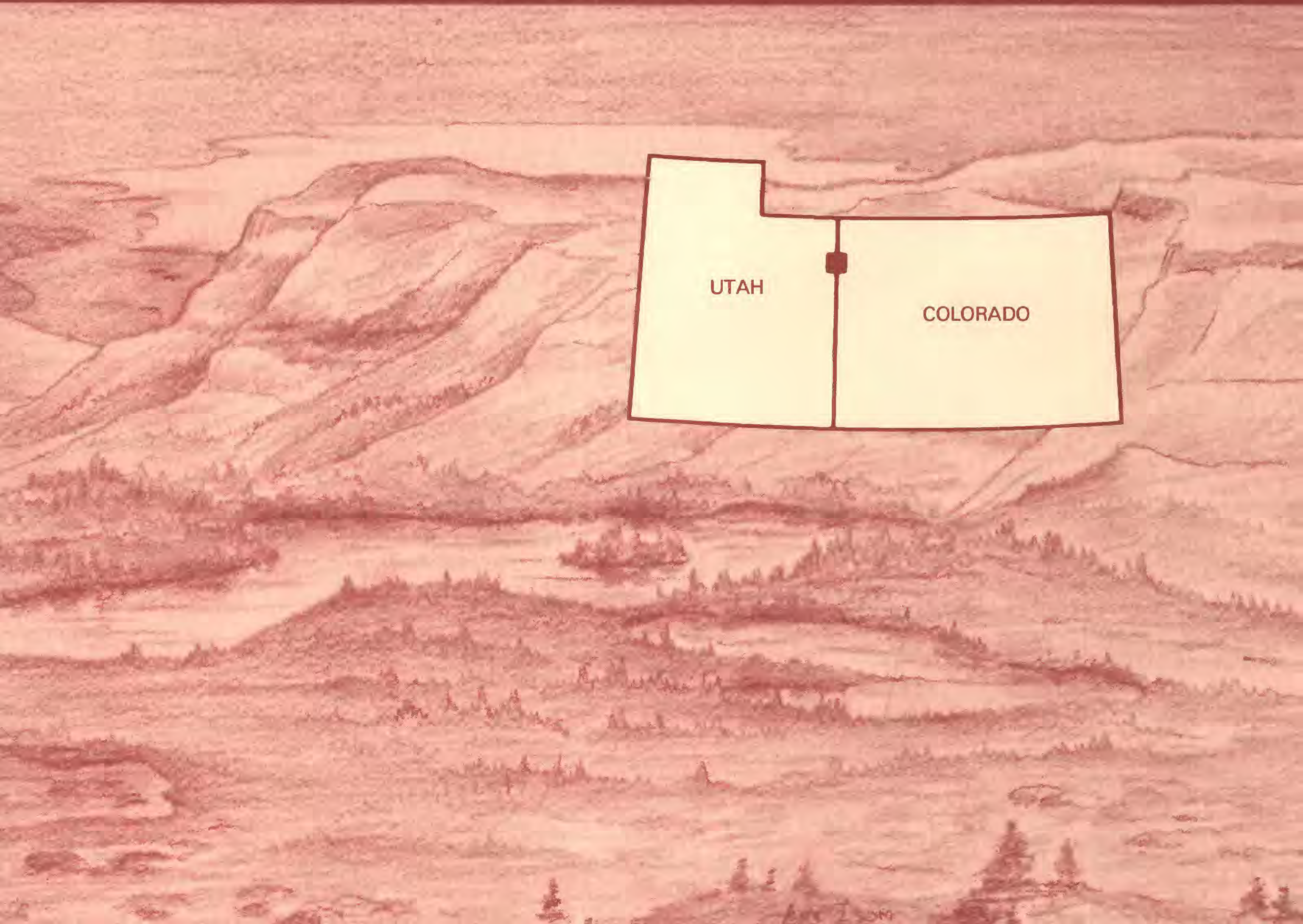
# Mineral Resources of the Bull Canyon Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah

## U.S. GEOLOGICAL SURVEY BULLETIN 1714–A



# 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.

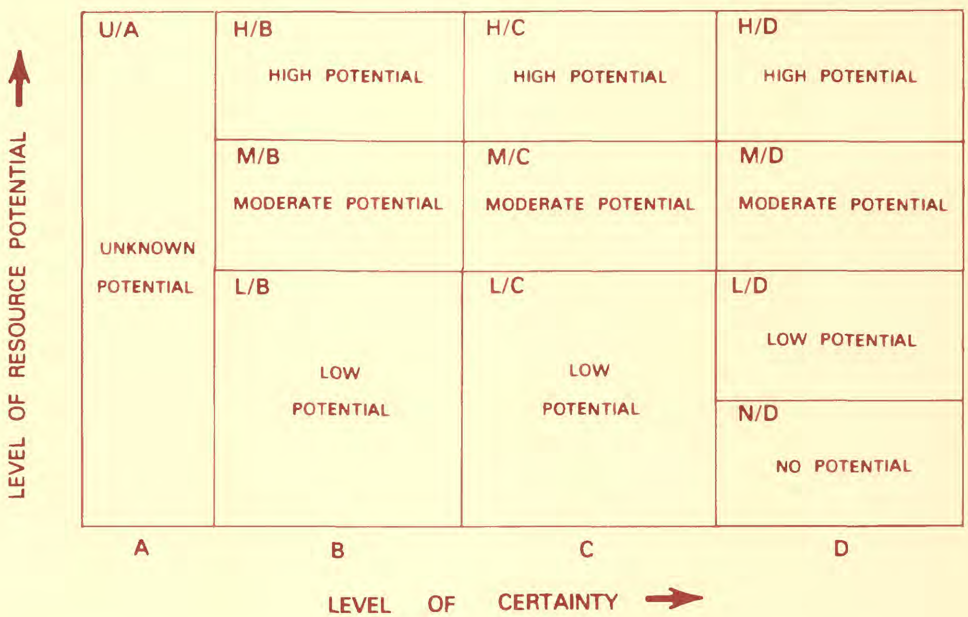
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

Goudarzi, G. H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84–0787, p. 7, 8.

Chapter A

# Mineral Resources of the Bull Canyon Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah

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U.S. GEOLOGICAL SURVEY BULLETIN 1714

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
BULL CANYON AND DIAMOND BREAKS, COLORADO AND UTAH

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1987

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

**Library of Congress Cataloging in Publication Data**

Mineral resources of the Bull Canyon Wilderness study area, Moffat County, Colorado, and Uintah County, Utah.

(Mineral resources of wilderness study areas—Bull Canyon and Diamond Breaks, Colorado and Utah ; chapter A)
Bibliography: p.
Supt. of Docs. No.: I 19.3:1714–A
1. Mines and mineral resources—Bull Canyon Wilderness (Colo. and Utah) 2. Geology—Bull Canyon Wilderness (Colo. and Utah) 3. Bull Canyon Wilderness (Colo. and Utah).
I. Soulliere, Sandra J. II. Series.
TN24.C6M48 1986 553'.09788'12 86–600204

## STUDIES RELATED TO WILDERNESS

### Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of part of the Bull Canyon (CO-010-001/UT-080-419) Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah.

## RESOURCE / RESERVE CLASSIFICATION

<table>
<tr><th rowspan="3"></th><th colspan="3">IDENTIFIED RESOURCES</th><th colspan="2">UNDISCOVERED RESOURCES</th></tr>
<tr><th colspan="2">Demonstrated</th><th rowspan="2">Inferred</th><th colspan="2">Probability Range<br>(or)</th></tr>
<tr><th>Measured</th><th>Indicated</th><th>Hypothetical</th><th>Speculative</th></tr>
<tr><td>ECONOMIC</td><td colspan="2">Reserves</td><td>Inferred Reserves</td><td rowspan="3" colspan="2"></td></tr>
<tr><td>MARGINALLY ECONOMIC</td><td colspan="2">Marginal Reserves</td><td>Inferred Marginal Reserves</td></tr>
<tr><td>SUB-ECONOMIC</td><td colspan="2">Demonstrated Subeconomic Resources</td><td>Inferred Subeconomic Resources</td></tr>
</table>

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.

# CONTENTS



PLATE



FIGURES

# Mineral Resources of the Bull Canyon Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah

*By* Sandra J. Soulliere, Mark A. Arnold, *and* Dolores M. Kulik, U.S. Geological Survey *and* Terry J. Kreidler, U.S. Bureau of Mines

## SUMMARY

In 1984, the U.S. Geological Survey and the U.S. Bureau of Mines studied 11,690 acres of the Bull Canyon (CO-010-001/UT-080-419) Wilderness Study Area in Moffat County, Colorado, and Uintah County, Utah. The area studied has no identified resources and a low mineral resource potential for undiscovered resources including all metals, uranium, and oil and gas (fig. 1). Located about 2 mi (miles) north of Dinosaur, Colo., the study area is accessible from the main road that leads to the canyon section of Dinosaur National Monument and from several small private roads and jeep trails (fig. 1).

Rimrock escarpments and steep canyons characterize the topography of the study area. Elevation ranges from 5,700 ft (feet) at the mouth of Bull Canyon to 7,400 ft at the northeastern boundary. The study area is on the southern flank of the Uinta anticline, in the northeastern part of the Colorado Plateau geologic province. Striking cliffs and beautiful canyons were formed by deep erosion of mostly flat lying Triassic through Cretaceous (about 240 to 60 m.y. or million years; see geologic time chart on last page of this report) sedimentary rocks. The axis of the Buckwater Ridge syncline passes north of the study area, and the Willow Creek anticline crosses the area. Beds dip no more than a few degrees near the crests of both folds. The surface geologic data do not clearly indicate the subsurface structure of the study area. Models of the subsurface geology were created using gravity data, well-log data, and previous geologic mapping. These models show a low-angle fault (Willow Creek fault) approaching the surface approximately 3 mi south and 1–2 mi west of the study area.

No mines, prospects, or other mineral-related workings were found in or within 2 mi of the study area. The entire study area, except for a tract of privately owned land near the center, was under oil and gas lease as of August 1984, but no drilling has been done and no evidence of exploration was found. Analysis of samples taken from the Glen Canyon Sandstone, the purest sandstone cropping out in the study area, showed it to be unsuitable for use in making glass. The sandstone is suitable for use as foundry sand, fracturing sand, and abrasive sand. However, there is currently no local market for these materials, and high transportation costs preclude shipment of the material very far.

No metallic mineral occurrences were identified at the ground surface, and the geochemical samples collected during this investigation contained no anomalous concentrations of any metals. Therefore, the mineral resource potential is low for all metallic minerals. Although uranium deposits are known 10–15 mi east of the study area in the Jurassic (205–138 m.y.) Morrison Formation, no surface evidence of uranium mineralization was noted during the field investigations, and no uranium was detected in the geochemical samples. Therefore, the study area is judged to have low mineral resource potential for uranium.

The study area has low mineral resource potential for oil and gas. The Middle Pennsylvanian (about 330 to 290 m.y.) Weber Sandstone may be present beneath the study area, but its oil and gas potential is unknown. Most of the oil at the Rangely oil field, 12 mi to the southeast, was produced from the Weber. Geophysical data and data from one well drilled in sec. 3, T. 5 N., R. 103 W., indicate that oil and gas may occur beneath the study area in folded Permian-Pennsylvanian sedimentary rocks. Well-log records for wells drilled within a 6-mi radius of the study area show traces of oil in drill cuttings, but no drill-stem tests were made. An accurate profile of subsurface structure is needed to delineate areas of oil and gas potential in the Weber.

## INTRODUCTION

The U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) studied 11,690 acres of the Bull Canyon (CO-010-001/UT-080-419) Wilderness Study Area in Moffat County, Colorado, and Uintah County, Utah (fig. 1). The study of this acreage was requested by the U.S. Bureau of Land Management (USBLM). In this report the studied area is called the "wilderness study area" or simply the "study area." Located about 2 mi

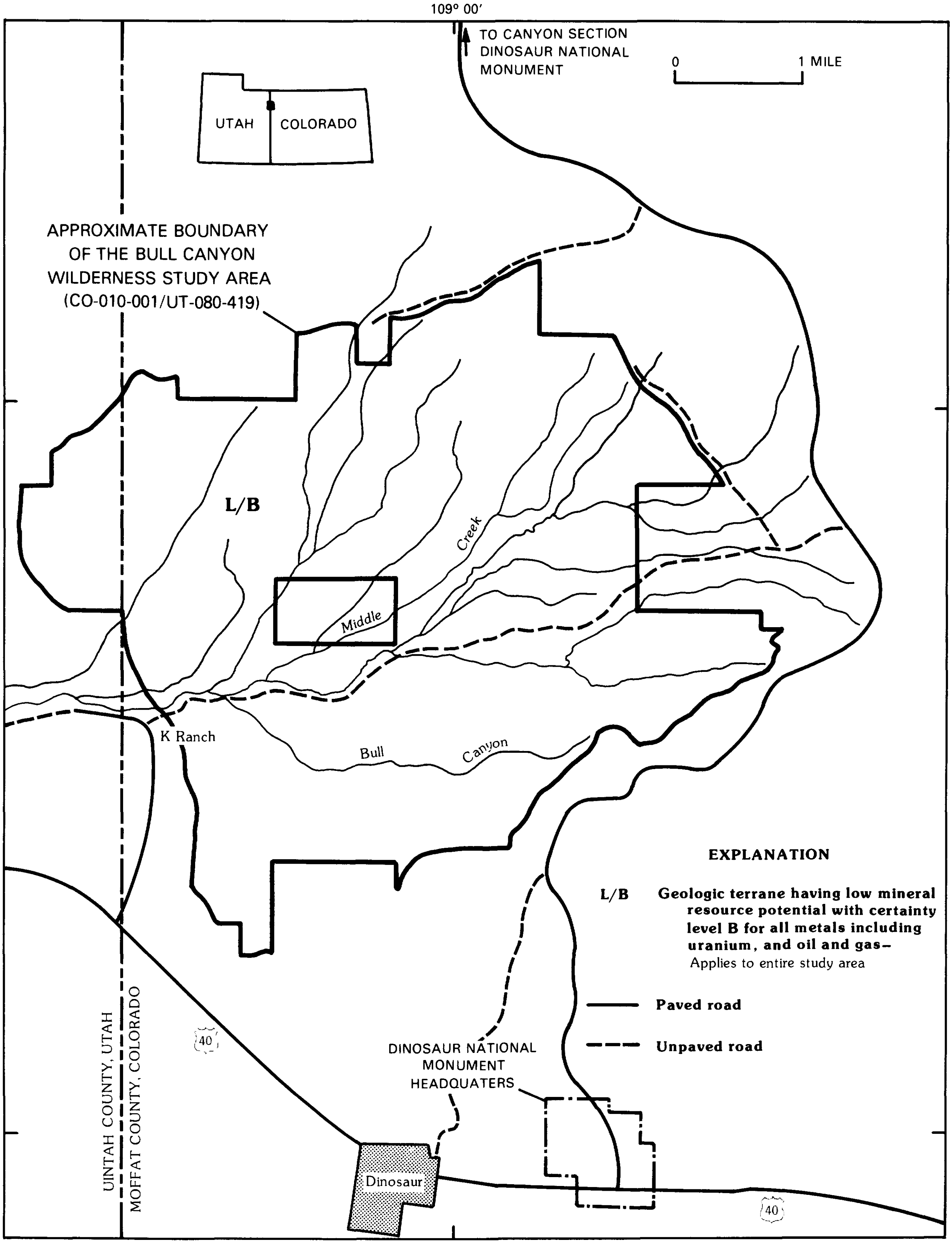



**Figure 1.** Mineral resource potential and index map of the Bull Canyon Wilderness Study Area, Moffat County, Colorado, and Uintah County, Utah.

north of Dinosaur, Colo., the study area is accessible from several small private roads and jeep trails. Access is also from the main road to the canyon section of Dinosaur National Monument. Picnic overlooks along this road afford scenic views of the study area. Striking cliffs and canyons, formed by the erosion of sedimentary rocks, characterize the topography of this area, which is in the Colorado Plateau geologic province. Elevations range from 5,700 ft at the mouth of Bull Canyon to 7,400 ft at the eastern boundary.

### Investigation by the U.S. Bureau of Mines

Before starting fieldwork, USBM personnel reviewed various sources of minerals information including published and unpublished literature, USBM files, and mining-claim and oil-and-gas lease records at the USBLM state offices in Denver, Colo., and Salt Lake City, Utah. Discussions on the mineral resources of the study area were held with USBLM personnel at the district office in Craig, Colo.

Fieldwork, completed in about 10 employee-days in June 1984, consisted of traverses across the study area by vehicle and on foot. A scintillometer was carried on all traverses to detect any radioactivity above background levels. Nine samples of the Glen Canyon Sandstone (pl. 1) were analyzed for silica, iron oxide, alumina, and chromium content by inductively coupled plasma, atomic-absorption, and wet chemical methods. They were also analyzed for 40 elements by semiquantitative optical emission spectroscopy. Complete USBM analytical data are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

### Investigation by the U.S. Geological Survey

S. J. Soulliere and M. A. Arnold reviewed published and unpublished information about the Bull Canyon Wilderness Study Area, compiled and field checked existing geologic maps, and collected stream-sediment samples for geochemical analyses. Jane Olson helped collect stream-sediment samples; R. B. Vaughn and P. H. Briggs analyzed the samples. D. M. Kulik collected data from 77 new gravity stations and compiled a gravity map of the area. The mineral resource potential of the study area was assessed and classified using the system of Goudarzi (1984) (see inside front cover of this report).

## APPRAISAL OF IDENTIFIED RESOURCES

### By Terry J. Kreidler, U.S. Bureau of Mines

### Mining Activity

No mines, prospects, or other mineral-related workings were found inside or within 2 mi of the study area. The nearest mining activity occurred in the late 1950's, when small amounts of uranium were mined from the Jurassic Morrison and Cretaceous Dakota Formations 10 to 15 mi east of the study area.

### Metallic and Nonmetallic Minerals

No evidence of any type of mineral-deposit workings was found in or near the study area. Analysis showed the samples of Glen Canyon Sandstone (the purest sandstone cropping out in the study area) to be unsuitable for use in making glass because of the high iron, chromium, and aluminum content (Kreidler, 1985, table 1). The sandstone is suitable for use as foundry sand, fracturing sand, and abrasive sand according to criteria described by Bates (1960). Currently, there is no local market for these materials, and high transportation costs preclude shipment of the material very far. The formation crops out over an extensive area of the Colorado Plateau and thus is readily available closer to prospective markets.

The Morrison Formation in the study area lacks the characteristics that are associated with the formation of uranium deposits such as carbonaceous material, clay galls, and petrified wood. Nevertheless, several traverses were made with a scintillometer across Morrison outcrops in the study area; they indicated no radioactivity above the background levels obtained over the Glen Canyon Sandstone, a nonuraniferous unit.

### Oil and Gas

The entire study area, except for a tract of private land near the center, was under oil and gas lease as of August 1984 (fig. 2). No drilling has been done and no evidence of exploration-related activity was found. The Rangely oil field is 12 mi southeast of the study area. It is the largest field in Colorado and produces from the Middle Pennsylvanian Weber Sandstone. The Weber Sandstone underlies the study area at a depth of approximately 2,500-3,000 ft. According to Spencer (1983), the Weber is exposed on the eastern flank of the Skull Creek anticline, about 10 mi east of the study area. Because the Weber is exposed, its reservoir pressure is lower and thus its potential for hydrocarbons is reduced. Spencer rated the petroleum potential as low. However, if the Willow Creek anticline is a separate structure from the Skull Creek anticline, as Rowley and Hansen (1979) suggested, the petroleum potential may not be affected by the exposure of the Weber and may merit further exploration. This structural interpretation may explain the extensive leasing of the land in and near the study area for oil and gas exploration. A check of well-log records for wells drilled within a 6-mi radius of the study area showed that although traces of oil were present in drill cuttings, no drill-stem tests were made. The nearby wells were plugged and abandoned.

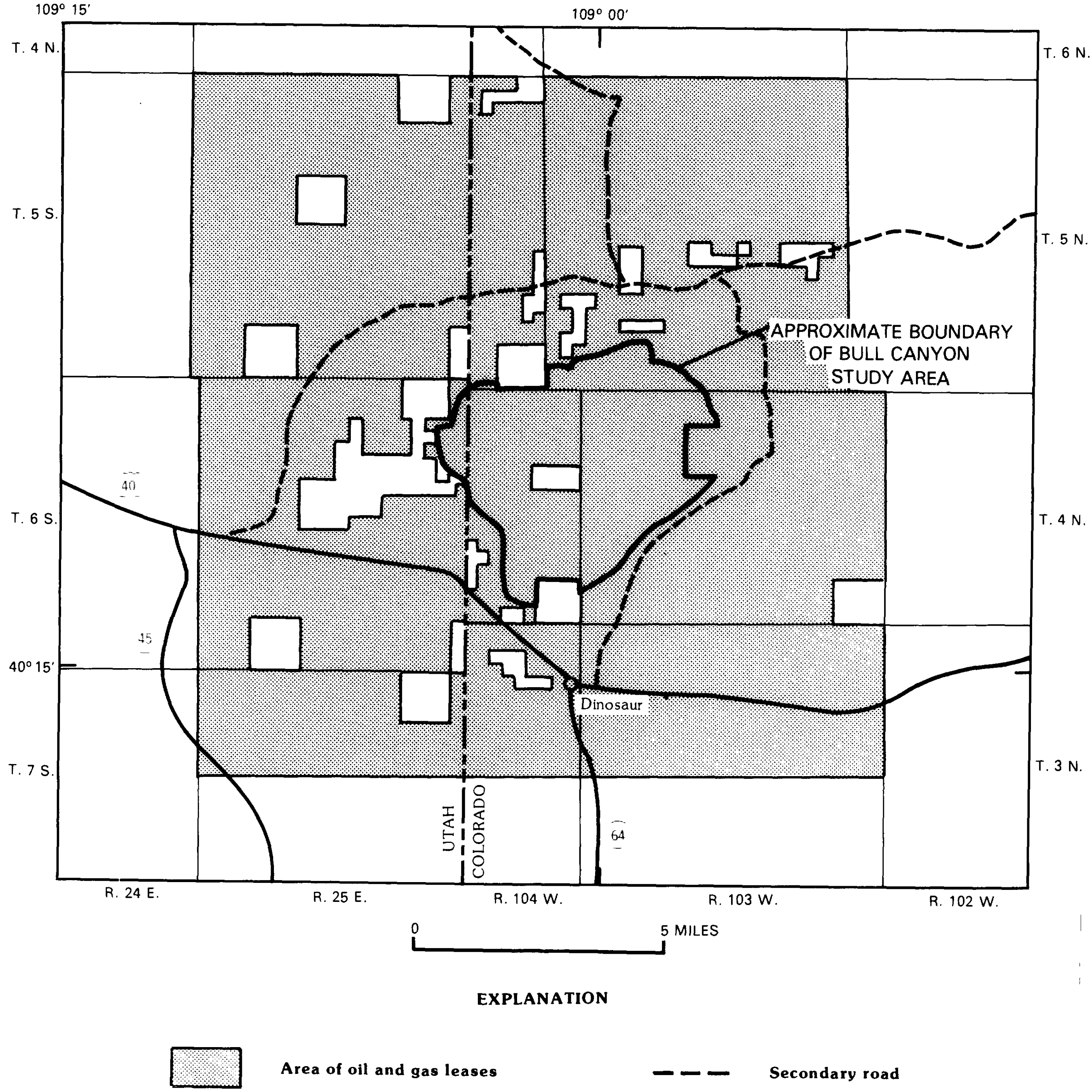



**Figure 2.** Oil and gas leases in and near the Bull Canyon Wilderness Study Area, Colorado and Utah.

## ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES


## By Sandra J. Soulliere, Mark A. Arnold, and Dolores M. Kulik, U.S. Geological Survey


## Geology

### Geologic Setting

The Bull Canyon Wilderness Study Area is on the southern flank of the Uinta anticline, in the northeastern part of the Colorado Plateau geologic province. This fold extends east from the Uinta Mountains. The study area is underlain by mostly flat lying Triassic through Cretaceous sedimentary rocks that have been differentially eroded to form massive cliffs and steep canyons. In ascending order, the formations exposed in the study area are the Glen Canyon Sandstone, Carmel Formation, Entrada Sandstone, Stump Formation, Morrison Formation, Cedar Mountain Formation, and Dakota Sandstone (pl. 1). Locally, surficial landslide deposits have accumulated below steep slopes that are underlain by soft incompetent rocks. Alluvium covers valley floors.

Two plunging folds make up the surface structure; the Buckwater Ridge syncline passes north of the study area, and the Willow Creek anticline crosses the area. Beds dip no more than a few degrees near the crest and trough of these folds; according to Rowley and Hansen (1979), the Willow Creek anticline is almost a monocline. These types of folds are common in the eastern Uinta Mountains.

The subsurface structure of the study area is obscure from the surface geologic data. We relied on data from one exploratory well (Tenn Gas Trans Co 1-A Hicks-Government) drilled for oil about 3 mi south of the study area (sec. 3, T. 5 N., R. 103 W.). The interpretation of these data by Anderman (1961) indicated that a low-angle, north-trending reverse fault (Willow Creek fault) associated with a major fold may be present at depth. Rowley and Hansen (1979) stated that the displacement along this fault probably accounts for the folding of the Willow Creek anticline.

### Description of Rock Units

The following description of rock units was modified from Rowley and Hansen (1979). The Upper Triassic Chinle Formation is confined to the subsurface of the study area. It consists of red and pink to light-gray and light-green, thin- to medium-bedded siltstone, ripplemarked and crossbedded, and fine-grained sandstone, claystone, and shale. The Chinle is conformable with the overlying Glen Canyon Sandstone (Lower Jurassic and Upper Triassic). The Glen Canyon Sandstone consists of pink, light-gray, and buff, thin- to medium-bedded sandstone, crossbedded and fine to medium grained. Thickness is about 650 ft. An unconformity marks the contact of the Glen Canyon Sandstone with the overlying Carmel Formation. The Jurassic Carmel Formation is about 60 ft thick at Plug Hat Rock. It consists of red to dark-red, thin- to medium-bedded sandy shale, fine- to medium-grained sandstone, siltstone, and mudstone. Locally the Carmel contains thin beds of light-yellow sandstone, light-gray gypsum, and red and gray siltstone and shale.

The Jurassic Entrada Sandstone is conformable with the Carmel Formation. The Entrada is about 120 ft thick and consists of gray, buff, and pink, medium- to thick-bedded, crossbedded, fine- to medium-grained sandstone. The Jurassic Stump Formation unconformably overlies the Entrada Sandstone; the two formations have been mapped together at some localities. According to Rowley and Hansen (1979), the Stump Formation is divisible into the Middle Jurassic Curtis Member and the Upper Jurassic Redwater Member. The Curtis Member, about 30 ft thick, consists of light-gray or greenish-gray, thin- to medium-bedded sandstone, crossbedded and medium to coarse grained. The sandstone is fossiliferous and glauconitic, and it commonly contains clay galls and carbonaceous plant trash. The Redwater Member is about 110 ft thick and overlies the Curtis Member. The Redwater Member consists of light-green, mostly fissile glauconitic shale and siltstone with sparse interbeds of sandy glauconitic oolitic limestone and fossiliferous sandstone. The limestone beds are tan, purplish-gray, and greenish-gray, thin-bedded, locally ripplemarked, and vaguely crossbedded. Some limestone beds are composed of a coquina of oysters, clams, and belemnites.

The Jurassic Morrison Formation has an estimated thickness of 650 ft and is unconformable with the underlying Stump Formation. The Morrison Formation consists of gray, light-purple, and bluish-gray shale, claystone, and siltstone interbedded with medium-bedded, crossbedded, fine- to coarse-grained sandstone with local conglomerate and limestone. The Cretaceous Cedar Mountain Formation unconformably overlies the Morrison Formation. The Cedar Mountain Formation consists of gray to tan, medium-bedded, crossbedded sandy pebble conglomerate, and fine- to coarse-grained sandstone overlain by gray shale, mudstone, and limestone. Thickness of the formation is estimated at 100–200 ft. The Cretaceous Dakota Sandstone is about 40 ft thick and unconformably overlies the Cedar Mountain Formation. The Dakota consists of light-gray to light-yellow, medium- to thick-bedded sandstone, crossbedded and medium to coarse grained, and pebbly medium- to coarse-grained sandstone, and less abundant pebble conglomerate.

Most of the northern and western part of the study area is covered by a landslide of rotated blocks and boulders of the Cedar Mountain Formation. A smaller volume of debris is derived from the Dakota Sandstone. All of this material is enclosed in a matrix of light-gray to light-greenish-gray clay of the Morrison Formation. The slide has a maximum thickness of 150 ft and contains the hummocky topography and abundant springs that characterize many landslides.

Poorly sorted sand, silt, and gravel were deposited in channels, flood plains, and intermittent tributary streams in the study area. Alluvial slope wash and colluvium were deposited on and below steep slopes adjacent to streams.

## Geochemistry

### Analytical Methods

Stream-sediment samples were collected from 22 sites in the study area. Samples were taken from stream drainages that range from 1 to 3 mi in length. At each site, a panned-concentrate sample was prepared for analysis of the heavier metallic elements such as copper, lead, zinc, silver, and gold, and a separate fine-fraction sample of mud and clay was collected to analyze for metals such as molybdenum, uranium, and arsenic, which typically adhere to clay minerals.

Each panned-concentrate sample represents a composite of three to five grab samples of coarse stream sediment that was sieved in the field through a 10-mesh (0.039-inch) stainless-steel screen. The sediment was panned to reduce the amount of common rock-forming minerals, such as quartz and feldspar, and to create a concentrated sample. In the laboratory, samples were dried and sieved to minus-35 mesh (0.0165 inch), and a hand magnet was used to remove the magnetite. Bromoform (specific gravity 2.85) was used to separate the samples into light- and heavy-mineral fractions. The light-mineral fraction, which contained mostly quartz and feldspar, was discarded. The heavy-mineral fraction was separated with a magnetic separator, using a forward and side angle setting of 15°, at 0.2 A (amperes). The magnetic heavy-mineral fraction at 0.2 A, containing primarily magnetite and ilmenite, was discarded. The remaining nonmagnetic heavymineral fraction was separated electromagnetically at 0.6 A. The nonmagnetic heavy-mineral fraction at 0.6 A was analyzed for 31 elements by the semiquantitative, six-step, direct-current arc, optical emission spectrographic method, following the techniques of Grimes and Marranzino (1968).

A separate fine-fraction sample, about 25 ounces of clay and mud, was collected at each site. In the laboratory these samples were ground with a mortar and pestle to release clay-cementing aggregates and were then sieved to minus-100 mesh (0.0059 inch). Half of this fraction was analyzed for 44 elements using ICP (inductively coupled plasma atomic-emission spectroscopy). The procedure for ICP sample preparation and analysis followed the techniques of Taggart and others (1981). The remaining half of the fine fraction was analyzed for uranium and thorium with a pulsed laser fluorimeter following the procedures of Rose and Keith (1976).

The analytical data for each element were compiled as histograms to identify anomalous values. Analytical results for these samples are available for public inspection at the U.S. Geological Survey, MS 905, Building 25, Denver Federal Center, Denver CO 80225.

#### Results of Survey

The spectrographic analyses of the nonmagnetic heavy-mineral and fine-fraction samples identified no anomalous concentrations of metallic elements. The concentration of barium in the nonmagnetic heavy-mineral fractions was greater than 10,000 ppm (parts per million) and that of strontium ranged from 7,000 ppm to greater than 10,000 ppm. Both elements are distributed uniformly throughout the study area. The barium is present as barite, and the strontium is probably in the form of celestite ($SrSO_4$). Both minerals are commonly found in limestone and in the cement of sandstone rock types present in the study area. Fluorometric analyses of the fine fraction of stream sediments indicated no anomalous concentrations of uranium or thorium.

## Geophysics

#### Analytical Methods

Gravity studies were undertaken as part of the mineral resource assessment to provide information on the subsurface structure of the Bull Canyon Wilderness Study Area. In 1984, gravity measurements were made at 77 stations in and adjacent to the study area. These data were combined with selected data from files of the Defense Mapping Agency of the U.S. Department of Defense.

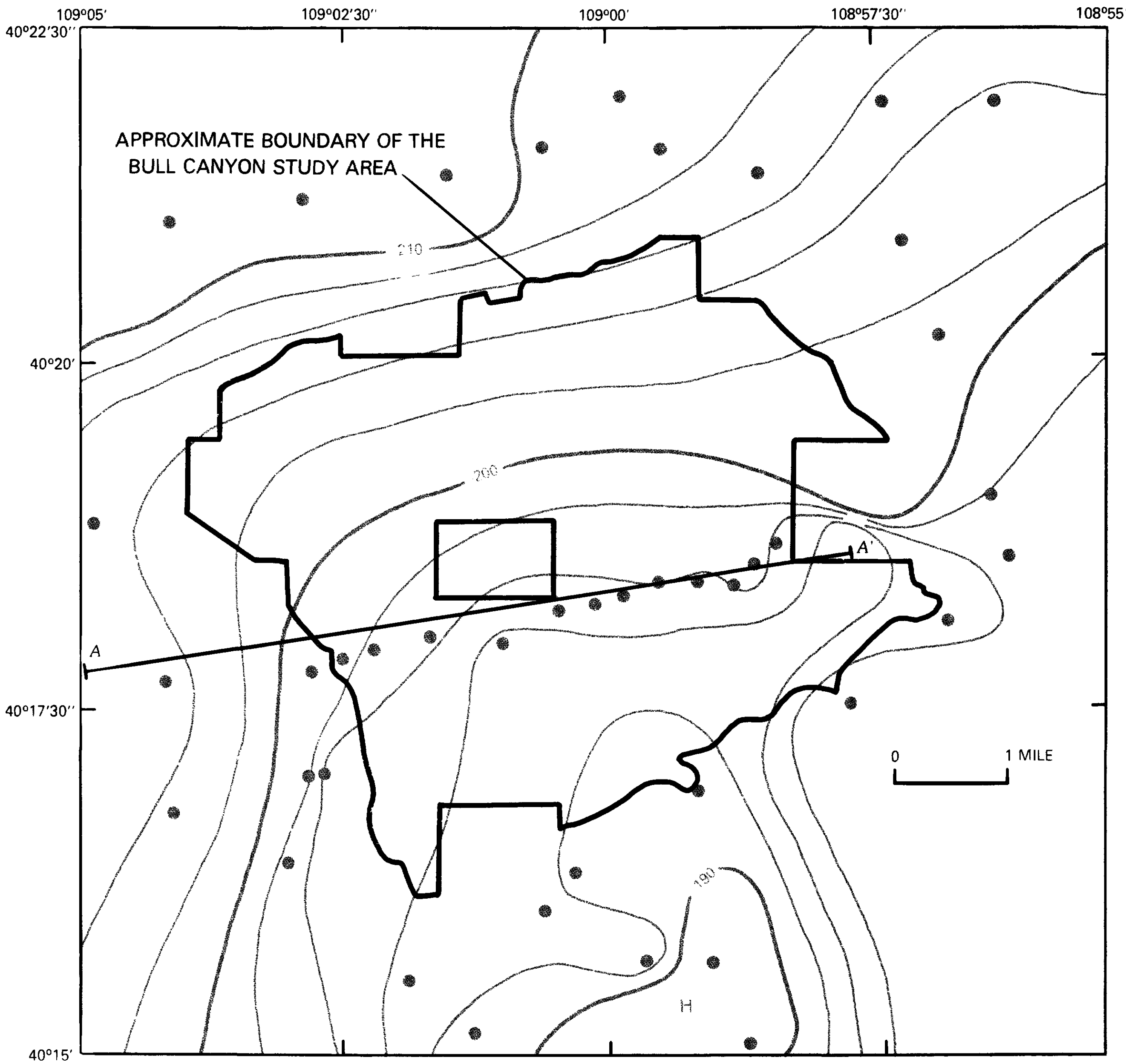
Bouguer gravity anomaly values were computed using the 1967 gravity formula (International Association of Geodesy, 1967) and a reduction density of 2.67 grams per cubic centimeter. Terrain corrections were made by computer for a distance of 100 mi from the station using the method of Plouff (1977). The data are shown contoured on figure 3*A*.

#### Results of Survey

The Bull Canyon Wilderness Study Area is underlain by nearly flat lying Phanerozoic sedimentary rocks over crystalline basement rocks that have been thrust south and west over the adjacent basin on the low-angle Willow Creek fault. This fault approaches the surface approximately 3 mi south (Cullins, 1969) and 1–2 mi west of the study area, based on the gravity data. A gravity gradient associated with the Buckwater Ridge syncline overwhelms the gravity pattern in all but the extreme southern part of the study area. No gravity anomaly is associated with the Willow Creek anticline. Therefore, the structural relief on the anticline is probably less than 300 ft.

A gravity model along profile line *A–A′* (pl. 3*B*) was calculated to determine the structural geometry and amount of overhang of the Willow Creek fault. The model is based on an assumed geologic cross section similar to that of Rowley and Hansen (1979), which was constructed using information from the Tenn Gas Trans Co 1-A Hicks-Government well in sec. 4, T. 3 N., R. 103 W. (pl. 1) approximately 3 mi south of the study area. The densities assumed are based on averages from unpublished sample measurements by the author (Kulik) and density logs in other locations having similar rocks.

The modeled profile used data obtained from stations along the only accessible route judged in the field to lie perpendicular to the Willow Creek fault at the western edge of the study area. The western part of the




**A**

**EXPLANATION**

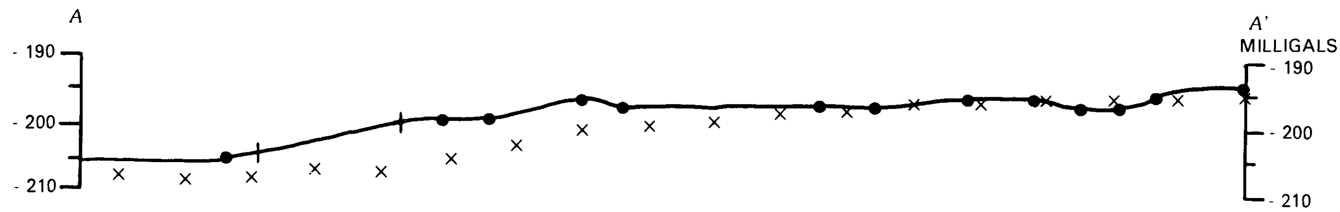
190 — **Gravity contour**—Contour interval 2 milligals

● **Gravity station**

H **Gravity high**

A—A' **Line of section shown on figure 3*B* and 3*C***

**Figure 3** (Above and following pages). Complete Bouguer gravity anomaly map and structural interpretations at the Bull Canyon Wilderness Study Area, Colorado and Utah. *A*, Complete Bouguer gravity anomaly map; *B*, Gravity profile along line *A–A'* and calculated model of structure (from Rowley and Hansen, 1979); *C*, Alternative structural models of gravity profile *A–A'*.

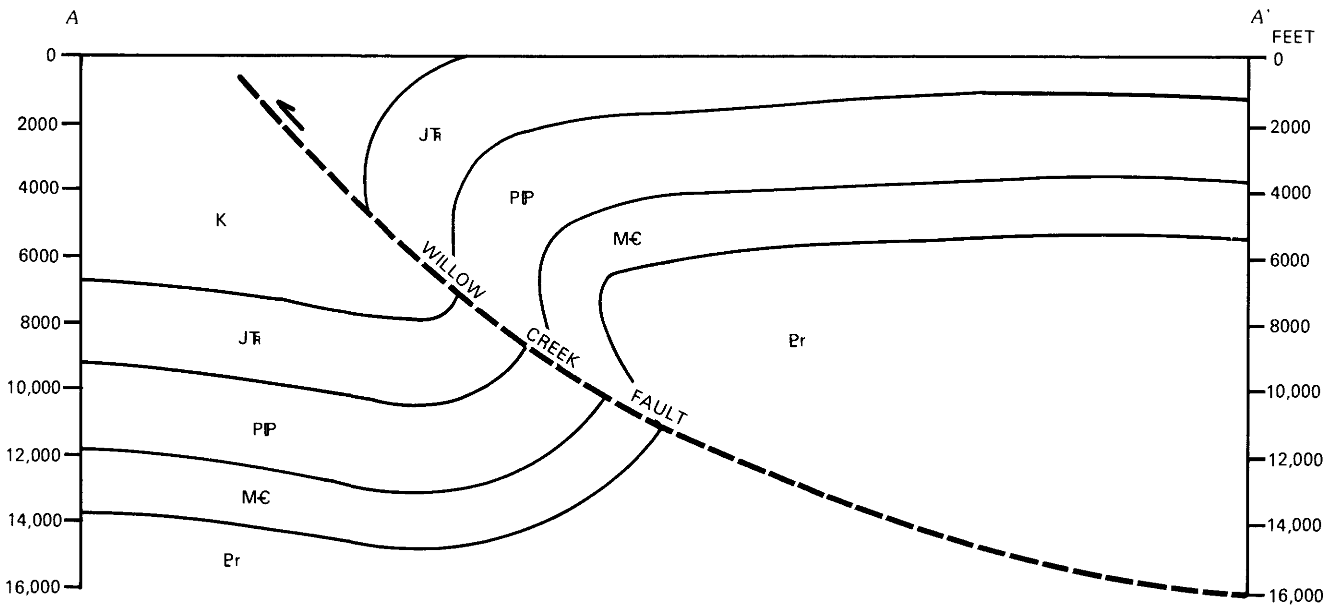



**EXPLANATION**

● **Observed gravity value**

| **Value derived from contours**

× **Calculated gravity value**




***B***

**EXPLANATION**

| | |
|---|---|
| K | **Cretaceous rocks, undivided. Assumed average density 2.51 g/cm$^3$** |
| J℟ | **Jurassic and Triassic rocks, undivided. Assumed average density 2.60 g/cm$^3$** |
| PIP | **Permian and Pennsylvanian rocks, undivided. Assumed average density 2.65 g/cm$^3$** |
| M€ | **Mississippian through Cambrian rocks, undivided. Assumed average density 2.72 g/cm$^3$** |
| Ꝑr | **Proterozoic rocks, undivided. Assumed average density 2.67 g/cm$^3$** |

**Figure 3.**—*Continued*

profile in the area of the fault lies perpendicular to the gravity contours. The eastern part of the profile, although perpendicular to the main anomaly in the southern part of the study area, lies on the gradient caused by the Buckwater Ridge syncline and is parallel to the gravity contours. This alignment caused some distortion in two-dimensional modeling; hence, the eastern part of the model should be considered schematic. The gravity data require that the Willow Creek fault dip at an angle less than 45°. The calculated values in the center part of the model are lower than the observed values, indicating that additional rocks with relatively high density must be present in the subsurface. Two alternative structural models (fig. 3*C*) would better match the observed profile: (1) a panel of Paleozoic rocks may occur between fault segments, or (2) rocks in the lower plate may be flat lying

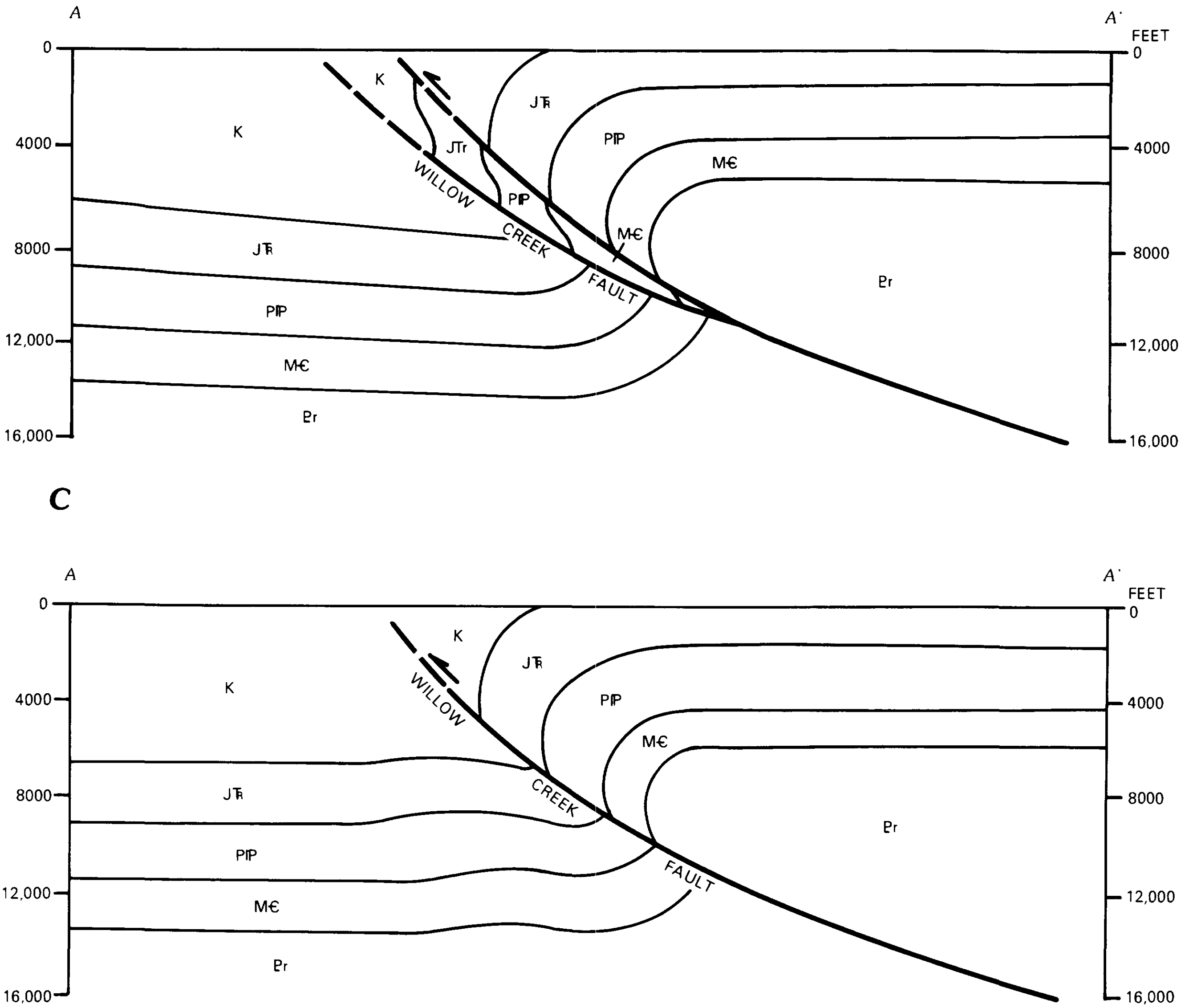



**Figure 3.**—*Continued*

or slightly anticlinal rather than synclinal. Traps for hydrocarbons may occur in the area of folding and overlap along the fault in upper or lower plate rocks.

## Mineral and Energy Resources

The geochemical samples contained no anomalous concentrations of uranium or any metals indicative of mineral deposits. The mineral resource potential for the study area is low for all metals and uranium; certainty level is B (pl. 1). The geologic environment is not favorable for metallic mineral deposits. Although host formations for uranium occur in the study area, no uranium has been discovered.

The mineral resource potential for oil and gas is low in the Bull Canyon Wilderness Study Area; certainty level is B. The Willow Creek fault zone and accompanying fold may extend into the subsurface of the study area. If so, traps for oil and gas may be present. Most of the oil at the Rangely oil field, 12 mi to the southeast, was produced from the Weber Sandstone. According to the cross section of Rowley and Hansen (1979), the Weber Sandstone may be present about 2,000 to 3,500 ft below the study area.

Spencer (1983) rated the potential as low for oil and gas in the study area due to lack of success of wells drilled on structure and the partial exposure nearby of likely host formations.

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## GEOLOGIC TIME CHART

Terms and boundary ages used by the U. S. Geological Survey, 1986

| 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 |
| | | Tertiary — Paleogene Subperiod | Oligocene | 38 |
| | | | Eocene | 55 |
| | | | Paleocene | 66 |
| | Mesozoic | Cretaceous | Late | 96 |
| | | | Early | 138 |
| | | Jurassic | Late<br>Middle<br>Early | 205 |
| | | Triassic | Late<br>Middle<br>Early | ~ 240 |
| | Paleozoic | Permian | Late<br>Early | 290 |
| | | Carboniferous Periods — Pennsylvanian | Late<br>Middle<br>Early | ~ 330 |
| | | Carboniferous Periods — Mississippian | Late<br>Early | 360 |
| | | Devonian | Late<br>Middle<br>Early | 410 |
| | | Silurian | Late<br>Middle<br>Early | 435 |
| | | Ordovician | Late<br>Middle<br>Early | 500 |
| | | Cambrian | Late<br>Middle<br>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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