite; they contain local concentrations of gold, silver, copper, and barite. The Precambrian rocks are exposed in the bottoms of most of the deeper canyons. The complexly folded gneisses and amphibolites are of probable sedimentary and volcanic origin (Case, 1966). During periods of deformation these gneisses were intruded by granodiorite in the vicinity of Coates Creek, Little Dolores River, Mee Canyon, and Knowles Canyon. A metadiorite pluton is exposed in Marble Canyon and lower Little Dolores River Canyon, and small ultramafic plugs and dikes occur in upper Westwater Canyon (Case, 1966; Hedge and others, 1968; Case and Joesting, 1972; Toth and others, 1983).

Pegmatite dikes containing feldspar, quartz, hornblende, and tourmaline are scattered throughout the Proterozoic terrane of the study areas. Copper, lead, and silver are sparsely disseminated in Proterozoic age aplitic float in a small area in Devils Canyon, and a felsite dike containing trace amounts of gold occurs in Rattlesnake Canyon in the Black Ridge Canyons Wilderness Study Area. Three adits located in shear zones and dikes in the Proterozoic gneiss were examined in Westwater Canyon and found to contain weakly altered and sparsely mineralized rocks. In Dry Gulch, adjacent to the southern boundary of the Westwater Canyon Wilderness Study Area, there are four silicified fracture zones containing barite, fluorite, and trace amounts of gold. In upper Westwater Canyon an outcrop of metapyroxenite cut by fracture zones and felsite dikes has anomalous concentrations of gold, barite, and copper. High concentrations of chromium and nickel are also present in these ultramafic rocks, but not in amounts considered abnormal for this rock type. No other indication of mineralization has been observed in Proterozoic-age rocks of the study areas.

Mesozoic-age rocks of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas include the Chinle Formation of Late Triassic age, the Wingate Sandstone, Kayenta Formation, Entrada Sandstone, Wanakah and Morrison Formations of Jurassic age (Peterson and Pipiringos, 1979), and the Burro Canyon Formation and Dakota Sandstone of Cretaceous age. Although the Glen Canyon Group (Wingate Sandstone, Kayenta Formation, and Navajo Sandstone) has been assigned in part to the Triassic by numerous authors (Hackman, 1959; Lohman, 1965; Cashion, 1973; Heyman, 1983; Toth and others, 1983), this report follows Pipiringos and O'Sullivan (1978) and Peterson and Pipiringos (1979) in assigning the Glen Canyon Group to the Lower Jurassic. These rocks occur as flat-lying beds on top of the Precambrian basement, except where they are folded over basement faults or are themselves faulted.

In the lower part of Devils Canyon, in the eastern part of the Black Ridge Canyons Wilderness Study Area, copper has been localized in a paleochannel at the base of the Upper Triassic Chinle Formation (pl. 1). A channel-fill conglomerate at the base of the Chinle Formation in Mee Canyon was found to contain anomalous amounts of copper, lead, silver, arsenic, barium, and molybdenum. The Edna uranium mine is located near the head of Devils Canyon in a carbonaceous channel sandstone in the Upper Jurassic Morrison Formation (Toth and others, 1983; Chatman, 1987). No other mineralized areas were observed in Mesozoic-age rocks in the study areas.

Recent deposits of unconsolidated to fairly well cemented fluvial sand and gravel occur in the canyon bottoms adjacent to the Colorado River and on benches overlooking it. Some of these gravel deposits, located at the head of Westwater Canyon, have been worked for placer gold. There are also placer claims along the Colorado River north of the Black Ridge Canyons Wilderness Study Area, between Pollack and Rattlesnake Canyons.

The structure of the Uncompahgre Plateau is that of a large fault block that has been uplifted thousands of feet and cut by several subordinate faults. The plateau is bounded on the northeast and southwest by northwest-trending normal faults, high-angle reverse faults, and monoclines. These faults parallel other major structures in the region and may be controlled by crustal weaknesses dating from Precambrian time (Stone, 1977; Baars and Steven, 1981; Toth and others, 1983). On the southwest side of the Uncompahgre Plateau, the Uncompahgre fault has thrust Proterozoic rocks southwestward over the Paleozoic rocks at depth (Frahme and Vaughn, 1983).

Several of the subordinate faults on the Uncompahgre Plateau modify the landscape of the wilderness study areas (pl. 1). The Flume Creek fault and Rattlesnake monocline are in the northernmost part of the Black Ridge Canyons Wilderness Study Area and trend west-northwest. There is 300 ft of displacement on the north-dipping Flume Creek fault in the vicinity of Pollack Canyon. The Flume Creek monocline lies about 2 mi north of the Flume Creek fault, dips 21° to the north, and dies out to the northwest and southeast. West of Rattlesnake Canyon the Flume Creek fault turns into the Rattlesnake monocline and dips 35° to the north. In the vicinity of Rattlesnake Canyon the Bull Canyon fault splays off to the west, disappears beneath slumped mudstones of the Morrison Formation, and reappears at the Colorado River near Mee Canyon. The Black Rocks monocline lies southwest of the Bull Canyon fault. This monocline trends west-northwest and dips 17–25° to the north. The Little Dolores River fault, also trending west-northwest, displays 450 ft of displacement on the north side of Snyder Mesa, but dies out a few miles to the northwest. Just south of the Westwater Canyon Wilderness Study Area, along Coates Creek and Dry Gulch, are the east-west-trending Dry Gulch and Coates Creek fault zones. Whereas all faults north of here are down to the north with little or no brecciation, the Dry Gulch fault is down to the south, and exhibits a brecciated zone several yards wide, with modest amounts of silica, calcite, and barite present.

The geologic history of the Uncompahgre Plateau is one of periodic uplift and erosion, followed by deposition of terrestrial and marine sedimentary rocks. This pattern of erosion and deposition has dictated what mineral resources can occur on the plateau. The uplift of the Ancestral Uncompahgre Highland during Pennsylvanian time shed detritus westward into the Paradox basin, and removed all potential Paleozoic petroleum source rocks from the highland. The Ancestral Uncompahgre Highland was eventually worn down to a low-lying peneplane of Precambrian rocks. The Precambrian surface was buried during Late Triassic time by sediments of the Chinle Formation (Stone, 1977; Toth and others, 1983). The Chinle Formation is much thicker west of the Uncompahgre Plateau, where uranium deposits occur in the channel sandstones of the lower part. During Early and Middle Jurassic time eolian, fluvial, and marine sediments of the Wingate, Kayenta, Entrada, and Wanakah Formations were deposited. Although these formations make adequate reservoir rocks for oil and gas in many parts of the Colorado Plateau, they are exposed at the surface by erosion, incised by canyons, and are far from source rocks so that they are not petroleum bearing on the Uncompahgre Plateau. During Late Jurassic and Cretaceous time, the Morrison Formation, Burro Canyon Formation, and Dakota Sandstone were deposited in a low-lying terrestrial environment, with volcanic activity supplying material from the west (Craig and others, 1955; Toth and others, 1983). This volcanic material is believed to have been the source of the uranium that has been concentrated in channel sandstones in the lower part of the Morrison Formation (Finch, 1967; Thamm and others, 1981). Younger formations have been removed from the study areas by erosion (Lohman, 1965). During the Laramide orogeny, 70–35 m.y. ago, there was recurring dip-slip and reverse movement on the major boundary faults and minor faults in the study areas. This activity folded and faulted the Mesozoic age sedimentary rocks and in some instances thrust Precambrian crystalline rocks over the sedimentary rocks of the adjacent Paradox basin (Stearns and Jamison, 1977; Frahme and Vaughn, 1983; Heymen, 1983). Continued uplift of the Uncompahgre Plateau occurred as the Colorado River established its present course, depositing river gravels derived, in part, from the gold-producing districts further upstream (Hunt, 1956; Lohman, 1965).

Description of Rock Units

All unit symbols below refer to plate 1.

Early and Middle Proterozoic crystalline rocks (unit YXm).—For the purposes of this study the Proterozoic rocks are largely undivided, except for some metapyroxenite bodies that were mapped separately. They consist of layered gneisses ranging from lighter colored felsic to darker colored mafic gneiss and amphibolite. The felsic gneiss is composed of quartz, plagioclase, potassium feldspar, biotite, and garnet. The mafic gneiss and amphibolite contain principally hornblende and biotite, some plagioclase, and accessory magnetite, apatite, and sphene. The gneiss is medium grained and well foliated, and contains migmatitic layers of quartz and occasional augens of quartz and feldspar. These rocks were intruded by quartz monzonite, diorite, some pegmatite, and small local bodies of ultramafic rocks. The quartz monzonite is medium to coarse grained, porphyritic, and often foliated; it contains quartz, potassium feldspar (phenocrysts as long as 2 in.), plagioclase, and biotite. The diorite is medium grained and contains hornblende, biotite, plagioclase, and quartz. The pegmatite dikes typically contain quartz, potassium feldspar, plagioclase, muscovite, biotite, and hornblende, and they may exhibit simple zoning.

Early and Middle Proterozoic metapyroxenite (unit YXp).—This unit has been mapped separately only in the Westwater Canyon Wilderness Study Area. It consists of small bodies of ultramafic rocks that have largely been converted to hornblendite. The green hornblende contains occasional cores of pyroxene.

There is often a red weathered zone 1–5 ft thick at the top of the Proterozoic rocks. Proterozoic intrusive rocks in and near the study areas have been variously dated at 1670, 1630, and 1480 Ma (age in millions of years) and are not much younger than the host gneisses (Hedge and others, 1968).

Upper Triassic Chinle Formation (unit ŦRc).—This slope-forming unit nonconformably overlies the Proterozoic rocks and consists of red siltstone and thin layers of fine-grained sandstone and one layer of pink and gray limestone. Occasionally this formation contains basal, conglomeratic, channel sandstones. Within the study areas this formation varies between 25–60 ft thick, thickening to the northeast.

Lower Jurassic Wingate Sandstone (unit Jw).—This unit is a buff-colored, massively crossbedded, well-sorted, eolian sandstone that forms cliffs throughout the study areas. It unconformably overlies the Chinle Formation and is about 350 ft thick.

Lower Jurassic Kayenta Formation (unit Jk).—Conformably overlying the Wingate Sandstone, the Kayenta Formation consists of a buff-colored, coarse-grained, crossbedded, fluvial sandstone about 110 ft thick. It forms ledgy slopes and overhangs above the Wingate Sandstone. Within the study areas the Kayenta Formation forms broad, flat surfaces upon which may occur Quaternary sand deposits.

Middle Jurassic Entrada Sandstone (unit Je).—This unit is a salmon- to white-colored, fine-grained, crossbedded, eolian sandstone with horizontal bedding near the top. The Entrada Sandstone often forms cliffs and arches in the study areas. It varies widely in thickness but is about 145 to 200 ft thick in the study areas. It is in unconformable contact with the Kayenta Formation below and the Wanakah Formation above.

Middle Jurassic Wanakah Formation and Upper Jurassic Tidwell and Salt Wash Members of the Morrison Formation, undivided (unit Jms).—At the base of the unit is the Wanakah Formation, highly variable in thickness (5–20 ft thick in the study areas) and consisting of thinly bedded, fine-grained, red, buff, and yellow sandstone and shale. Although most previous workers have called this the Summerville Formation in the area of the Uncompahgre Plateau, O'Sullivan (1980, 1981, 1983) has demonstrated that the Summerville Formation pinches out beneath a regional unconformity southeast of

Moab, Utah; the finely laminated mudstones east of Kane Springs, Utah, belong to the Wanakah Formation. Other workers have found that what is mapped as the Summerville Formation in the Colorado National Monument is laterally continuous with the Wanakah Formation to the south (Charles G. Patterson, personal commun. 1986). The Morrison Formation unconformably overlies the Wanakah Formation. The lowest part of the Morrison Formation is the flat-bedded, fine-grained sandstone, mudstone, and nodular limestone of the Tidwell Member. Above this transition zone, the Salt Wash Member is a series of crossbedded, poorly sorted, buff-colored, channel sandstones, and variegated red, gray, and green mudstones. The channel sandstones are more continuous near the bottom than at the top and may contain carbonaceous debris. This unit is 350–370 ft thick and forms steep slopes, benches, and small cliffs.

Upper Jurassic Brushy Basin Member of the Morrison Formation (unit Jmbb)—The Salt Wash Member grades upward into the Brushy Basin Member, a gray, green, red, purple, and brown bentonitic mudstone that contains occasional thin, discontinuous channel sandstone bodies. A few multicolored chert pebble conglomerates and silicified plant and vertebrate remains may also be present. In this report the contact between the top of the Salt Wash Member and the bottom of the Brushy Basin Member is put at the top of the youngest, widely persistent sandstone. This member is about 500 ft thick and may exhibit a hummocky mudflow topography, as slope failure is common.

Lower Cretaceous Burro Canyon Formation and Upper Cretaceous Dakota Sandstone, undivided (unit Kdb)—The Burro Canyon Formation is a white to gray, thickly bedded to massive sandstone with interbedded green siltstone and mudstone. The Dakota Sandstone unconformably overlies the Burro Canyon Formation. It consists of buff- and gray-colored sandstone, interbedded gray to black carbonaceous shale, and thin, discontinuous coal seams. The two formations taken together are about 140 ft thick at their maximum in the study areas.

Quaternary surficial deposits (units Qrf, Qls, and Qal)—These deposits include rock fall deposits (Qrf), landslide and mudflow deposits (Qls), and alluvium and colluvium (Qal) of Pleistocene and Holocene age. Quaternary sand deposits on the Kayenta surface may be in situ weathered or wind deposited. For simplicity these sand deposits are usually lumped together on the map with the Kayenta Formation, except where they are thick enough to partially or completely obscure the underlying Entrada Sandstone, in which case they are mapped as Qal.

Geochemistry

Methods

A reconnaissance geochemical survey was conducted in the Westwater Canyon and Black Ridge Canyons Wilderness Study Areas during the summer of 1986. Minus-80-mesh stream sediments and heavy-mineral concentrates derived from stream sediments were selected as the primary sample media. Stream-sediment samples represent a composite of rock and soil exposed in the drainage basin upstream. Chemical analysis of the stream sediments may provide information that could identify basins containing unusually high concentrations of elements that may be related to mineral occurrences.

Chemical analysis of heavy minerals concentrated from stream sediments provides information about the chemistry of high-density, resistant minerals eroded from the drainage basin upstream. The removal of most of the rock-forming silicates, clays, and organic material permits the determination of elements in the concentrate that are not generally detectable in bulk stream sediments by the analytical methods available. Some of these elements can be constituents of minerals related to ore-forming processes rather than of rock-forming minerals. These can include sulfide and oxide minerals as well as gold, barite, and scheelite.

Stream-sediment samples and panned concentrates were collected from active alluvium at 58 stream sites. Rock which appeared unaltered was collected to provide information on geochemical background values. Altered and mineralized rock samples were collected and analyzed. A gamma-radiation detector was used to determine radiation levels at all sampling sites as an indication of possible uranium or thorium mineralization.

Stream-sediment samples were prepared for analysis by sieving through 80-mesh stainless-steel sieves; that portion passing through was saved for analysis. To produce the heavy-mineral concentrates, bulk stream sediment was sieved through a 10-mesh screen, and approximately 10 pounds of the finer material was panned to remove most of the quartz, feldspar, organic materials, and clay. The panned concentrate was separated in the laboratory into light and heavy fractions using bromoform (heavy liquid, specific gravity 2.8). Material of a specific gravity greater than 2.8 was then separated on the basis of magnetic properties, and only the nonmagnetic portion was analyzed.

Stream-sediment, heavy-mineral concentrate, and rock samples were analyzed for 31 elements using a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968). In addition, stream sediment was analyzed for arsenic, antimony, bismuth, cadmium, gold, uranium, and zinc by specific chemical methods (Crock and others, 1987).

Results

Anomalous values are defined for this report as being any element concentration above the upper limit of background values. These were determined for each element by inspection of the analytical data rather than by statistical techniques. For some elements in certain environments (silver, arsenic, gold, bismuth, cadmium, molybdenum, antimony, tin, tungsten, thorium, uranium) any occurrences above the detection limit could be anomalous.

Geochemical sampling confirmed the presence of placer gold along the Colorado River, and revealed altered rocks on top of the Precambrian basement in Mee Canyon to be enriched in arsenic, barium, copper, lead, molybdenum, and silver. Concentrate from an unnamed north-flowing tributary near its confluence with Jones Canyon, approximately 1.8 mi east of the Colorado River in the Black Ridge Canyons Wilderness Study Area (pl. 1), contains 30 ppm gold. The stream sample site is located in alluvium deposited by the Colorado River. Enrichment of copper, lead, silver, barium, arsenic, and molybdenum in sedimentary rocks overlying the Precambrian rocks is indicated by rock samples taken from a site approximately 1.0 mi upstream (southwest) in Mee Canyon from its confluence with the Colorado River (pl. 1). The Mesozoic sedimentary rocks nonconformably overlying Precambrian gneiss showed visible alteration and copper mineralization near the contact. One basal conglomerate sample contained the following anomalous element concentrations (ppm): arsenic 200, barium greater than 5000, copper greater than 20,000, lead 30, molybdenum 20, and silver 20. No anomalous values were detected in either stream-sediment samples or heavy-mineral concentrate samples of stream sediments taken in tributaries near Mee Canyon. Anomalous amounts of barium, copper, strontium, manganese, vanadium, molybdenum, silver, and lead for rocks of this type are associated with metapyroxene bodies located north of the confluence of the Little Dolores River and the Colorado River (J.E. Case, written commun., 1987).

Although the Morrison Formation, which is known to contain uranium deposits elsewhere, does crop out in parts of the study areas, no detectable amounts of uranium were found in any of the sample media, nor were any anomalous gamma radiation levels observed.

Geophysics

Methods

Gravity (fig. 4) and magnetic (fig. 5) surveys were conducted over the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas to provide information about the distribution of exposed and concealed Precambrian rocks and about the thickness and structure of the sedimentary rocks of the northwestern part of the Uncompahgre uplift and vicinity. The geophysical data also assist in determining the amount of structural relief across the faulted northeastern and southwestern flanks of the uplift. The geophysical data may be pertinent to evaluation of the potential for metallic and oil and gas resources of the study area.

Gravity and magnetic data were collected in several stages. In the western part of the study areas (west of 109° W.) gravity and magnetic surveys were made as part of the Colorado Plateau Regional Studies project, and the data and interpretations were included in reports by Case (1966) and Case and Joesting (1972). For the Black Ridge Canyons Wilderness Study Area, new aeromagnetic surveys were flown in 1985 (U.S. Geological Survey, 1987). Additional gravity surveys were made in 1986 in both the Black Ridge Canyons and the Westwater Canyon Wilderness Study Areas. Gravity and magnetic maps for this report have been compiled at 1:250,000 scale (figs. 4, 5).

Airborne magnetic surveys were flown in 1956–1958 over the area west of 109° W. Flight lines were spaced about 1 to 2 mi apart on east-west lines at a barometric elevation of 8,500 ft above mean sea level, using a fluxgate magnetometer. The surveys between 108°42' W. and 109°02' W. were flown in 1985 at about 500 ft above the mean terrain along lines spaced 0.5 mi apart using a proton-precession magnetometer enhanced by a horizontal gradiometer.

A magnetic survey of part of the area was flown at about 400 ft above the surface as part of the National Uranium Resource Evaluation (NURE) program, and the results were interpreted in terms of basement lineaments (Johnson, 1983). The surveys were flown along flight lines spaced at about 3 mi, and substantial differences occur between the contour maps of the NURE data and the maps of this report, which are based on more closely spaced data.

Earlier gravity surveys were made in 1962–63 using a Worden gravity meter[1]; altimetric surveys, photogrammetric spot elevations, and a few benchmarks provided elevation control. Gravity surveys in 1986 were made using a LaCoste & Romberg gravity meter. Both old and new surveys were reduced using standard procedures; the gravity map (fig. 4) uses a reduction density of 2.67

[1]The use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

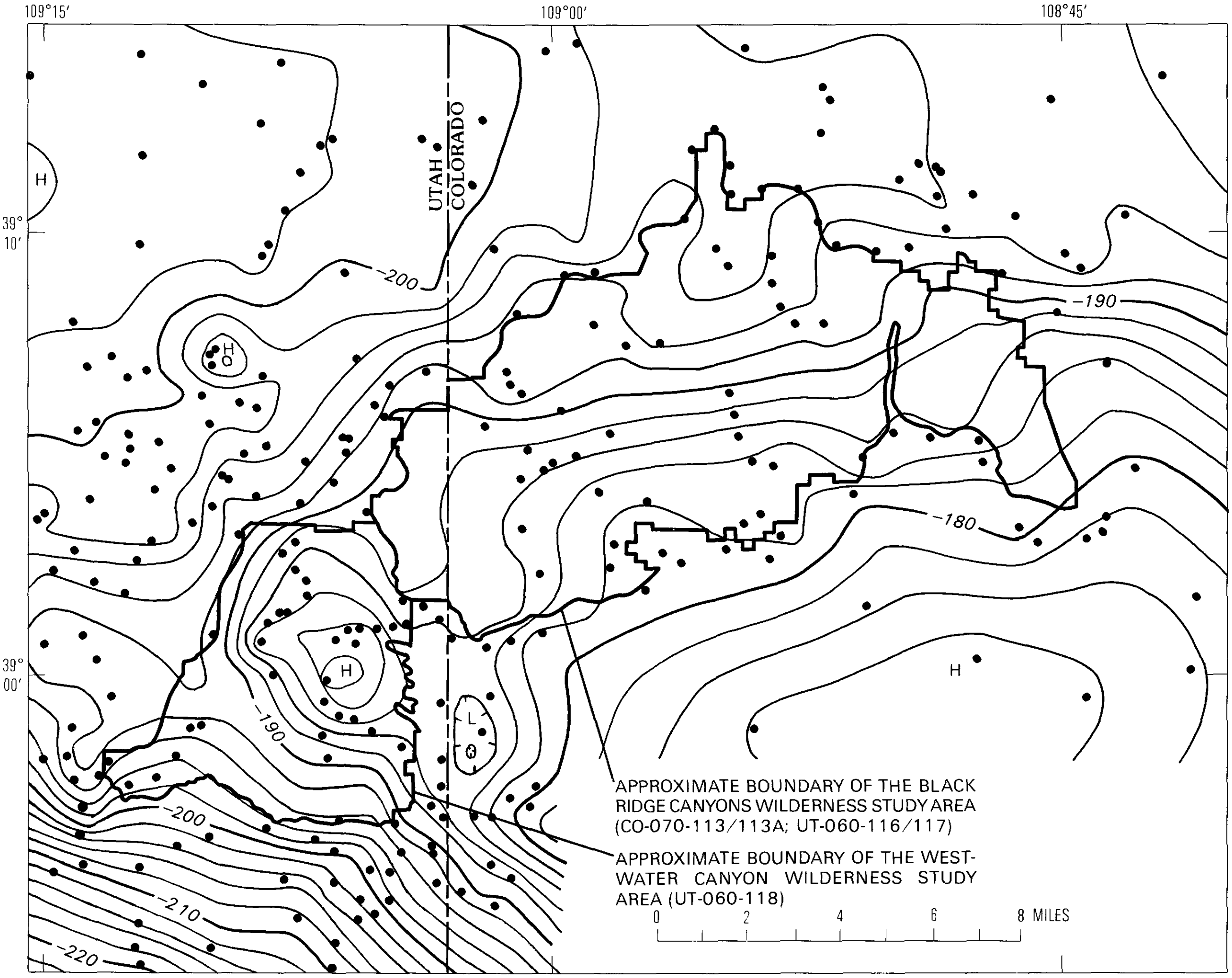

Figure 4. Bouguer gravity anomaly map of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas, Colorado and Utah. Gravity data compiled at a reduction density of 2.67 g/cm^3; gravity measurements observed at each station are reduced by standard procedures. Terrain corrections applied to a radius of 100 miles. Contour interval is 2 milligals; L = gravity lows, H = gravity high, dots are gravity stations. Scale = 1:200,000.

grams/cubic centimeter. Terrain corrections were applied for distances of ¼ to 100 mi from the station. Principal facts for the gravity survey have been released in open-files (Morin, 1987).

A remote-sensing investigation was undertaken in support of the mineral resource assessment of the wilderness study areas. Anticipated potential resources were metallic mineral deposits, uranium, and oil and gas. Landsat Multispectral Scanner (MSS) imagery data were acquired and processed to map variations in limonite. The images were used to target possible hydrothermal alteration associated with mineralization, or limonite anomalies presumably associated with either uranium deposition or oil and gas seepage. Landsat images were also used as the basis of a lineament analysis that covered a large area of western Colorado and eastern Utah. Linear features mapped on the images were interpreted to derive longer lineaments. Lineaments were interpreted, along with geophysical surveys and deep-drilling data, for possible basement structures. The methods used are described more fully in Lee (1987).

Results

Bouguer gravity anomalies range from maximum values of about minus 174 mGals (milligals) over the crest of the uplift in the Glade Park area, to minimum values of about minus 222 mGals in the southwest part of the study area, in the direction of the Paradox basin (figs. 1, 4). To the northeast, values range from about minus 198 to minus 202 mGals in Grand Valley. Most of this relief in the gravity field is attributed to relief on the Precambrian surface, because the Precambrian rocks are denser than the Mesozoic strata. Additionally, the more negative values in the Paradox basin are attributed partly

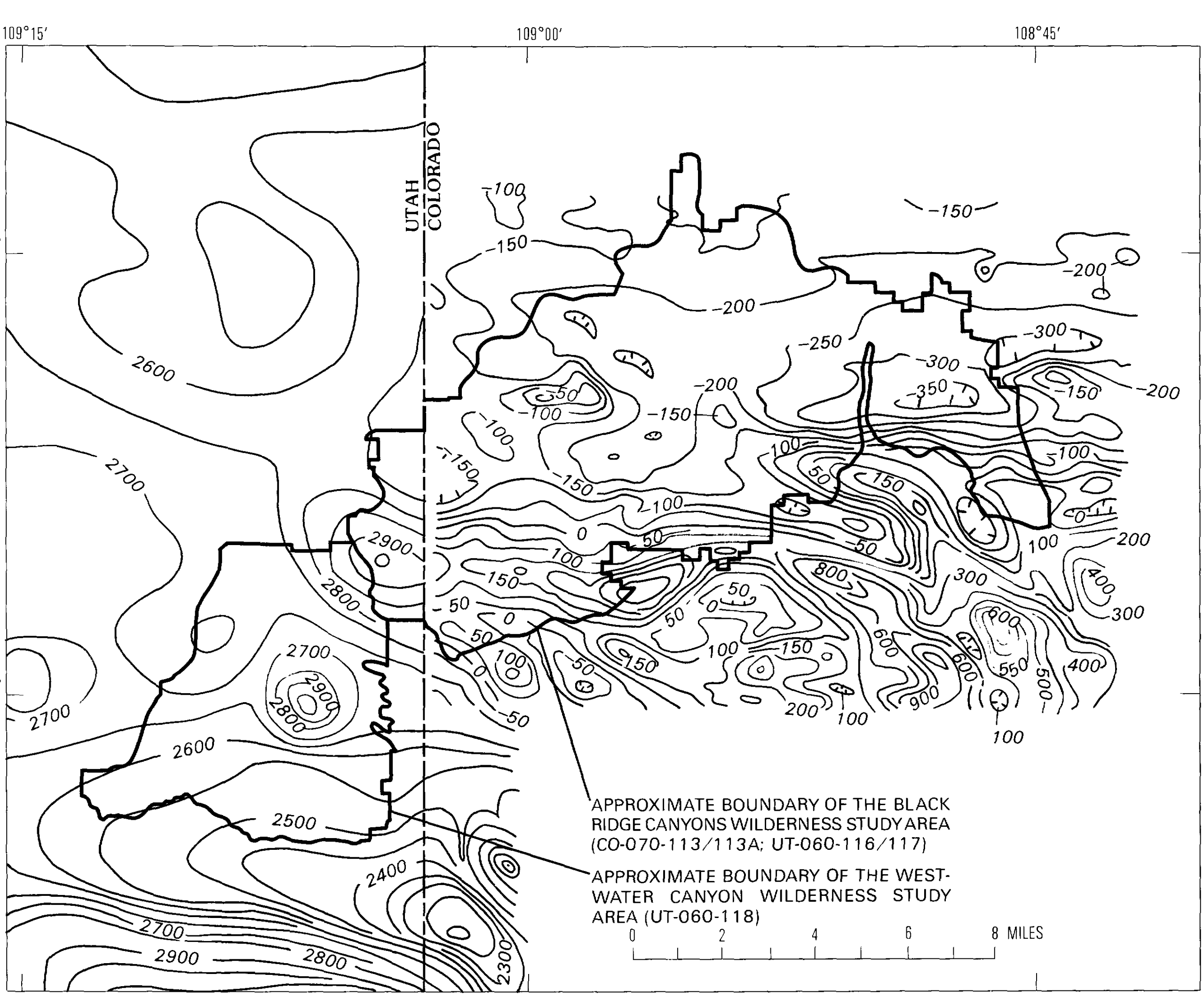

Figure 5. Residual total-intensity aeromagnetic anomaly map of the Black Ridge Canyons and Westwater Canyons Wilderness Study Areas, Colorado and Utah. Magnetic surveys of part of the area east of 109° 02′ were flown in 1985, west of 109° in 1956–1958. Contour interval 50, 100, and 500 gammas; hachures indicate closed area of relative low. Scale = 1:200,000.

to the low-density evaporites of the Middle Pennsylvanian Paradox Member of the Hermosa Formation.

Two local gravity highs are superimposed on the main high of the uplift; a pluton, composed of metagabbro and metadiorite, near the center of the Westwater Canyon Wilderness Study Area causes a residual positive anomaly of 4 to 8 mGals, depending on choice of regional field. The body, which is about 2 mi in diameter, also produces a magnetic high. Farther northwest, a gravity high of 3 to 4 mGals near 39° N., 109°14' W. is interpreted as being caused by a small, concealed mafic pluton because of its associated ovoid gravity and magnetic anomalies.

A major regional zone of steepened gravity gradient trends northwest, parallel to the southwestern flank of the Uncompahgre Plateau. The gravity relief of about 50 mGals from the Paradox basin to the crest of the uplift can be attributed to three main factors: (1) structural relief of about 16,000 to 20,000 ft from the axis of the Paradox basin to the crest of the uplift, (2) wedge-out of about 4,000 ft of Pennsylvanian evaporites of low density against the late Paleozoic Uncompahgre front, and (3) presence of relatively dense rocks near the crestal region of the uplift, corresponding to the gneissic granodiorite, amphibolite, and amphibolitic gneiss within the metamorphic sequence (Case, 1966). Gravity data, as well as magnetic data, indicate that the buried late Paleozoic front is relatively steep. A model based on these gravity and magnetic data (Case, 1966), as well as seismic data (Frahme and Vaughn, 1983) show a relatively simple planar interface between the Precambrian basement and the adjacent sedimentary rocks; however, the steep gravity gradient across the front can also be matched by models in which either a set of steeply dipping, high-angle normal faults or a set of distributive reverse faults are present at depth (see also White and Jacobson, 1983). Fifteen miles west of the area discussed here, the Mobil No. 1 McCormick Federal "C" (sec. 11, T. 21 S., R. 22 E., Grand County, Utah) penetrated a reverse fault by drilling through 14,000 ft of Precambrian granite before encountering at least 1,702 ft of Paleozoic sedimentary rocks beneath the granite (Frahme and Vaughn, 1983).

The Phanerozoic rocks of the area are effectively nonmagnetic as observed at a distance of 500 ft or more above them, so that virtually all magnetic anomalies arise from sources within the Precambrian rocks (Case and Joesting, 1972). The newer magnetic surveys of the Black Ridge Canyons Wilderness Study Areas (fig. 5) are characterized by a series of northwest- to west-trending magnetic highs of 300 to more than 1,000 gammas in amplitude. Few of these highs correspond with gravity highs, within the limits of the rather widely spaced gravity data, so that basement rocks of average density and moderate to high magnetization produce most of the anomalies. The best candidate for a source of these magnetic highs is the Vernal Mesa(?) Quartz Monzonite, which produces magnetic highs but no gravity anomalies in adjacent areas south of the study areas where these rocks are exposed (Case, 1966).

A very large, relatively high magnetic anomaly of 1,500 gammas or more, just east of the Utah-Colorado border near 38°56' N., 108°58' W. (fig. 5), has a largely concealed source, but small exposures of amphibolite-rich rock occur there. A large, ovoid, magnetite-rich lamprophyre or metapyroxenite body is postulated as a source for the anomaly (Case, 1966). A relatively high magnetic anomaly of about 300 to 400 gammas, as observed at about 3,000 ft above the source, is produced by the pluton near the center of the Westwater Canyon Wilderness Study Area. An ovoid outline of the pluton is indicated by the shape of the magnetic anomaly, locations of exposed outcrops, and by the general position of the residual gravity high associated with it. Low amplitude ovoid magnetic highs just to the west may also be produced by metagabbro and metadiorite bodies at shallow depth.

Regional gravity and magnetic anomalies have three principal uses in mineral resource assessments of the Black Ridge Canyons and Westwater Canyon Wilderness Study Areas: (1) to provide a better definition of regional geology beneath the cover of the Phanerozoic sedimentary rocks, (2) to provide data on the thickness and structure of the sedimentary rocks, pertinent to the potential for oil and gas resources, and (3) to characterize the geophysical setting of known metallic ore deposits and prospects with respect to Precambrian rock types. Prospect pits occur in metapyroxenite bodies north of the junction of the Little Dolores River with the Colorado River (pl. 1). These bodies have no associated gravity or magnetic anomalies at the scale of this investigation.

Paleozoic sedimentary rocks, potential hosts for oil and gas, occur beneath reverse faults along the southwestern flank of the Uncompahgre uplift (Frahme and Vaughn, 1983), and it might be speculated that they occur at great depth beneath the Westwater Canyon Wilderness Study Area. However, the reverse faults are high angle according to drill and geophysical data, and their trace is at least 5–10 mi west of the Westwater Canyon area. The presence of Paleozoic strata at depth beneath the area is considered unlikely. Over most of the Westwater Canyon and Black Ridge Canyons Wilderness Study Areas the preserved Mesozoic rock sequence is so thin (1,000 ft or less) that gravity and magnetic highs are caused principally by bodies within the Precambrian basement rather than by local structural relief of Mesozoic rocks.

The Black Ridge Canyons Wilderness Study Area is on one of the major lineaments that lies along the eastern boundary of the modern Uncompahgre Plateau. A basement fault has long been recognized to the southeast in the nearby Colorado National Monument. Here Precambrian rocks exposed at the surface are offset along high-angle, down-to-the-northeast faults. This surface faulting appears to diminish to the northwest, where the faults occur at greater depth and pass upward into monoclines. From lineament analysis, it appears this same fault system continues into the wilderness study area. From interpretation of Landsat data, no indication of hydrothermal alteration is apparent along it. No limonite anomaly, here interpreted as redox alteration, is found that can be related to migrating oil and gas, nor are any limonite anomalies noted that might be associated with uranium deposition. Most of the outcrops of interest are narrow with respect to the Landsat imagery resolution, and such anomalies would probably go undetected. These results are discussed more fully in Lee (1987).

Mineral and Energy Resource Potential

Uranium Deposits in the Salt Wash Member of the Morrison Formation

The model.—The Salt Wash Member may locally contain rocks deposited in a lacustrine environment or low- or high-energy fluvial environment. Regionally, uranium deposits in the Salt Wash Member occur along the following features: (1) depositional axes where the sandstones thicken, usually in the high-energy fluvial facies, (2) at local or regional redox boundaries between reduced and oxidized environments, (3) and down stream from local sedimentary paleobasins where the humate-generating favorable gray mudstones may have formed (McKay, 1955; Shawe, 1962; Peterson, 1980). These mudstones are associated with many uranium deposits in the Salt Wash Member and are believed to have generated humates that caused the uranium to precipitate out of solution (Peterson, 1980).

The Edna mine lies within the Black Ridge Canyons Wilderness Study Area in western Colorado and is typical of uranium deposits within the Salt Wash Member of the Morrison Formation. The following description is modified from Toth and others (1983). The mine workings are located near the head of Devils Canyon in a basal channel sandstone of the Salt Wash Member. The channel is 65 ft long by 23 ft thick and broadly lenticular. It consists of smaller crossbedded cut and fill units. The mineralized layer is localized along the base of a carbonaceous channel-fill sequence that contains fossil logs as much as 8 in. in diameter and is directly below a humate-generating favorable gray mudstone.

The ore consists of carnotite, vanadium micas, and possibly oxide and silicate uranium minerals distributed along bedding planes and joint surfaces. Concentrations of uranium ore minerals along bedding planes gave radiation levels of nearly 30 times background but covered less than 1 sq ft in area. At the Edna mine, all ore-grade rock appears to have been mined; there is no evidence for the further occurrence of ore (Toth and others, 1983; Chatman, 1987). The fine fraction of stream-sediment samples collected contains 10–20 ppm uranium near the Edna mine.

Resource potential.—The potential for uranium resources in the Salt Wash Member of the Morrison Formation is moderate in the southeastern corner of the Black Ridge Canyons Wilderness Study Area and low for the rest of that study area, with certainty level C. Outside the vicinity of the Edna mine, the Salt Wash Member in the study area is unfavorable for deposits because of the following criteria: (1) the sandstone bodies in the Salt Wash Member are not fluvial, but are dominanted by the less favorable lacustrine facies, (2) there is a paucity of carbonaceous matter in the sandstone bodies, (3) there were no observed favorable gray mudstones, (4) there were no indications of uranium anomalies from any of the geochemical samples. Additionally, there was no obvious depositional axis of thickening sandstone bodies in the Salt Wash Member within the study area (Toth and others, 1983). As the Salt Wash Member does not occur in the Westwater Canyon Wilderness Study Area in eastern Utah, the study area has no resource potential for uranium in the Morrison Formation, with a certainty level D. The Westwater Canyon Wilderness Study Area does have low potential for uranium in another unit, as discussed below.

Placer Gold Deposits

The model (Pussycat placer deposits).—Placer gold occurs in sand and gravel deposited by the Colorado River on the bench cut on Precambrian rocks below Snyder Mesa, near the head of Westwater Canyon (pl. 1). At this location the foliation in the Precambrian gneiss lies at right angles to the river and acts as natural riffles to trap and concentrate the gold. This area is currently under claim as the Pussycat claims, and the extent of the workings suggests that placer gold has been produced, although the amount is not known. As noted in the section on appraisal above, testing by the USBM in the spring of 1986 revealed that recoverable fine grain ($<$ 0.02 in.) gold occurs in the sand and gravel deposits at concentrations of about 0.005 oz per cu yd. However, the distribution of the gold within these deposits is not uniform (see also Chatman, 1987).

Resource potential.—The Black Ridge Canyons and the Westwater Canyon Wilderness Study Areas have a high mineral resource potential for gold in small placer deposits in areas near the Colorado River, with a certainty level D. The study areas have a number of recent sand and gravel deposits along the Colorado River and on benches as high as 400 ft above current river level. Most of these deposits are unconsolidated, though some of them have been moderately calichified. USBM personnel sampled and tested sand and gravel deposits for placer gold along Ruby and Horsethief Canyons, at the mouths of Mee Canyon, Moore Canyon, and Knowles Canyon in the Black Ridge Canyons Wilderness Study Area, and at Big Hole and the mouth of Westwater Canyon in the Westwater Canyon Wilderness Study Area (pl. 1). Recoverable gold was detected at all the above-mentioned locations along the Colorado River (except at the mouth of Westwater Canyon) and to a lesser extent on the benches above the river (Chatman, 1987, tables 3, 6; fig. 6). Geochemical sampling by USGS personnel revealed anomalous gold values in a gravel deposit near the mouth of Jones Canyon in the Black Ridge Canyons Wilderness Study Area. The distribution and range of gold values from the tested gravels suggest that untested gravel deposits on benches above the Colorado River may also contain recoverable placer gold. The geologic environment for resources of placer gold is well defined in the wilderness study areas.

Metals (Including Uranium) in the Chinle Formation

Copper occurs in an adit in the Upper Triassic Chinle Formation in the lower part of Devils Canyon, within the boundaries of the Black Ridge Canyons Wilderness Study Area (pl. 1). The mineralized layer is in a channel-fill conglomeratic sandstone at the base of the Chinle Formation. The sandstone layer is mottled red and white and contains jasper and silicified wood. The mineralized material consists of malachite and azurite interstitial to grains of sand. An adit 65 ft long was driven into the deposit, and most of the mineralized rock was removed.

About 650 ft south of this occurrence disseminated copper, lead, and silver were found in float of Precambrian aplite. The mineralized aplite is extremely localized and is found nowhere else in the Precambrian bedrock. The mineralized aplite is bleached white with some hematite alteration along joints. It is not known if, or how, this occurrence might relate to the copper occurrence in the adjacent Chinle Formation (Toth and others, 1983).

Geochemical sampling has revealed a local concentration of copper, lead, silver, arsenic, barium, and molybdenum in an altered channel conglomerate at the base of the Chinle Formation near the mouth of Mee Canyon. This occurrence is very localized, and the concentrations are well below ore grade.

Anomalous amounts of very fine grained gold and mercury have been reported in the Petrified Forest Member of the Chinle Formation in northern Arizona and southern Utah. Past attempts to commercially extract the gold at Paria and Lees Ferry in northern Arizona have failed; no attempts to extract the mercury have been made (Lawson, 1913; Lauson, 1936; Patten, 1968). The Petrified Forest Member thins to the north, pinching out or grading into other members in the Four Corners region, and exists nowhere near the Black Ridge Canyons or Westwater Canyon Wilderness Study Areas (Stewart and others, 1972, p. 36–38).

Uranium deposits occur in the Chinle Formation in basal fluvial sandstone bodies directly above the mid-Triassic unconformity. They are similar to deposits in the Salt Wash Member of the Morrison Formation in that they form in carbonaceous channel sandstones that have undergone reducing alteration (Finch, 1959; Stewart and others, 1959). The Chinle uranium occurrence nearest the study areas is the Shinarump No. 1 mine, located 31 mi southwest of Westwater Canyon. Regional geologic analysis (Finch, 1959) suggests that the Chinle Formation is not favorable in or near the wilderness study areas for the occurrence of uranium deposits.

Resource potential.—The resource potential for the occurrence of gold, mercury, copper, silver, and uranium deposits in the Chinle Formation within the Black Ridge Canyons and the Westwater Canyon Wilderness Study Areas is low, with a certainty level C. The favored host rocks for gold, mercury, and uranium do not extend into the study areas. Radiometric surveys, geochemical sampling, and field mapping failed to reveal radioactive anomalies, geochemical anomalies, or altered or mineralized rock, except at two locations. The adit in Devils Canyon contains modest amounts of copper in a local channel sandstone, and one local occurrence in Mee Canyon in the Black Ridge Canyons Wilderness Study Area contains anomalous amounts of arsenic, barium, copper, lead, molybdenum, and silver above the contact between the Chinle and the Precambrian rocks. This apparently localized enrichment of those metals in Mee Canyon was probably leached from the underlying Precambrian rocks and deposited in the overlying sedimentary rocks.

Metal Deposits in Precambrian Rocks

Along the Dry Gulch fault zone adjacent to the southern boundary of the Westwater Canyon Wilderness Study Area, several silicified and mineralized fracture zones occur in the Precambrian gneiss. Sampling by the USBM revealed that these fracture zones contain barite, fluorite, and low concentrations of gold, silver, copper, and lesser amounts of lead and tungsten (see section on Appraisal of Identified Resources above, and Chatman (1987)). Subsequent investigations by the USGS discovered the continuation of these fracture zones in Star Canyon in the wilderness study area (pl. 1). Geochemical data from the Star Canyon occurrences indicate high concentrations of barium and anomalous amounts of copper. These fracture zones are believed to be related to the Dry Gulch fault zone and are confined to the southern part of the Westwater Canyon Wilderness Study Area.

Metapyroxenite bodies a few hundred to a few thousand feet in diameter crop out on the Precambrian bench along the Colorado River north of the Little Dolores River, in the Westwater Canyon Wilderness Study Area (pl. 1). These bodies have been metamorphosed, cut by fracture zones, and intruded by felsite dikes. Geochemical sampling of these rocks and the prospect pits in them by the USBM (Chatman, 1987) show that they contain anomalous amounts of barium, copper, molybdenum, tungsten, and lead for rocks of this type. A trace of gold was also present. Geochemical data from the USGS (J.E. Case, written commun., 1987) show these rocks to be unusually high in barium, copper, strontium, vanadium, manganese, and silver, but low in chromium, cobalt, and nickel for ultramafic rocks.

Resource potential.—There is a moderate potential for the occurrence of gold, silver, copper, and barite resources in veins along fracture zones in the Precambrian rocks along Dry Gulch and in Star Canyon in the southern part of Westwater Canyon Wilderness Study Area, with a certainty level C. The potential for chromium, nickel, and cobalt (metals normally associated with ultramafic rocks) in the metapyroxenites of the Westwater Canyon Wilderness Study Area is low, with a certainty level C. Precambrian rocks have not been mapped in detail in all canyons of the Black Ridge Canyons Wilderness Study Area, hence it is not known with certainty if metapyroxenites occur there. The Black Ridge Canyons Wilderness Study Area is assigned a low resource potential for chromium, nickel, and cobalt, with certainty level C. The potential for the occurrence of metallic and barite resources other than those mentioned above in the Precambrian rocks of the Westwater Canyon and Black Ridge Canyons Wilderness Study Areas is low, with a certainty level C.

Coal

The model.—Coal has been produced within 3 mi of the Black Ridge Canyons Wilderness Study Area from seams in the Dakota Sandstone, near the Gunnison River in Colorado. The seams are from 3 in. to 3.3 ft thick and range in grade from high volatile A to bituminous C. Production took place during the late 19th century and the early 20th century for local use (Lohman, 1965; Schwochow, 1978). Murray (1976) places part of the Black Ridge Canyons Wilderness Study Area in a coal resource area on the basis of the presence of the Dakota Sandstone.

Resource potential.—The potential for coal deposits in the Dakota Sandstone in the Black Ridge Canyons Wilderness Study Area is low, with certainty level C, and there is no potential in the Westwater Canyon Wilderness Study Area, with a certainty level D, because favorable geologic conditions are not known to exist within the study areas. The Dakota Sandstone has been removed from the study areas by erosion, except for a part of Black Ridge itself. Field investigations in the spring of 1986 revealed that the part of Black Ridge within the Black Ridge Canyons Wilderness Study Area boundary contains only sandstone, mudstone, and conglomerate of the Burro Canyon Formation and lower part of the Dakota Sandstone. Coal is unknown in rocks older than the Burro Canyon Formation in western Colorado and eastern Utah. The Dakota Sandstone does not occur in the Westwater Canyon Wilderness Study Area in eastern Utah, hence there is no potential for coal in this study area.

Oil and Gas

The model.—Natural gas, CO_2, and some oil have been produced from structural and stratigraphic traps in the Mancos Shale, Dakota Sandstone, Morrison Formation, and Entrada Sandstone in the Mack Creek, Highline Canal, Bar X, Asbury Creek, and other oil and gas fields north of the Black Ridge Canyons Wilderness Study Area (Schwochow, 1978). West of the wilderness study areas near Cisco, Utah, oil and gas have been produced from structural traps associated with the Cisco Dome, Harley Dome, and Seiber nose, and stratigraphic traps in the Dakota Sandstone and the Cedar Mountain and Morrison Formations (see fig. 1) (Mahoney and Kunkel, 1963). Entrapment of oil and gas may occur beneath Precambrian crystalline rocks thrust over Paleozoic sedimentary rocks along the Uncompahgre fault zone in the western part of the Westwater Canyon Wilderness Study Area, but this is highly speculative (Stone, 1977; Frahme and Vaughn, 1983).

Resource potential.—The oil, gas, and carbon dioxide potential is classified as low by Krivanek (1981). Possible source rocks are absent from the wilderness study areas, and possible reservoir rocks that have been productive in adjacent basins have been removed by erosion, breached by canyons, or stripped of impermeable cap rocks. Although a possibility exists that oil, gas, and carbon dioxide may occur beneath suspected thrust faults in the westernmost part of the Westwater Canyon Wilderness Study Area in eastern Utah, Stone (1977) suggests that this area is unfavorable. One such well drilled by Mobil Oil Corporation through the Uncompahgre thrust fault west of Cisco, Utah, proved to be dry (Frahme and Vaughn, 1983). Previous assessments of the area (Krivanek, 1981; Molenaar and Sandberg, 1983; Spencer, 1983) have assigned the region a low to zero potential for hydrocarbons.

A low resource potential for oil, gas, and carbon dioxide is assigned, with a certainty level D, for the Black Ridge Canyons Wilderness Study Area and for most of the Westwater Canyon Wilderness Study Area, because favorable geologic conditions are not present in the study areas. A low resource potential for oil, gas, and carbon dioxide is assigned, with a certainty level C, to the southwestern part of the Westwater Canyon Wilderness Study Area, as the available data gives a good indication of the level of resource potential.

Geothermal Energy

There are no warm or hot springs in or near the study areas (Pearl, 1980), although there are abundant fresh-water seeps in the canyons of the study areas; these usually occur at contacts between the sedimentary formations. There is no evidence of Cenozoic or recent volcanic activity within many miles of the study areas, and no geologic or geophysical evidence to suggest high heat flow. The resource potential for geothermal energy is low, with a certainty level C.

Recommendations For Further Work

Additional sampling and analysis, coupled with geophysical techniques such as induced polarization, telluric traversing, and audiomagneto-telluric soundings would be useful in determining if mineralized rock increases in grade with depth beneath the silicified fractures in Star Canyon and Dry Gulch. Additional sampling and analysis would be useful in determining whether the chemical changes in the metapyroxenite are significant indications of mineralization.

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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 →

<table>
<tr><td rowspan="4">U/A

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

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.

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.

*U.S. GOVERNMENT PRINTING OFFICE: 1988-0-573-047/66064