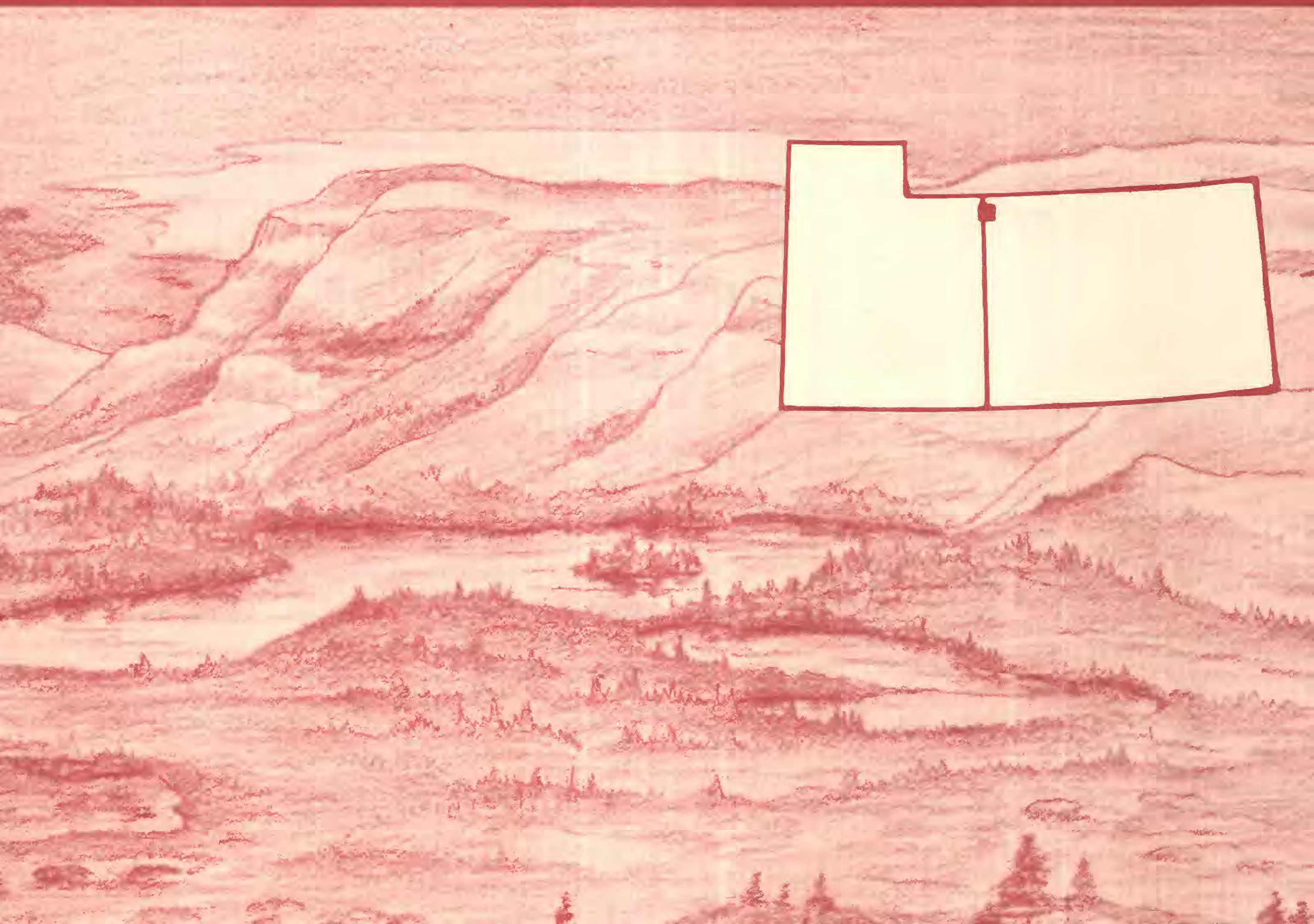
Mineral Resources of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah

U.S. GEOLOGICAL SURVEY BULLETIN 1714–B



Chapter B

Mineral Resources of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and Congress. This report presents the results of a mineral survey of the Diamond Breaks (CO–010–214/UT–080–113) Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah.

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PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah

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ABSTRACT

The Diamond Breaks (CO–010–214/UT–080–113) Wilderness Study Area consists of 36,240 acres in northwesternmost Colorado and northeasternmost Utah. The study area has inferred subeconomic resources of sand, gravel, and common variety rock. The potential for undiscovered resources of gold, uranium, copper, lead, zinc, or other metals, tuff (pumicite), and oil and gas is rated as low. There is no resource potential for coal, manganese, phosphate, clay and shale, limestone, and gypsum. The resource potential for barite and commercial-grade silica is unknown. This conclusion is based on field studies conducted in 1986 and 1987.

SUMMARY

The Diamond Breaks Wilderness Study Area lies about 40 mi (miles) northeast of Vernal, Utah, and abuts Dinosaur National Monument on the east and Browns Park National Wildlife Refuge on the northeast (fig. 1). Principal access is via Colorado Highway 318, 54 mi northwest of the town of Maybell, Colo., but the study area is accessible by road from all directions except the east. Jeep trails enter the study area via Dry Creek on the south and Allen and Marshall Draws on the west; a jeep trail on the south bank of the Green River skirts the study area on the northeast and a through road connecting Vernal to Browns Park skirts the western edge of the study area in Crouse Canyon. The study area is mountainous, in places heavily wooded, and has a maximum relief of 3,313 ft (feet).

The wilderness study area lies in the eastern part of the Uinta Mountains on the southern limb of a open anticlinal fold formed in coarse sandstone of the Middle Proterozoic (see "Appendix") Uinta Mountain Group. These rocks dip gently to the south or southwest. They are broken by a series of northeast-trending faults that are generally offset less than 200 ft. These structures may have formed as much as 70 m.y. (million years) ago, during a time of major mountain building in the Rocky Mountain area. A few near-vertical silicified and broken (breccia) zones, also trending northeast, are exposed in the north-central part of the study area.

Rocks in the Uinta Mountain Group underlie most of the study area. These rocks are approximately 1,000 m.y. old. They consist largely of red, thin- to thick-bedded, conglomeratic sandstone, deposited by streams draining a nearby ancient highland located north or northeast of the study area. The lower 3,000 ft of the formation is practically shale-free, and in its eastern parts is much subdued in color, many beds being more gray than red. A thin middle unit, about 200 ft thick, consists of thinly bedded, interlayered, fine- to medium-grained sandstone and mud-cracked shale which in many places are greenish-gray rather than red. The upper 5,000 ft of the formation is more reddish-brown than the lower part and contains more shale.

Valleys that head in the study area are covered with a variety of unconsolidated materials ranging from fine silt to unsorted, coarse, bouldery deposits. The Upper Oligocene and Miocene Browns Park Formation is locally exposed in many valleys in the northern part of the area, usually at or just below terrace edges. It is a light-colored, locally crossbedded, soft sandstone; parts of it are composed of fine, volcanically erupted ash (tuff). The Oligocene Bishop Conglomerate, a coarse bouldery formation, probably underlies the alluvium in most valleys in the southern half of the study area.

The Diamond Breaks Wilderness Study Area has inferred subeconomic resources of sand, gravel, and common variety rock. No prospect pits or other traces of mining activity are known in the study area. Near-vertical faults and breccia zones in the area display little visible alteration, although one breccia zone in the north-central part of the area contained trace gold and two others contained low levels of arsenic, generally regarded as a gold "pathfinder" element. Geophysical surveys suggested altered rock at depth in association with a possible small intrusive body in the north-central part of the study area. These data, in connection with a high concentration of lineaments (mostly fractures) in the same part of the study area, suggest a deep-seated mineralizing system that may account for this trace gold occurrence. The potential for undiscovered resources of gold in breccia zones is therefore low in the central part of the study area.

Trace gold was also found in heavy-mineral concentrates of stream sediments in the northern part of the study area. This placer gold is believed to be reworked from alluvium of the Green River. The potential for undiscovered resources of gold in alluvium in the northern part of the study area is low.

The Browns Park Formation is a known host for uranium deposits in northwest Colorado, but hand-held radiometric surveys revealed no unusual radioactivity over the formation within the study area. The thin and spotty distribution of the formation reduces the likelihood of uranium deposits in the study area; the mineral resource potential for uranium is therefore low. The Uinta Mountain Group is a "redbed" formation, and as such could serve as a host for stratiform deposits of copper, lead, or zinc, but such mineralization is unknown in the group and no indications of such mineralization were observed inside the study area. The potential for undiscovered resources of copper, lead, and zinc is therefore low.

Rock alteration and geochemical or geophysical anomalies indicative of other metal mineralization are lacking within the study area, and the mineral resource potential for all other metals is low. Tuff, in the Browns Park Formation, occurs in minor quantities in the northern part of the study area, and there is a low mineral resource potential for tuff (pumicite). Host rocks for barite and commercial-grade silica may exist at depth (greater than 2 mi) within the study area, but the mineral resource potential for these two commodities is unknown. Host rocks for coal, manganese, phosphate, clay and shale, limestone, and gypsum do not exist within the study area; thus, there is no mineral resource potential for these commodities.

Subsurface geologic structures formed during mountain building have locally emplaced rocks known elsewhere for their oil and gas content in potential traps below low-angle faults at relatively shallow depths south of the study area; similar structures inside the study area, if they exist, probably lie at depths of about 9 mi or more, too deep for the existence of oil and gas. The energy resource potential for oil and gas is rated low.

INTRODUCTION

The U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS) studied 36,240 acres of the Diamond Breaks (CO–010–214/UT–080–113) Wilderness Study Area. The study of this acreage was requested by the U.S. Bureau of Land Management. In this report, the studied area is called "wilderness study area" or simply the "study area."

The wilderness study area lies 25 air mi (miles), and about 40 road mi, northeast of Vernal, Utah (fig. 1). It is bordered on the east by Dinosaur National Monument and on the north by Browns Park National Wildlife Refuge. Principal access is via Colorado Highway 318, 54 mi northwest of Maybell, Colo., but the study area is accessible by road (weather permitting) from all directions except the east. Unpaved roads skirt the study area on the north, west, and south; the road through Crouse Canyon connects Vernal with Browns Park. Jeep trails enter the study area via Dry Creek on the south, Allen and Marshall Draws on the west, and Chokecherry Draw on the north. Hoy trail in the center of the study area connects Dry Creek to Browns Park by a horse trail. All road access except from the north passes through private property. The study area is moderately rugged, heavily forested in its higher parts, and has a maximum relief of 3,313 ft (pl. 1). The highest point is 8,673 ft, near the west-central boundary, and the lowest point is 5,360 ft, in the northeast corner near the mouth of Hoy Draw.

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

Investigations by the U.S. Bureau of Mines

The Diamond Breaks Wilderness Study Area was examined by the U.S. Bureau of Mines in July 1986

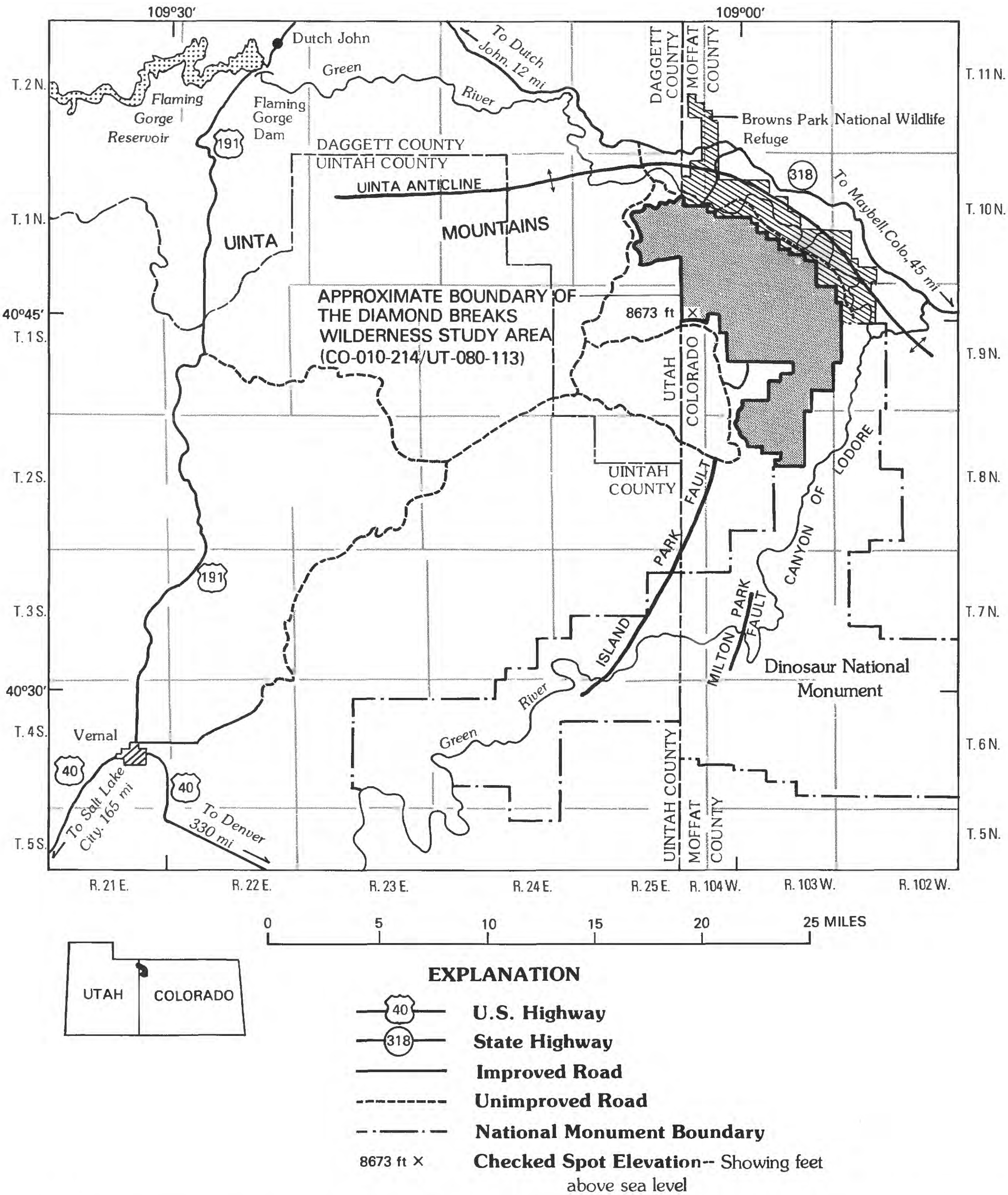


Figure 1. Index map showing location of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah.

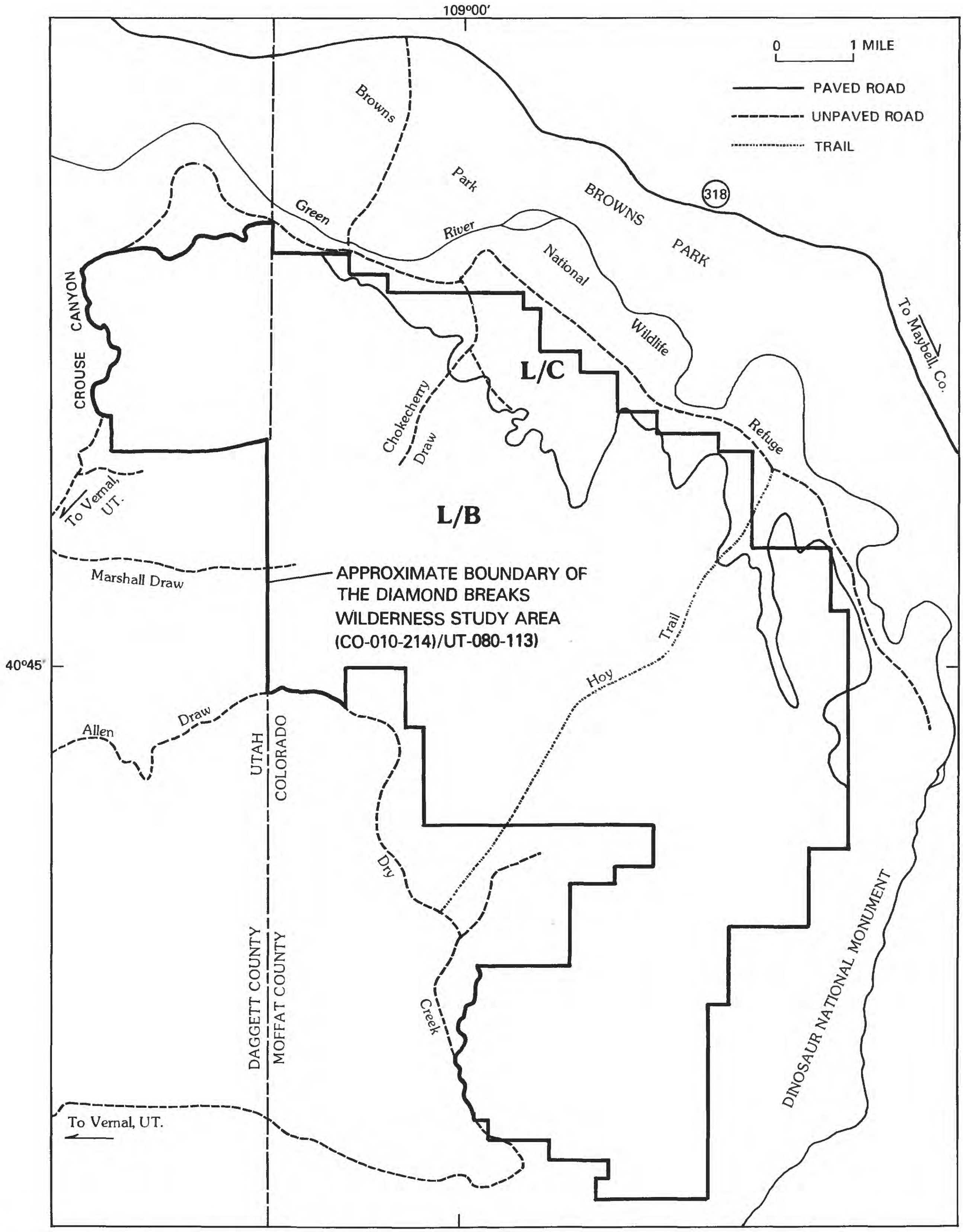


Figure 2. Map showing mineral resource potential of the Diamond Breaks Wilderness Study Area, Moffat County, Colorado, and Daggett County, Utah.

(Ryan, 1987). This examination included a review of mining claim and master title plat information in the Bureau of Land Management's state offices in Denver and Salt Lake City, and a literature review of published material related to mineral resources and mining activities in or near the study area. Two USBM geologists conducted a 10-day field examination that included reconnaissance by 4-wheel-drive vehicle, helicopter, and foot traverses. Forty-three stream-sediment samples were collected within and near the study area (Ryan, 1987), and one chip sample of a vein was taken near the northern boundary (sample BM18, pl. 1). These samples were analyzed by the Bureau of Mines Reno Research Center, Reno, Nev., for 40 elements by semiquantitative optical emission spectrography; the vein sample was fire-assayed for gold and silver. In addition, scintillometer readings were made over limited exposures of the Browns Park Formation to test for anomalous radioactivity. Additional information is available from the Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, Colo. 80225.

Investigations by the U.S. Geological Survey

A geologic map of the wilderness study area was prepared by the U.S. Geological Survey in June 1986 (pl. 1). During this mapping, a total of 35 rock samples were collected within or near the study area. Previous mapping was available for the southern half and the northwestern edge of the study area (Hansen, 1965; Hansen and others, 1983). A stream-sediment geochemical survey was done in 1986, resulting in an additional 24 samples. Both rock and stream-sediment samples were analyzed in laboratories of the U.S. Geological Survey in Denver, Colo., using atomic absorption and semiquantitative emission spectrographic techniques. Gravity data were collected in 1987 and added to previously available information. These data, together with aeromagnetic data and satellite imagery, were analyzed and interpreted. A cursory radioactivity survey by hand-held scintillometer was made over both the Uinta Mountain Group and the Browns Park Formation.

EXPLANATION OF MINERAL RESOURCE POTENTIAL

[Entire wilderness study area has low mineral resource potential for copper, lead, zinc, and all other metals except as noted below, and for oil and gas, with certainty level B; unknown mineral resource potential for barite and commercial-grade silica; and no mineral resource potential for coal, manganese, phosphate, clay and shale, limestone, and gypsum]

L/B Geologic terrane having low mineral resource potential with certainty level B for gold in breccia zones

L/C Geologic terrane having low mineral resource potential with certainty level C for gold, uranium, and tuff (pumicite)

APPRAISAL OF IDENTIFIED RESOURCES

By George S. Ryan U.S. Bureau of Mines

The only identified mineral resources in the Diamond Breaks Wilderness Study Area are inferred subeconomic resources of sand, gravel, and common variety rock. There are no identified near-surface energy resources.

In the last decade, claims have been staked 2 mi north and 3 mi northeast of the study area in the Browns Park Formation. The claims were probably staked for uranium, but there is no record of development or mining; the claims were dropped prior to 1986.

A 6- to 18-in. (inch)-wide silicified breccia zone, one of four observed in the study area, crops out in the south-center of sec. 28, T. 10 N., R. 103 W. (pl. 1). The zone is in red sandstone of the Uinta Mountain Group and stands 1 to 4 ft above the surface for a distance of 110 ft. The zone strikes N. 38° E., and slickensides indicate movement in the zone was the result of normal vertical displacement. The zone contains quartz stringers and minor hematite staining. No sulfides or other ore minerals were visible. Fire assay of an 18-in. chip sample (sample BM18, pl. 1) indicated a trace of gold but no silver (Ryan, 1987, p. 5). No other unusual element concentrations were noted.

The sand, gravel, and common rock deposits observed in the study area were not large, well-sorted, clean, or unique. Inferred subeconomic resources of sand and gravel that occur in the drainages of the study area could be used as aggregate in concrete, road metal, and fill. Transportation costs and low unit price limit the economic marketing range to local uses. Abundant supplies of similar material exist north of the study area on the extensive flood plains of the Green River.

The study area lies in the center of a number of highly productive oil fields in Colorado, Utah, and Wyoming. There are no oil and gas leases within the study area.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Jon J. Connor, Tracy A. Delaney, Dolores M. Kulik, Don L. Sawatzky, and James A. Whipple
U.S. Geological Survey

Geology

The Diamond Breaks Wilderness Study Area (pl. 1) lies on the southern flank of the east dome of the Uinta anticline, a compound, arcuate, east-west trending feature of over 160 mi in northeastern Utah and northwestern Colorado (Hansen, 1965, p. 137). The study area is largely underlain by about 8,000 ft of strongly jointed conglomeratic sandstone of the Uinta Mountain Group. These rocks are broken by a series of northeasterly oriented, near-vertical faults of less than 200 ft offset. Four zones of near-vertical silicified sandstone breccia each trending about N. 35–40° E. were observed in the north-central part of the study area.

The Uinta Mountain Group in the study area consists almost entirely of coarse, conglomeratic, red to reddish-gray, ledgy, crossbedded sandstone. Sandstones in the group commonly range in composition from relatively pure but conglomeratic quartz-rich sandstone to feldspar-rich arkose. These sandstones were deposited during Middle Proterozoic time (see geologic time chart in Appendix) about 1,000 m.y. ago (Hansen and others, 1983). The persistent west to southwest direction of crossbedding suggests deposition by streams draining source areas to the east or northeast.

Inside the study area, the group is easily subdivided into three units consisting of two thick sandstone blankets separated by a medial shale, suggesting that the Uinta Mountain Group in the study area consists of at least two major fan complexes which spread out to the west or southwest. The lower part of the Uinta Mountain Group (unit Yul, pl. 1) consists of red to reddish-purple or gray, thick-bedded, crossbedded, fine- to medium-grained, poorly to well sorted, locally conglomeratic quartz sandstone as much as 3,000 ft thick. The middle part of the Uinta Mountain Group (unit Yum) is red, green, and gray, thin-bedded, interbedded, mud-cracked, poorly sorted siltstone and fine-grained impure sandstone as much as 200 ft thick that rarely crops out. The upper part of the Uinta Mountain Group (unit Yuu) is composed of red to reddish-brown, thin- to thick-bedded, poorly to well sorted, strongly crossbedded, fine- to coarse-grained, locally conglomeratic, quartzose sandstone and arkose as much as 5,000 ft thick.

Filling the heads of valleys developed in the Uinta Mountain Group are soft, poorly sorted sediments deposited within the last 30(?) m.y. Two formally named formations are recognized in these sediments; the Oligocene Bishop Conglomerate deposited largely south of the drainage divide separating the Green River from Pot Creek, and the Upper Oligocene and Miocene Browns Park Formation deposited largely north of that divide. The regional relation between these two valley-filling episodes and its bearing on the history of mountain-building and regional drainage development are described in detail in Hansen (1986a). Because of the scarcity of outcrop, the distribution of the Bishop Conglomerate was not mapped during this work although Hansen (1986a, fig. 13) shows it as underlying most of the valleys in the southern half of the study area.

The Browns Park Formation crops out mostly near the rims of low terraces in valleys draining north. Remnants of the formation were observed at elevations up to 6,200 ft. In addition, a pervasive bleaching of the red sandstone of the Uinta Mountain Group along joint surfaces up to an altitude of about 6,700–7,000 ft in the northern half of the study area may reflect previous burial of the Uinta Mountain Group to that altitude by sediments of the Browns Park. The bleaching in the group likely reflects alteration by fluids percolating downward from the Browns Park.

The Browns Park Formation (unit Tbp, pl. 1) is gray to orange, thin-bedded, and locally crossbedded. In typical exposures, Hansen (1986a, p. 28) described it as consisting "chiefly of light-colored to nearly white, loosely cemented, generally calcareous sandstone and light-gray to white, vitric and ashy to earthy, friable to firm, rhyolitic tuff." It is very poorly exposed within the study area and its thickness there is unknown, but it may not exceed 100 ft. Two outcrops of light-colored, soft sandstone similar to that in the Browns Park Formation were seen in the southern part of the study area. A sample collected in Davis Draw (GS02, pl. 1) contained high barium (1,000 ppm (parts per million)), which is typical of tuffaceous material in the Browns Park (Hansen, 1965, p. 120), and both the outcrop from which this sample was collected and a similar outcrop in sec. 32, T. 9 N., R. 103 W., were arbitrarily placed in the Browns Park Formation.

Unconsolidated sandy materials of Quaternary age in the study area consist of sandy stream alluvium, bouldery colluvium on lower hillslopes and heads of valleys, wind-blown sand and silt dunes (unit Qal, pl. 1), and large fields of steep talus high on the mountain sides (unit Qt). Unit Qal is made up of unconsolidated, poorly sorted deposits of mixed clay, silt, sand, cobbles, and boulders and includes alluvium of the Green River along northern edge of the study area. It may also include unmapped and unrecognized outcrops of the Bishop Conglomerate in the southern half of the study area.

A gently curved, abandoned channel of the Green River cuts through the east side of the study area (secs. 12 and 13, T. 9 N., R. 103 W., pl. 1). Well-worn cobbles and gravels of rocks exotic to the study area in this channel demonstrate the Green River heritage. Similar deposits of poorly exposed gravel between Yellow Jacket and Warren Draws suggests that Green River alluvium likely underlies much of the broad plain in secs. 20, 21, 27, and 28, T. 10 N., R. 104 W.

The eastern Uinta Mountains, of which the wilderness study area is a part, were shaped by a long history of uplift, warping, and intermittent erosion beginning in latest Cretaceous time, about 70 m.y. ago. Hansen (1986b, p. 16), however, noted that geologic deformation in the general region has occurred intermittently since the Early Proterozoic, more than 1,600 m.y. ago. The mountains are bounded in part on both the north and the south by reverse faults that dip under the flanks of the range (fig. 4). Hansen (1986b, p. 10) postulated that these flanking fractures result from "underthrusting caused by crowding of the * * * Uinta Mountain Group and younger sediments between the Colorado Plateau to the south and the Wyoming shelf to the north." Following this period of regional compression, an extensive erosion surface was carved across the region and the Bishop Conglomerate and the Browns Park Formation were deposited on it. In the Miocene, about 20 m.y. ago, renewed deformation, in an extensional mode, resulted in lowering of the crest of the range and an inward tilting (Hansen, 1986b, p. 15). Faulting has continued since in the region but at a diminishing rate (Hansen, 1986b, p. 17).

Geochemistry

Analytical Methods

A reconnaissance geochemical survey of the wilderness study area was based on wet chemical and spectrographic analysis of minus-80-mesh stream sediments and heavy-mineral concentrates from stream sediments collected at 24 sites within or adjacent to the study area. The samples were collected from first-order (unbranched) or second-order (below the junction of two first-order) streams and consisted of composited active alluvium. A complete listing of the analytical results and concise description of the sampling and analytical techniques are given in Delaney (1988).

Results of Study

Microscopic examination of the heavy-mineral concentrates revealed that five samples along the north edge of the study area contained visible flour gold (samples DB08, DB11–14, pl. 1). The gold occurs as small (less than 0.001 in.), copper-yellow colored, rounded flakes with rough surfaces. Analysis of three grains by scanning electron microscope indicates a composition of 94.37–96.22 weight percent gold, 2.40–3.27 weight percent lead, 0.50–1.95 weight percent copper, 0.00–0.29 weight percent silver, and 0.00–0.46 weight percent iron. The purity, size, and shape of the grains suggest a source remote from the sample site (Boyle, 1987).

Of 31 elements analyzed for in the stream sediments, none was judged to occur at anomalous levels. In particular, elements of interest, such as gold, silver, arsenic, bismuth, cadmium, molybdenum, antimony, tin, tungsten, thorium, and zinc, were below the limits of analytical detection in all samples. Numerous other metals, such as iron, titanium, manganese, boron, barium, beryllium, cobalt, chromium, copper, lanthanum, niobium, nickel, lead, vanadium, and yttrium, were detected but only at ordinary levels.

Of the same elements in the heavy-mineral concentrates, barium (>1 percent), lanthanum, strontium, yttrium (1,000 ppm), and zirconium ($>2{,}000$ ppm) were consistently found in above average amounts. More, sample DB11, one of the gold-bearing samples (pl. 1), contained an anomalous 500 ppm tin.

Barite, zircon, rutile, and sphene occurred in abundance in the heavy-mineral concentrates; apatite, monazite, and anatase occurred in smaller amounts. The barium (referred to above), and perhaps the strontium, reside in the heavy mineral barite. The barite grains were generally large (0.02 in. across), subhedral, and frosted, indicating a detrital source. The lanthanum and yttrium probably reside in monazite and sphene. The zirconium resides in the heavy mineral zircon. Zircon grains are euhedral, colorless, and approximately 0.01 in. in size. Sources of these minerals are probably multiple; zircon and sphene are widespread in sandstone of the Uinta Mountain Group, but any of these minerals could have come from virtually any rock in the surrounding region. Hansen (1965, p. 184–185) noted the local occurrence of phosphate (apatite) and barite deposits upstream of the study area.

Geophysics

Analytical Methods

Magnetic data were extracted from survey data of the U.S. Department of Energy (1982). Flight lines were flown east-west at 2–5 mi intervals and 400 ft above the ground surface. Four flight lines and one north-south tie line cross the study area. Residual intensity magnetic data are shown as a contour map with a contour interval of 20 nT (nanoteslas) (fig. 3*A*).

Bouguer gravity data (fig. 3*B*) were obtained in and adjacent to the study area in 1987 and were supplemented by regional data from Behrendt and Bajwa (1974). Individual station values were not available for the regional data; the regional contour data were adjusted by hand to include station values from the 1987 data. Stations measured in this work were established using Worden gravimeter W–177.[1] These data were tied to the International Gravity Standardizations Net 1971 (U.S. Defense Mapping Agency Aerospace Center, 1974) at base station ACIC 0557–0, Vernal, Utah. Station elevations were obtained from benchmarks, spot elevations, and estimates from topographic maps at 1:24,000 and 1:62,500 scales, and are accurate to plus-or-minus 20–40 ft. The error in the Bouguer anomaly is less than 2.5 mGal (milligals) for errors in elevation control.

Gravity values were computed using the 1967 gravity formula (International Association of Geodesy, 1971) and a reduction density of 2.67 g/cm^3 (grams/cubic centimeter). Mathematical formulas are given in Cordell and others (1982). Terrain corrections were made by computer for a distance of 100 mi from the station using the method of Plouff (1977). Results of the gravity survey are shown as a complete Bouguer anomaly map with a contour interval of 5 mGal (fig. 3*B*). Both magnetic and gravity studies provide information on the subsurface distribution of rock masses and their structural framework. The data provided here are reconnaissance in nature and are adequate only in definition of regional structural features.

A lineament analysis of the wilderness study area and adjacent lands was made in 1987 based on Landsat multispectral scanner images at a scale of 1:800,000. Lineaments are the topographic and spectral expression of rock fracture patterns and other structural or lithologic linears; their analysis in conjunction with geologic or geophysical knowledge may reveal such things as fracture control of mineralization. A map of the concentration of lineaments oriented N. 5–35° E. is given in figure 3*C*.

Results of Study

The most intriguing feature in the geophysical data is the presence of a closed (oval-shaped) low anomaly in the magnetic map (fig 3*A*, feature A) straddling the northern boundary of the study area. This weak magnetic low is located over the gold-bearing breccia zones in the study area and permits, though it does not demonstrate, the possibility of a buried intrusive body beneath the zones.

Two magnetic highs occur over the the eastern Uinta Mountains (B and C in fig. 3*A*). Magnetic high B occurs over the southern part of the study area and extends eastward. It appears to be augmented by uplift along a possible northern extension of the Douglas Creek arch, a prominent structural feature known about 30 mi south of the study area. The eastern flank of the arch is defined by the north-trending gravity gradient east of the study area (fig. 3*B*). The magnetic gradient between highs B and C and centered on low A (fig. 3*A*) trends northeast through the northern part of the study area. This feature is part of a regional trend that extends for many tens of miles both to the northeast and the southwest and may represent a basement fracture zone. Magnetic lows on this trend could be caused by alteration of magnetic minerals by hydrothermal (mineralizing) fluids, such as might be given off from a cooling intrusion.

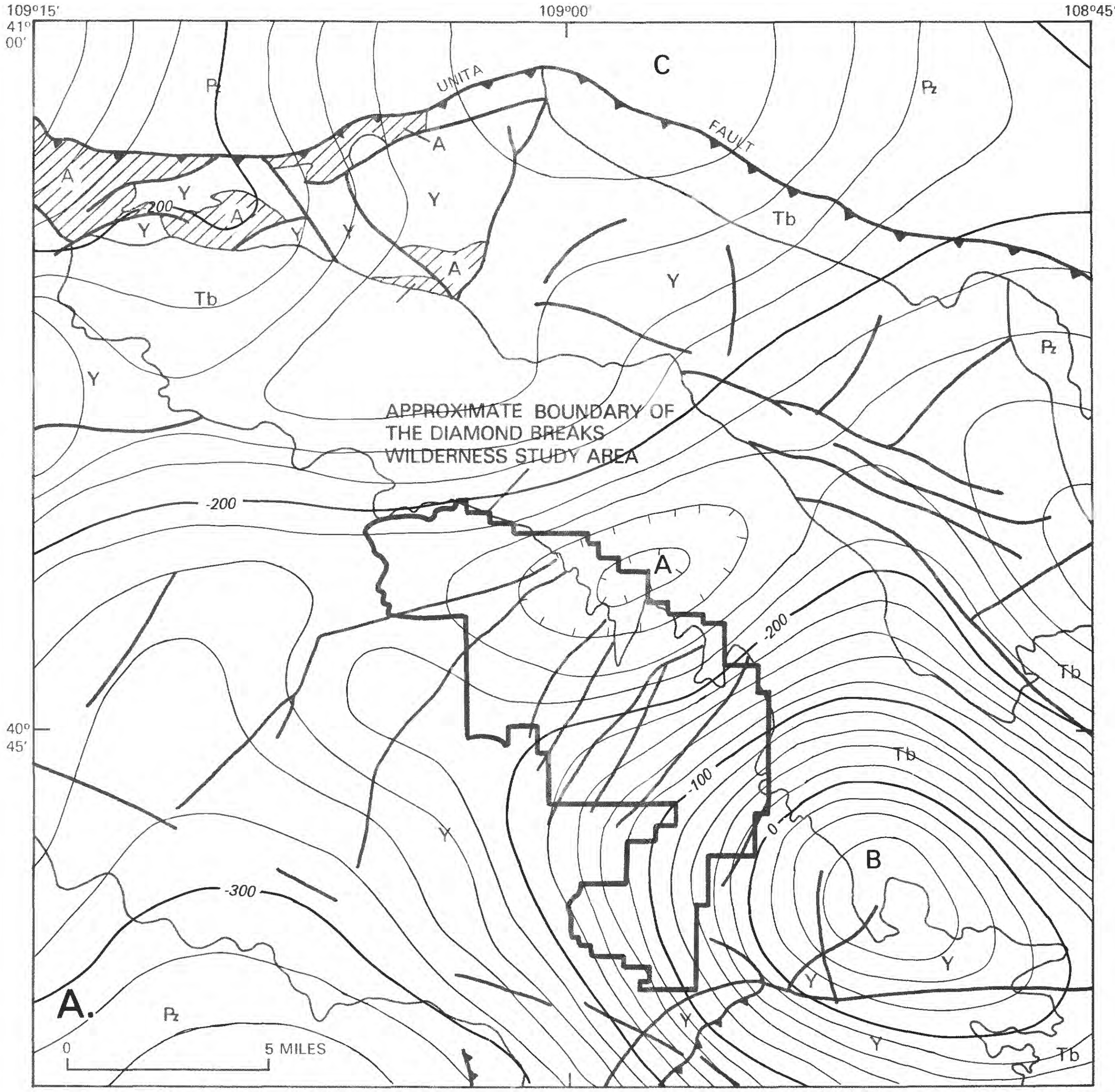
A gravity high (A, fig. 3*B*) occurs over the study area. A high of lesser magnitude continues westward beyond the area of figure 3*B*, and is associated with the rocks of the Uinta uplift. A north-northeast-trending deflection in the contours of the gravity high and the small aligned high and low anomalies (B and C in fig. 3*B*) are part of a more extensive trend associated with the Mitten Park-Island Park fault system to the south and suggests that the system is present in the subsurface along the southeastern boundary of the study area.

Only a local gravity low (D in fig. 3*B*) is associated with rocks of the Browns Park Formation, which are more than 0.15 grams per cubic centimeter lower in density than the Middle Proterozoic rocks. The small magnitude of the anomaly suggests, as do field observations, that the Browns Park does not exceed a few hundred feet in thickness in this area.

Finally, but importantly, preliminary evaluation of the gravity gradient across the Uinta fault zone along the traverse shown in the northeastern corner of figure 3*B* and the gradient along a detailed profile north of the area suggests that the Uinta fault may dip southward at a lower angle than shown in the cross section of figure 4.

Multispectral scanner lineaments of every direction (orientation) were interpreted in the study area. The most common lineament direction was in the range N. 5–35° E., an orientation parallel with the faults and breccia zones mapped on plate 1. More, these northeast linears are most highly concentrated in the north-central part of the study area (fig. 3*C*), coinciding with a magnetic low (A in fig. 3*A*) and the breccia zones. The association of abundant linears (possibly representing an

[1]Use of brand names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.



Geology adapted from Rowley and others, 1985

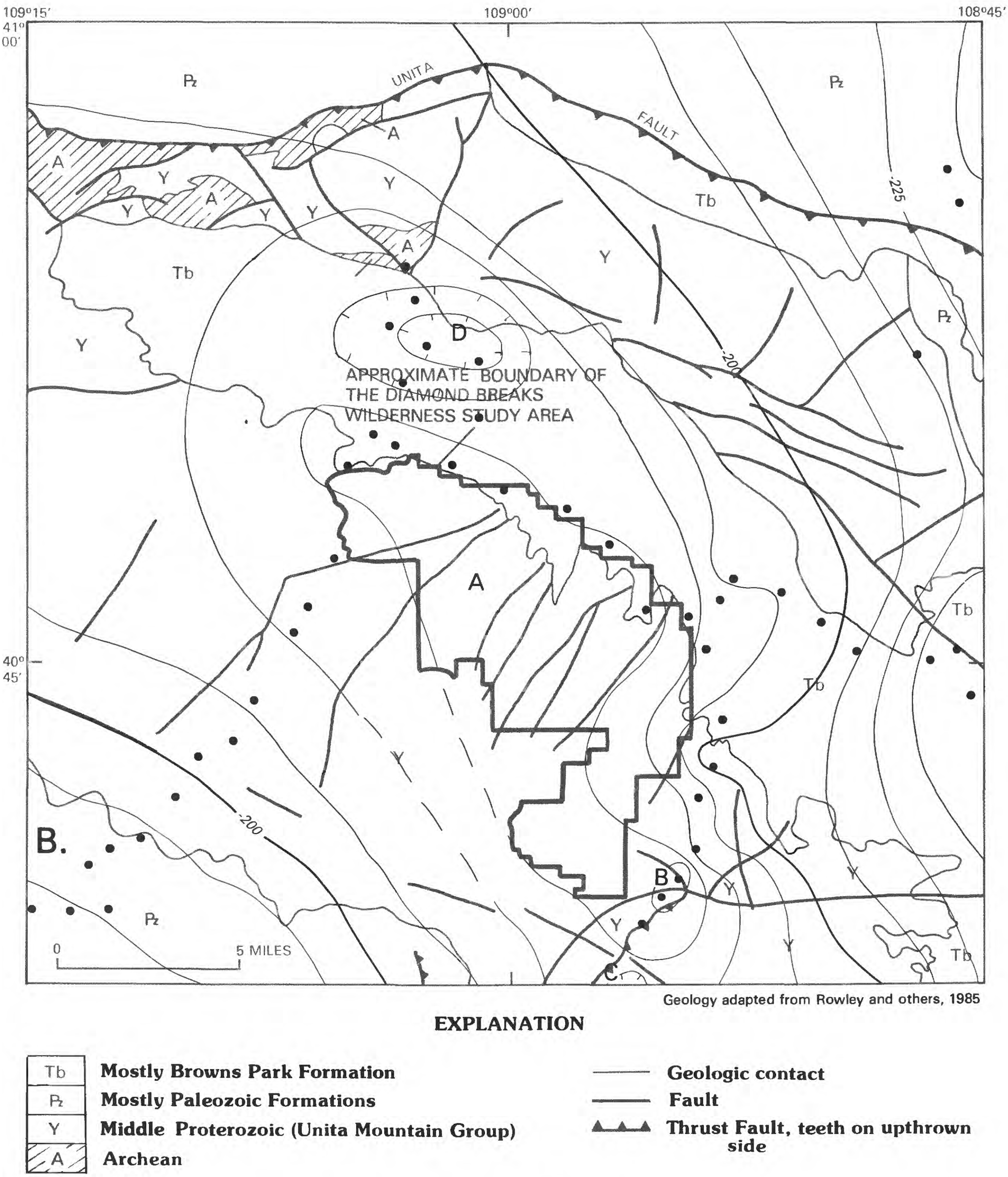
EXPLANATION

Tb	**Mostly Browns Park Formation**
Pz	**Mostly Paleozoic Formations**
Y	**Middle Proterozoic (Unita Mountain Group)**
A	**Archean**

- Geologic contact
- Fault
- Thrust Fault, teeth on upthrown side

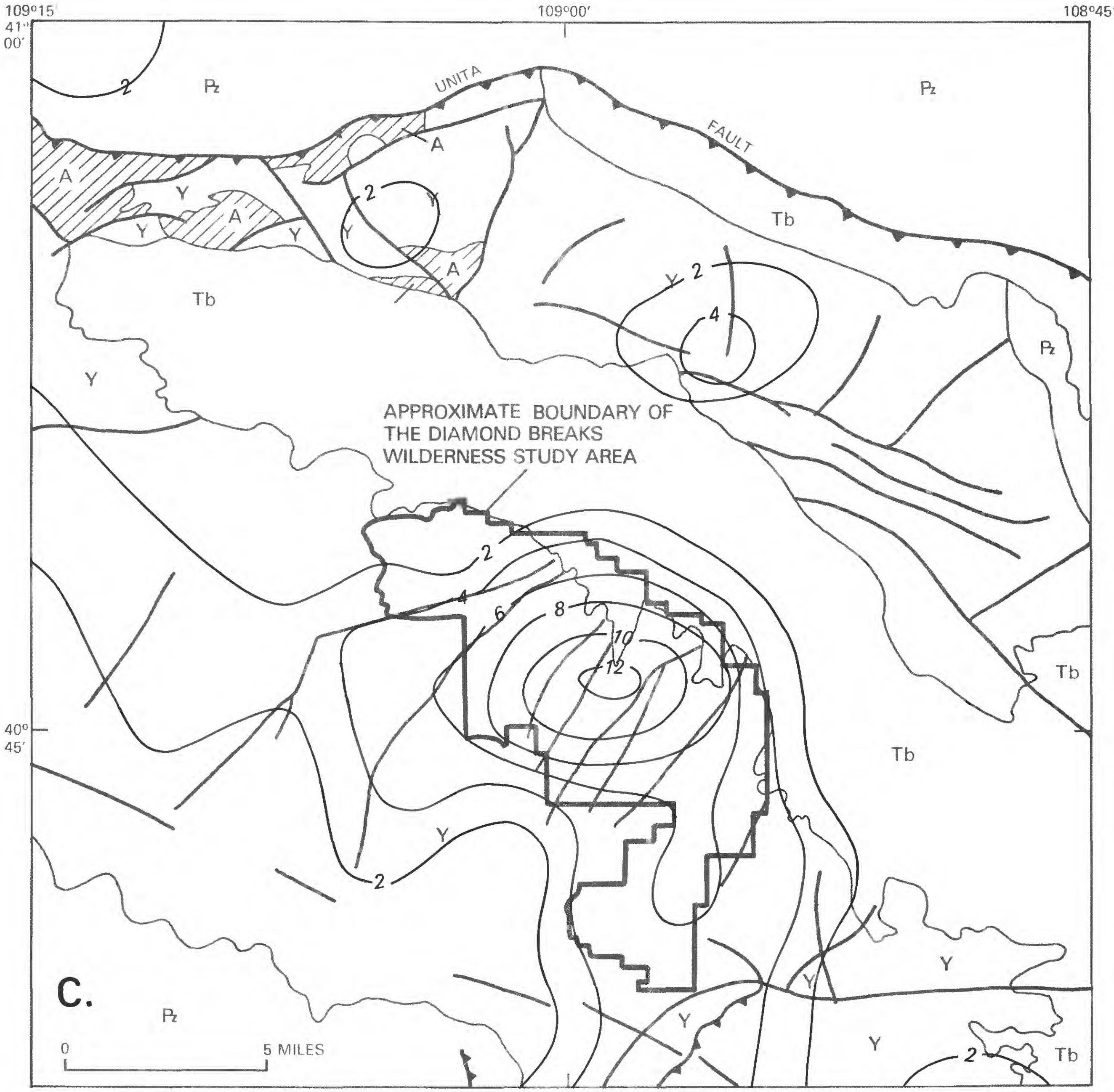
A. Residual intensity magnetic anomaly map. Contour interval 20 nT.

Figure 3. MAJOR STRUCTURAL FEATURES AND GEOPHYSICAL PATTERNS IN THE REGION OF THE DIAMOND BREAKS WILDERNESS STUDY AREA.



B. Complete Bouguer gravity anomaly map. Contour interval 5 mGal. Gravity locations occupied in this study shown by dots. Regional contours from Behrend and Bajwa (1974).

Figure 3. MAJOR STRUCTURAL FEATURES AND GEOPHYSICAL PATTERNS IN THE REGION OF THE DIAMOND BREAKS WILDERNESS STUDY AREA—Continued



Geology adapted from Rowley and others, 1985

EXPLANATION

Tb	**Mostly Browns Park Formation**
Pz	**Mostly Paleozoic Formations**
Y	**Middle Proterozoic (Unita Mountain Group)**
A	**Archean**

Geologic contact

Fault

Thrust Fault, teeth on upthrown side

C. Concentration of lineaments with azimuths in the range N. 5–35° E. in Landsat multispectral scanner (MSS) images. Contour interval 2 lines per 100 square kilometers.

Figure 3. MAJOR STRUCTURAL FEATURES AND GEOPHYSICAL PATTERNS IN THE REGION OF THE DIAMOND BREAKS WILDERNESS STUDY AREA.—Continued

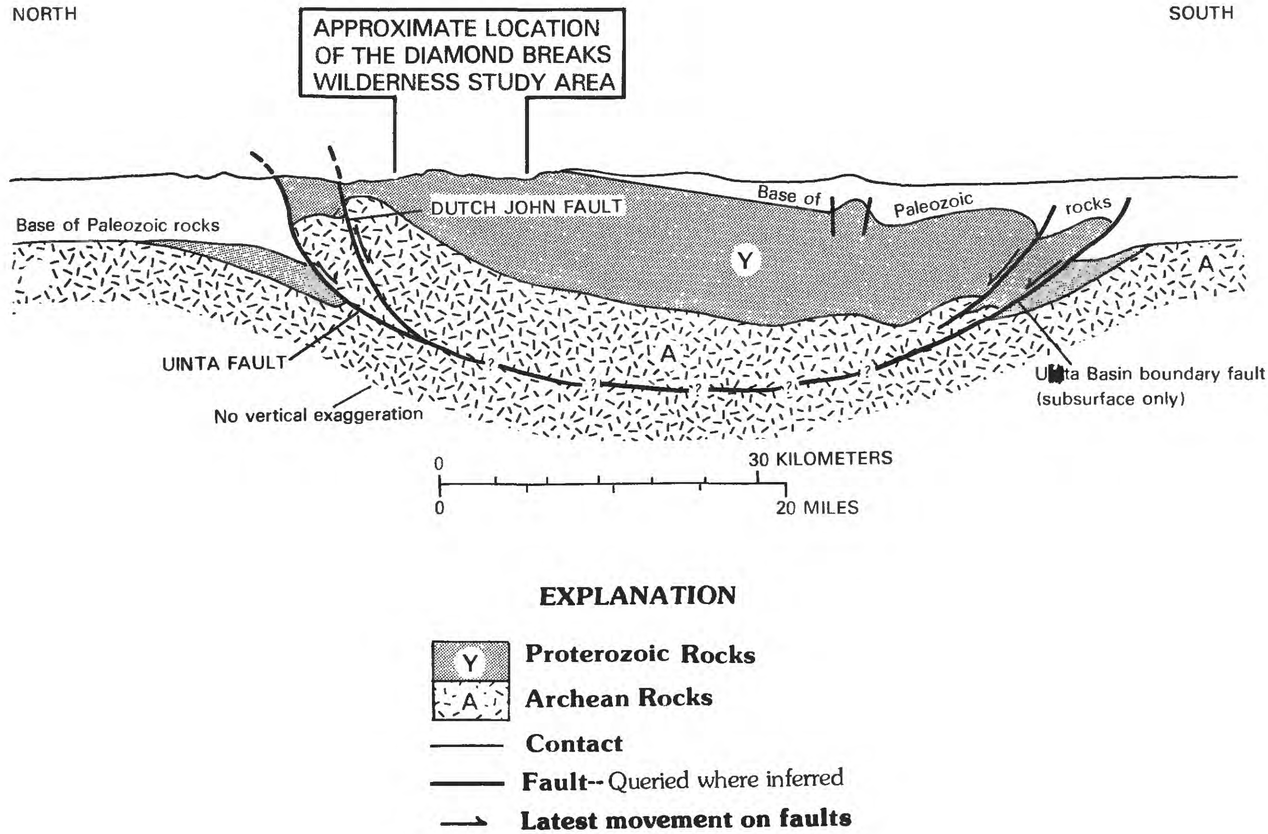


Figure 4. Probable deep structure in the general region of the Diamond Breaks Wilderness Study Area. Taken from Hansen (1986a, fig. 26). Line of section is approximately 10 miles west of study area.

abundance of vertical conduits) with a possible buried intrusive may account for a gold and arsenic chemical anomaly noted in the breccia zones (see below).

Mineral and Energy Resource Potential

Gold in Breccia Zones

Four short, narrow, northeast-trending silicified and brecciated zones were noted in the central part of the wilderness study area (pl. 1). A sample from one of these zones contained detectable gold (sample BM18, pl. 1). Nearby, to the southeast, three other exposed breccia zones are also weakly silicified and locally limonitic; samples from two of them (samples GS21 and GS22, pl. 1) contained detectable arsenic, a common "pathfinder" element in low-temperature gold deposits. The breccia clasts are locally derived (they are sandstone of the Uinta Mountain Group) and no sulfides or other unusual minerals were noted in any of the zones. The brecciated zones are oriented about N. 35–40° E., stand near vertical, and are about 1 ft thick and 2,500 ft long. Sample GS12 (pl. 1) was also brecciated; it was collected from float (that is, it was not found in place in bedrock) and suggests that more breccia zones than those mapped may be present in the study area. Neither sample GS12 nor sample GS18 contained anomalous metal concentrations. The magnetic low seen in this area (feature A, fig. 3*A*) suggests that mineralization in these zones could be related to igneous intrusion at depth.

Because the breccia zones are small and their metal content low, the resource potential of gold in breccia in the north-central part of the study area is judged to be low at certainty level B (see definitions in Appendix).

Gold Placers in Green River Sediments

Trace placer gold was observed in the heavy mineral fraction of five stream-sediment samples collected along the northern boundary of the study area (samples BD08, BD11–14, pl. 1). The gold is present as fine flour in these sediments which were most likely deposited by the Green River. Such gold has been known in the Green River alluvium since at least the turn of the century (Hansen, 1965, p. 183). Sample DB11 contained anomalous amounts of tin, as well as visible gold. The source of the tin, like the source of the gold, presumably lies upstream in the Green River drainage.

The low tenor of these deposits coupled with only minor quantities of Green River sediment within the boundaries of the study area suggest a low resource potential at certainty level C for gold in alluvium in the northern part of the study area.

Uranium in the Browns Park Formation

The Browns Park Formation locally hosts "pene-concordant sandstone-type" uranium deposits (Craig and others, 1982, p. 15). There are known uranium occurrences in the formation on the north side of Browns Park a few miles north of the study area, but a more favorable area for deposits is near the center of Browns Park where the formation is thickest (Craig and others, 1982, p. 18).

The nearest known commercial uranium deposits lie east of Maybell, Colo., some 55 mi to the east of the study area, where over 5,000,000 pounds of uranium, as U_3O_8, have been produced (Chenoweth, 1986, p. 291). The deposits apparently formed when hydrocarbon-bearing (reducing) solutions from the underlying Cretaceous rocks migrated into the Browns Park Formation and encountered internally derived uranium-bearing (oxidizing) solutions, thus chemically precipitating the uranium (Chenoweth, 1986, p. 290).

Within the study area, uranium in a tuffaceous sample of the Browns Park Formation collected from the northwest corner of sec. 29, T. 10 N., R. 103 W. (sample GS01, Chokecherry Draw) was slightly high at 6.38 ppm. In addition, slight but widespread bleaching along joints in the sandstone of the Uinta Mountain Group suggests the possible former presence of reducing solutions in the Browns Park. However, radioactive surveys by hand-held scintillometer ecorded no readings over the Browns Park Formation in the study area higher than twice the regional background (about 150 counts/sec.).

Because the Browns Park has been severely eroded within the study area and because no hydrocarbon-bearing rocks lie in contact with it there, the resource potential for uranium in the study area is rated low at certainty level C.

Stratiform Copper, Lead, and Zinc in the Uinta Mountain Group

Thick, red, sandy units ("redbeds") the world over are persistent features of rock sequences containing sediment-hosted stratiform deposits of copper, lead, and zinc. These deposits can range from miniscule to giant and generally occur as sheet-like (stratiform) disseminations of metal sulfides. A preferred locus of deposition is in or near organic-rich (chemically reduced) sediment interbedded with the redbeds (Gustafson and Williams, 1981). As a thick redbed, the Uinta Mountain Group constitutes a possible host of such deposits.

Important features of sediment-hosted stratiform deposits are missing within the study area, however. In addition to the need for nearby organic-rich sediment, which provides the chemical reductants needed to form such a deposit, Gustafson and Williams (1981) cited a close association of stratiform deposits with both basaltic rocks (the probable metal source) and evaporitic rocks (which provide the brines to move the metals from source to deposit). Neither basaltic nor evaporitic rocks are known in the Uinta Mountain Group, although the middle unit of the group in the study area is chemically reduced (gray color). However, no evidence of stratiform sulfide mineralization was observed anywhere in the study area, and stream-sediment analysis showed only normal levels of base metals in stream courses draining the area.

Because the Uinta Mountain Group lacks intercalated beds of volcanic or evaporitic rocks, the mineral resource potential for stratabound copper, lead, and zinc in the study area is rated low at certainty level B.

Other Metals

Evidence for the occurrence of other base, precious, and ferrous metals in the study area is lacking. Neither mineralization (or associated rock alteration) nor geochemical and geophysical anomalies (other than those noted in the discussion of the gold and uranium resource above) were observed within the study area. Therefore, the resource potential for other metals is rated low at certainty level B.

Oil and Gas in Subthrust Foreland Fault Plays

Oil and gas fields in the Uinta Mountains and nearby White River uplift produce from reservoirs developed in Pennsylvanian, Permian, Triassic, Jurassic, Cretaceous, and Tertiary rocks (Osmond, 1986). Spencer (1983a, b) rated the petroleum potential of the study area as zero, largely because of the absence of such strata there. Such strata do occur locally below the reverse flanking faults bounding the eastern Uinta Mountains where they constitute "subthrust foreland fault plays." Powers (1986) described such a play along the Willow Creek fault some 30 mi south of the study area. Although this play produced oil shows, Powers concluded that the play was too restricted to justify economic exploration.

Similar plays within the study area are highly unlikely. Hansen (1986a, fig. 26) suggested that the eastern Uinta Mountains may rest at depth on a low-angle detachment surface formed by convergence of the flanking faults (fig. 4), but he shows this surface lying at a minimum of 9 mi below the study area, too deep for the occurrence of oil and gas. Although gravity data (fig. 3*B*) suggest that the northern flanking faults (Uinta fault) may dip south at a shallower angle than that shown in figure 4, the depth of the detachment surface below the study area must still be substantial. Whatever the actual depth, the geophysical data do not support the possibility that large slivers of petroliferous reservoir rocks have been placed deep along this surface during mountain-building adjustments.

Because possible reservoir rocks for oil and gas are believed to not exist at depth, the resource potential for oil and gas in the study area is rated as low at certainty level B.

Other Resources

In addition to resources discussed above, Hansen (1965) lists coal, manganese, phosphate, barite, clay and shale, tuff (volcanic ash), limestone, commercial-grade silica, and gypsum as resources in the region northwest of the Diamond Breaks Wilderness Study Area. However, because coal, manganese, phosphate, clay and shale, limestone, and gypsum deposits are apparently restricted to rocks (Hansen, 1965, p. 182–187) which, by virtue of long-continued erosion do not now occur in the study area, the mineral resource potential for these materials is rated as no potential at certainty level D.

Tuff (pumicite) occurs in the Browns Park Formation; but, as in the case of the uranium deposits, the severely eroded nature of the formation within the study area greatly reduces the likelihood of the occurrence of tuff there. The mineral resource potential for pumicite is rated as low at certainty level C.

Small deposits of barite and large deposits of commercial-grade silica crop out in the Archean rocks which form the basement complex on which sandstones of the Uinta Mountain Group rest. Such deposits in the study area, if present, would likely lie at depths in excess of 2 mi (below the Archean-Proterozoic contact in fig. 4). Because there is no adequate basis for assessing their presence at such depths, the mineral resource potential for barite and silica is rated as unknown at certainty level A.

Recommendations for Further Study

The heretofore unrecognized occurrence of gold-bearing breccia in the Diamond Breaks Wilderness Study Area should be confirmed by detailed follow-up work on distribution, size, and tenor of these resources, both within and without the study area.

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APPENDIX

DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

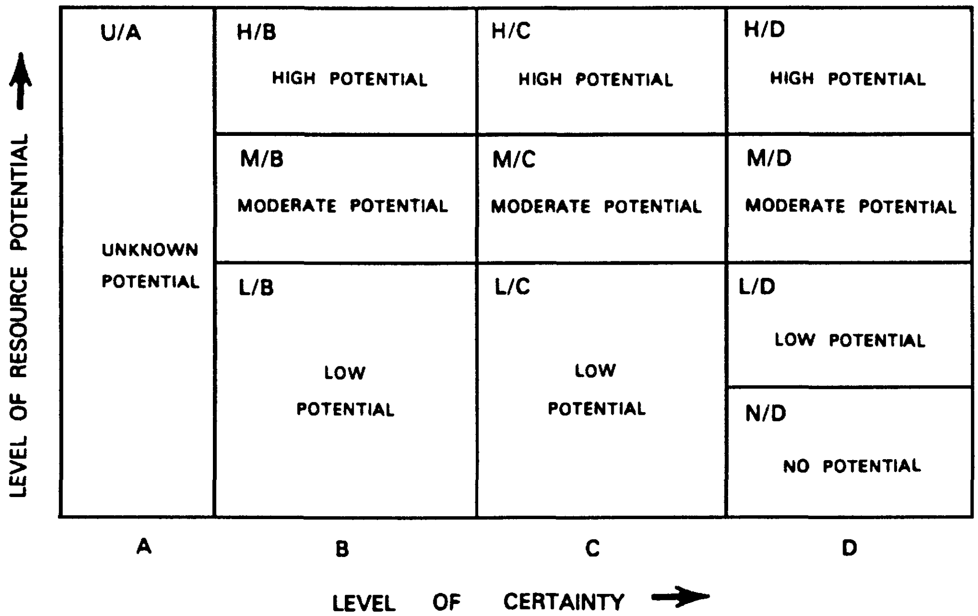
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

Abstracted with minor modifications from:

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

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

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RESOURCE / RESERVE CLASSIFICATION

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

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

GEOLOGIC TIME CHART

Terms and boundary ages used in this report

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

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

[2] Informal time term without specific rank.

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[Letters designate chapters]