Mineral Resources of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colorado

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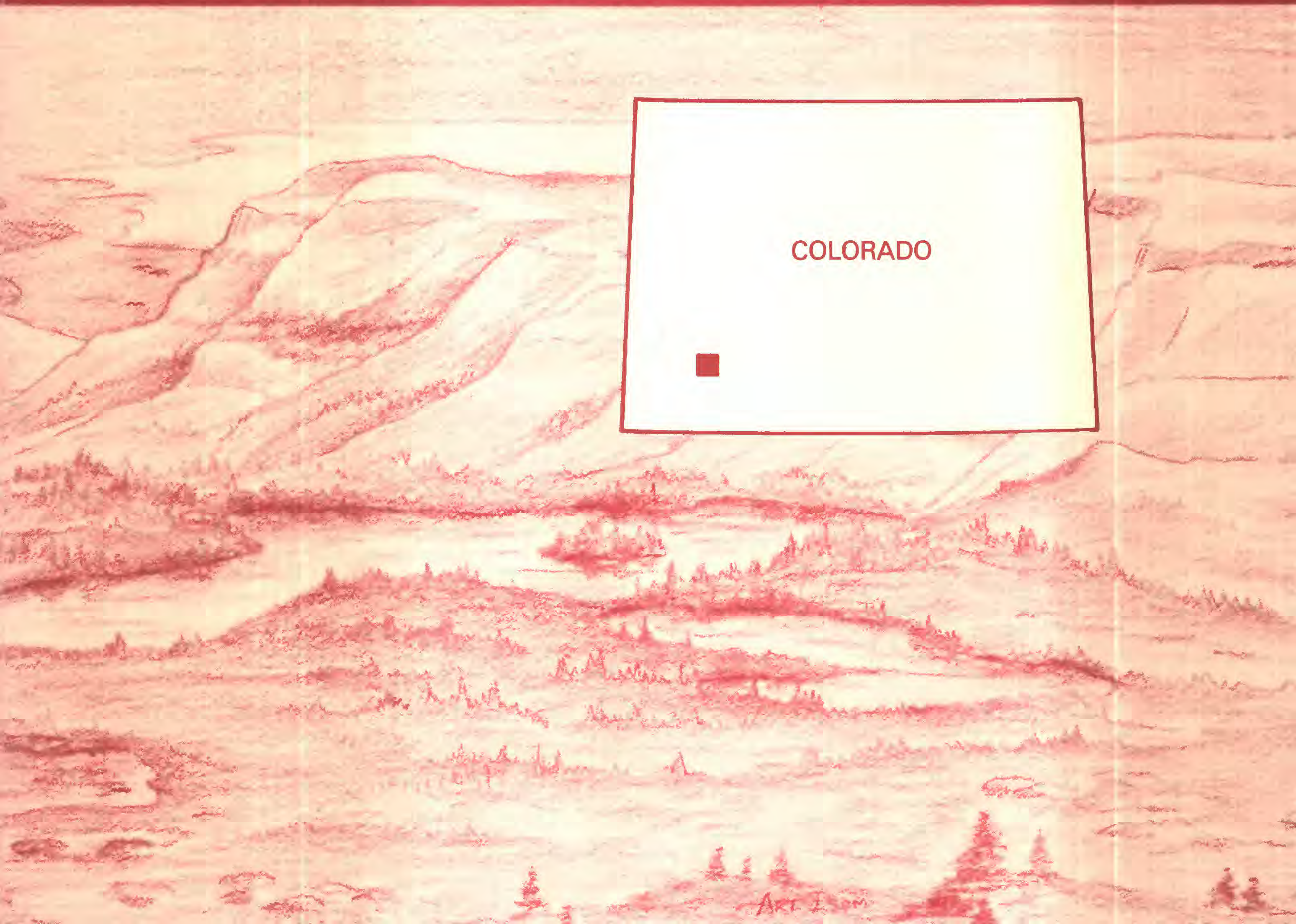

Chapter A

Mineral Resources of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colorado

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MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHWESTERN COLORADO

DEPARTMENT OF THE INTERIOR
DONALD PAUL HODEL, Secretary

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

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of a part of the American Flats Wilderness Study Area (CO–030–217), Ouray and Hinsdale Counties, Colorado.

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Mineral Resources of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colorado

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SUMMARY

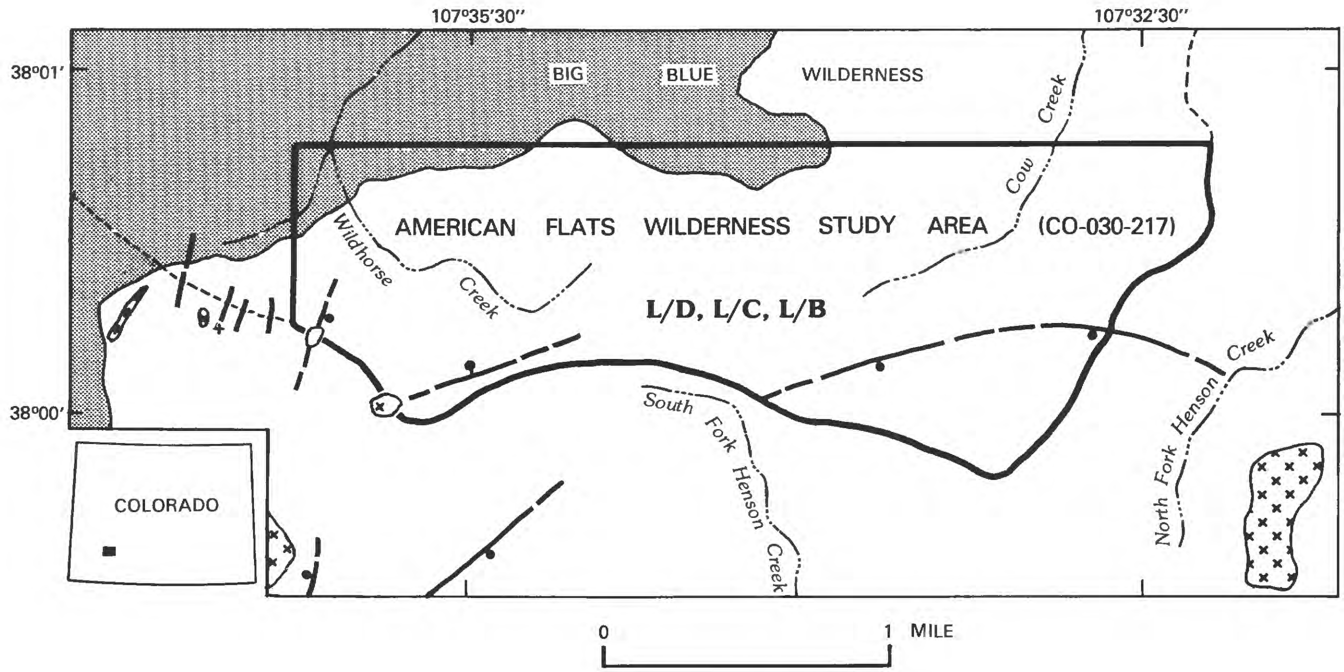
Abstract

At the request of the U.S. Bureau of Land Management, 1,505 acres of the American Flats Wilderness Study Area (CO–030–217) were studied. In this report the studied area is called the "wilderness study area" or simply the "study area." A mineral evaluation of the study area was conducted during 1984 and 1985, and although it lies within the highly mineralized western San Juan Mountains of Colorado, no identified mineral resources or indications of moderate or high mineral resource potential were found during this investigation. Accordingly, the overall mineral resource potential (particularly for molybdenum, uranium, and silver) within the study area (fig. 1) is considered to be low with a good degree of certainty (level C). Although some moderately productive, small-tonnage vein-silver deposits occur nearby on faults that parallel those in the study area, it is considered unlikely that similar deposits occur at depth in the study area. The likelihood within the study area for large vein deposits, similar to those responsible for most of the metal production in the western San Juan Mountains, is considered to be extremely low. There is no energy resource potential for oil, gas, or coal within the American Flats Wilderness Study Area because environments favorable for their formation or preservation are not present within the study area or in the immediate surrounding area. It is also considered unlikely that any sources of geothermal energy are present within the study area; the geothermal energy resource potential is assessed as low.

Character and Setting

The American Flats Wilderness Study Area is located in the western San Juan Mountains, between the towns of Ouray and Lake City, Colo. (fig. 2). The area consists of 1,505 acres of U.S. Bureau of Land Management-administered land that is bordered on the north and west by the Big Blue Wilderness, which lies within the Uncompahgre National Forest. The study area is almost entirely above treeline, with elevations ranging from approximately 11,500 to 13,000 feet above sea level.

The western San Juan Mountains, including the study area, are part of a large erosional remnant of an extensive volcanic field that covered much of south-central Colorado during Oligocene and Miocene time (see geologic time chart in appendix). The earliest volcanic activity in the western San Juan volcanic field is represented by andesitic to dacitic lava flows and associated material erupted from clusters of large volcanoes. Beginning about 30 m.y. (million years) ago, the nature of the volcanic activity changed dramatically. Tremendous volumes of ash and volcanic glass (50–500 cubic miles) were explosively erupted from large volcanic centers known as calderas and deposited as regional ash-flow sheets. One of the largest of these centers is the Uncompahgre–San Juan caldera complex and the associated Silverton caldera, a set of coalesced and nested calderas that extends from Lake City to Silverton (fig. 2). The main stage of caldera-forming eruptions ceased at about 27 m.y. in the western San Juan volcanic field. Miocene volcanic and intrusive activity (23–10 m.y. ago)



EXPLANATION OF MINERAL RESOURCE POTENTIAL

[Entire area has no potential for oil, gas, or coal (certainty level D)]

L/D, L/C, L/B Geologic terrane having low resource potential for commodities 2 and 5 (certainty level D), for commodities 1 and 6 (certainty level C), and for commodities 3 and 4 (certainty level B)

Commodities

1. Vein deposits (Ag, Au, Zn, Pb, Cu)
2. Breccia-pipe deposits (Ag, Pb, Zn, Cu, Au)
3. Porphyry-type molybdenum and copper deposits
4. Rhyolite-related uranium deposits
5. Gravel
6. Geothermal energy sources

Intrusive rocks

Rocks of the Uncompahgre-San Juan caldera complex

Precaldera volcanic rocks (early intermediate-composition assemblage)

Geologic contact

Fault—Dashed where approximately located; bar and ball on downthrown side

Approximate boundary of American Flats Wilderness Study Area

Approximate boundary of Big Blue Wilderness (USFS)

Figure 1. Summary map showing mineral resource potential of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colo.

consisted of volumetrically minor amounts of chemically distinct basalt and rhyolite, although some intermediate-composition intrusions were also emplaced during this time.

The American Flats Wilderness Study Area lies along the north-central margin of the Uncompahgre–San Juan caldera complex, just to the northeast of the Silverton caldera (fig. 2). Rocks exposed within the study area consist largely of lavas and some ash-flow tuffs that ponded within the Uncompahgre–San Juan caldera complex. However, along the northern boundary of the study area, rocks related to the earlier episode of volcano formation are exposed just outside of the margin of the Uncompahgre–San Juan caldera complex. A northeast- to southwest-trending zone of Miocene rhyolitic and intermediate intrusive rocks, which were emplaced during the period of basalt-rhyolite volcanism, also projects through the study area. However, only the intermediate-composition intrusive rocks are exposed within the study area.

Reserves, Resources, and Mineral Resource Potential

Mineralization in the western San Juan Mountains took place intermittently during both Late Cretaceous to

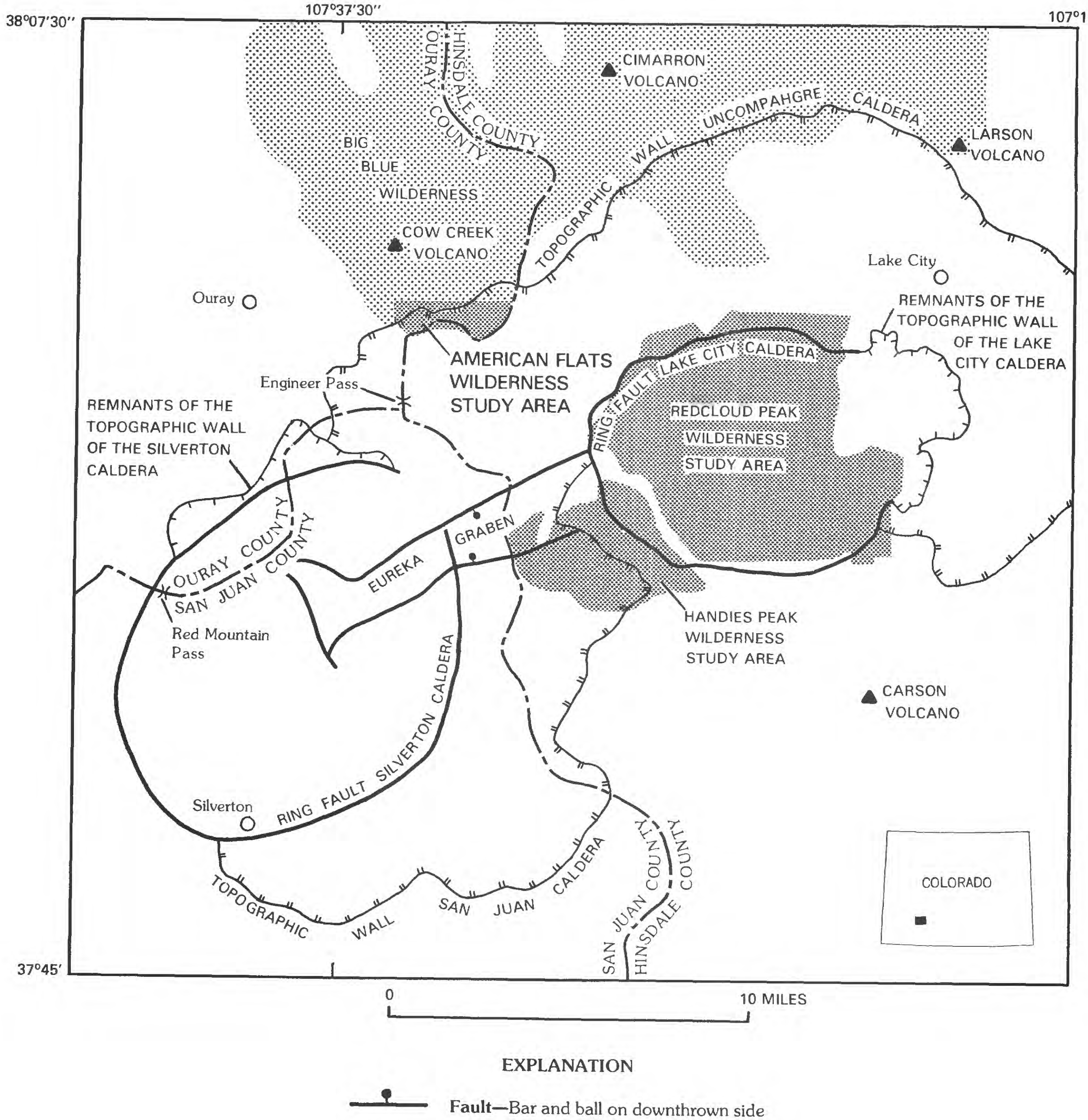


Figure 2. Index map showing geologic setting and location of the American Flats Wilderness Study Area in the western San Juan Mountains, Colo. (modified from Lipman, 1976a).

early Tertiary (60–70 m.y ago) and middle to late Tertiary (5–33 m.y. ago) periods of igneous activity. In the region surrounding the study area, all known and possible mineral deposits are likely to be of mid- to late-Tertiary age and include precious-metal (gold and silver) and base-metal (lead, zinc, and copper) vein deposits, porphyry-type copper and molybdenum deposits, silver and base-metal breccia-pipe deposits, and rhyolite-related uranium deposits. These occur in a variety of geologic environments that span the entire age range of Oligocene and Miocene igneous activity in the area.

There has been no mining activity within the American Flats Wilderness Study Area, and only a few shallow prospect pits are present. No reserves or resources, either economic or subeconomic, were identified within the study area during this investigation.

The only ore deposits with recorded production in the immediate vicinity of the study area are fault-controlled vein deposits located to the southwest, south, and southeast of the study area boundaries. Several of these deposits produced small amounts (less than 10,000 tons) of relatively high-grade silver ore. Only a few prospected mineral occurrences, which are present to the southwest of the study area, lie along faults that project into the study area. However, no veins were found along faults within the study area, and little evidence of hydrothermal alteration or geochemical anomalies that might indicate the presence of mineralized rock at depth was found on the surface along these structures. A mineralized breccia pipe is present about 1 mi (mile) southwest of the study area, where it is associated with a Miocene rhyolite complex (12–16 m.y. old). However, similar deposits are not thought to occur within the study area because no intense alteration or geochemical anomalies characteristic of this deposit type are evident. There are also no surface indications of intrusions or alteration patterns that might be related to porphyry-type copper and molybdenum or rhyolite-related uranium deposits within the study area. No rocks suitable for the formation of oil, gas, or coal occur within the study area, and no environments favorable for geothermal energy were identified.

The geological and geochemical data available at the time of this investigation provide little evidence that would indicate the presence of mineral or energy resources within the study area. Accordingly, the American Flats Wilderness Study Area is assigned a low mineral resource potential for all metals and nonmetals, a low energy resource potential for geothermal sources, and no energy resource potential for gas, oil, and coal; these assessments have a good degree of certainty (level C) (fig. 1).

INTRODUCTION

Location

At the request of the U.S. Bureau of Land Management (BLM), 1,505 acres of the American Flats Wilderness Study Area were studied. In this report, the studied area is called the "wilderness study area" or simply the "study area." The study area is in the San Juan Mountains, between the towns of Ouray and Lake City, Colo. (fig. 2). It is adjacent to the U.S. Forest Service (USFS) Big Blue Wilderness Area on its north and west boundaries and northwest of the Redcloud Peak and Handies Peak Wilderness Study Areas (BLM) (fig. 2). The American Flats Wilderness Study Area is most easily reached on foot from jeep roads on Engineer Pass and along the North Fork of Henson Creek several miles to the south and east, respectively. The study area lies almost entirely above treeline, with elevations ranging from approximately 11,500 to 13,000 ft (feet) above sea level.

The present investigation was conducted to appraise the identified mineral resources and mineral resource potential of the American Flats Study Area and is a result of a joint effort by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS) during 1984 and 1985. 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. Mineral resource potential is the likelihood of occurrence of undiscovered concentrations of metals and nonmetals, of unappraised industrial rocks and minerals, and of undiscovered energy sources (coal, oil, gas, oil shale, and geothermal sources). It is classified according to the system of Goudarzi (1984) and is shown in the appendix of this report.

Investigations by the U.S. Bureau of Mines

The USBM conducted investigations of individual mines and prospects inside of and within 2 mi of the study area in order to inventory past production, proven and unproven reserves, and subeconomic resources. During 1984, BLM records were checked for the location of patented and unpatented claims, and for oil and gas, geothermal, and other mineral leases in or near the study area. Complete results of this work have been published by the USBM (Hannigan, 1985).

Investigations by the U.S. Geological Survey

The USGS field-checked the geology in and around the study area, making necessary revisions in interpretation, examined and sampled rock units where necessary within potentially mineralized areas, and interpreted geophysical and geochemical data in order to assess the mineral resource potential of the study area. Detailed descriptions of the mineral deposits surrounding the study area, including their geology, mineralogy, geochemical characteristics, and production, are presented in a separate report (Hon and others, 1986). All of the available geochemical data for the American Flats Wilderness Study Area have been compiled by Hon (1986). These companion reports provide the supporting information necessary to make the mineral resource assessments presented in this report.

The terms "base-metal" and "precious-metal" are used throughout the report and refer to lead-zinc-copper and silver-gold assemblages, respectively. Terminology of the various rock units follows that of Lipman ond others (1973) and Lipman (1976a). Volcanic rock names used in this report were assigned according to the IUGS (International Union of Geological Sciences) classification recommended by Le Maitre (1984). Some rock names used differ from those used by Lipman (1976a) in that the terms "quartz latite" (65–70 percent SiO_2) and "rhyodacite" (60–65 percent SiO_2) as defined by Lipman (1975) are replaced by "high-potassium dacite" (63–69 percent SiO_2) and "andesite" (57–63 percent SiO_2), respectively. For ease of discussion, the modifier "high-potassium" has been left out and these rocks are referred to simply as "dacite" and "andesite." Potassium-argon (K–Ar) ages determined from rocks of the San Juan volcanic field prior to 1976 were replaced by the recalculated ages presented by Hon and Mehnert (1983).

Acknowledgments.—The USGS would like to acknowledge the local BLM officials, particularly Terry Reed, Arden Anderson, and John Sering, and Duane Harp of the USFS for their continued assistance and cooperation during the course of this study. Joe Hersey of Hersey Exploration and Greg Whitman of Molycorp provided information to the USBM regarding claims on the periphery of the study area. Brian Maher kindly provided us with a copy of his excellent thesis on the Engineer Pass area. Finally, we would like to thank Norma Swanson of Lake City, Colo., for allowing us access to her extensive collection of unpublished mining reports about claims in Hinsdale County. Assistance was provided during the course of this study by our colleagues Joseph Zamudio, Richard Sanford, and Ann Kramer of the USGS.

GEOLOGIC SETTING

Regional Geology

The American Flats Wilderness Study Area lies along the north-central margin of the 29- to 27-m.y.-old Uncompahgre–San Juan caldera complex (fig. 2). This large composite volcanic structure initially erupted and collapsed within a cluster of older (33–30 m.y.) volcanoes (Lipman and others, 1973). The andesitic to dacitic lava flows and related rocks erupted from these centers make up the early intermediate-composition assemblage of Lipman and others (1973) and Lipman (1976a). The Cow Creek and Cimarron volcanoes (fig. 2) represent the eroded cores of these early volcanoes near the study area (Lipman and others, 1973; Hon and others, 1986).

West of the study area and just south of Ouray, early intermediate-composition volcanic rocks unconformably overlie Early and Middle Proterozoic metasedimentary rocks of the Uncompahgre Formation (Burbank, 1940; Luedke and Burbank, 1962), whereas to the south of the study area such volcanic rocks are in contact with 1.4-b.y.(billion year)-old granite (Lipman, 1976a). Paleozoic and Mesozoic sedimentary rocks were removed in the vicinity of the study area by prevolcanic erosion (Burbank, 1940; Kelley, 1957).

The Uncompahgre–San Juan caldera complex collapsed about 29 m.y. ago, and a thick accumulation (more than 3,000 ft) of the concurrently erupting ash-flow sheet (Eureka Member of the Sapinero Mesa Tuff) ponded within these calderas. Large masses of older rocks on the walls of the caldera caved into the subsiding calderas during eruption and caused the caldera margins to expand outwardly well beyond their structural boundaries (Lipman, 1976b). The study area is outside the structural margin, but within the topographic boundary, of the Uncompahgre–San Juan caldera complex (fig. 2).

Significant volcanic activity continued for several million years as evidenced by the accumulation of postcollapse dacitic to andesitic lavas and the eruption of the Crystal Lake Tuff from the Silverton caldera (fig. 2) (Lipman and others, 1973). The final phase of igneous activity within the Uncompahgre–San Juan caldera complex was the emplacement of 25- to 28-m.y.-old quartz monzonite to monzonite stocks (Lipman and others, 1973; Slack, 1980).

Late bimodal igneous activity in the vicinity of the study area is represented by a linear trend of rhyolitic to dacitic and andesitic intrusive rocks extending from north of Lake City to Red Mountain Pass (fig. 2). The strong northeast to southwest trend of intrusive rocks, which passes through the study area, is suggestive of control by a major structural weakness (Luedke and Burbank, 1968; Hon and others, 1986). Northeast of Engineer Pass only 18- to 19-m.y.-old high-silica rhyolite porphyries occur along this trend (Lipman, 1976a; Lipman and others, 1976). In contrast, a diverse assemblage of crystal-poor, high-silica rhyolite felsites, and sanidine-bearing dacites and andesites, which range in age from 10 to 24 m.y. (Lipman and others, 1976), are present to the southwest of Engineer Pass (fig. 2). Although silicic alkali basalts characteristic of the bimodal assemblage are not present in the immediate vicinity of the study area, they occur farther to the east (Lipman and others, 1973; Lipman, 1976a).

Volcanic and Intrusive Rocks within the Study Area

The oldest rocks exposed within the study area are volcaniclastic facies conglomerates (pl.1, unit **Tec**) of the Oligocene early intermediate-composition assemblage. These consist of poorly to moderately sorted boulders, cobbles, and pebbles of volcanic rock in a sandy tuffaceous matrix. A thin lens of lava (pl.1, unit **Tef**) is interlayered with these volcaniclastic rocks on the west side of Wildhorse Peak (pl. 1) and barely crops out within the study area. These early intermediate-composition units are truncated by the wall of the Uncompahgre–San Juan caldera complex along the northern edge of the study area (pl. 1) (Lipman, 1976a). In this region, the topographic wall of the caldera is expressed as a pronounced angular unconformity separating the older volcaniclastic conglomerates to the north from post-collapse lavas related to the

Uncompahgre–San Juan caldera complex and Silverton caldera to the south (fig. 2).

Thick accumulations of biotite dacite of the Burns Member of the Silverton Volcanics (pl.1, unit **Tbb**) occur along the margin of the caldera. The porphyritic andesite (pl.1, unit **Tap**) and tuffaceous sandstone (pl.1, unit **Ths**) of the pyroxene andesite member and Henson Member of the Silverton Volcanics, respectively, both apparently lap against or interfinger complexly with this thick domal mass of dacite. The porphyritic andesite lavas and tuffaceous sandstone are the dominant rock types exposed in the American Flats Wilderness Study Area.

These units are overlain by the poorly welded distal end of the 28-m.y.-old Fish Canyon Tuff (pl.1, unit **Tf**) from La Garita caldera in the central San Juan Mountains and the moderately welded Crystal Lake Tuff (pl. 1, unit **Tcl**), which was erupted from the Silverton caldera (Lipman and others, 1973; Steven and Lipman, 1976). Both of these ash-flow sheets ponded passively within the San Juan–Uncompahgre caldera, probably in topographic lows adjacent to the resurgent dome. In the American Flats area, they are locally separated from each other by volcaniclastic sedimentary rocks (pl. 1; unit **Tvs**). Outcrops of these units cover about 20–30 percent of the study area along its southern boundary.

Only two small pluglike intrusions of dacite (pl.1, unit **Tid**) are known to occur within the study area, although a much larger stock of similar composition is present immediately southwest of the study area boundary (fig. 3, pl. 1) (Lipman, 1976a). The two plugs apparently intruded fault zones near the southwest border of the study area; however, neither intrusion displays significant effects of alteration or shearing indicative of postemplacement fault movement.

Structure of the Study Area

Three faults having mappable displacements occur within the wilderness study area (pl. 1), and two of these appear to be extensions of faults that are better developed to the southwest (fig. 3). These two faults have small displacements (less than 100 ft) and appear to define a minor uplifted block (fig. 3). Along the western edge of the study area and extending into the adjacent Big Blue Wilderness there is a series of small north- to northeast-trending faults (pl. 1). Only the easternmost of these structures has any mappable displacement, and the rest seem to be little more than fractures along which weak hydrothermal alteration has been localized.

Age of Mineralization in the Vicinity of the Study Area

Two major periods of mineralization have been recognized in the western San Juan Mountains: one during Late Cretaceous and early Tertiary time (60–70 m.y. ago) and one in the middle to late Tertiary (5–33 m.y. ago) (Burbank, 1940; Burbank and Luedke, 1968; Lipman and others, 1976). Only mid- to late-Tertiary mineral deposits are known to occur in the vicinity of the study area. These are associated with precaldera intermediate-composition centers (30–33 m.y.), late-stage magmatic activity within

EXPLANATION

Tertiary rocks

Tir	**Rhyolite intrusions (15-19 m.y.)**
Tid	**Intermediate-composition intrusions (22-24 m.y.)**
	Lake City caldera (23.1 m.y.)
Tsp	**Ash-flow tuff, megabreccia, and intrusions**
	Uncompahgre, San Juan, and Silverton calderas
Tmp	**Late quartz monzonite to monzonite intrusions (25-28 m.y.)**
Tsc	**Postcollapse lavas of the Silverton caldera**
Tup	**Upper lavas, sediments, and ash-flow tuffs (27-28 m.y.)**
Thb	**Postcollapse lavas and sediments**
Ts	**Intracaldera Sapinero Mesa Tuff, includes megabreccia (29 m.y.)**
Tl	**Older ash-flow tuff (29-30 m.y.)**
	Early intermediate-composition assemblage (30-33 m.y.)
Tei	**Intrusions**
Te	**Lavas, breccias, and related volcaniclastic rocks**
Yg	**Middle Proterozoic granite (1.4 b.y.)**
——	**Contact**
	Fault—Bar and ball on downthrown side
▼9	**Mine**

1. **Frank Hough**
2. **Polar Star**
3. **Mammoth**
4. **Palmetto**
5. **Wyoming**
6. **Golconda**
7. **Ruby-Pearl claims**
8. **Isolde and CFM**
9. **Dolly Varden group**
10. **Empire-Highland Chief**
11. **Moro**
12. **Czar and Czarina**

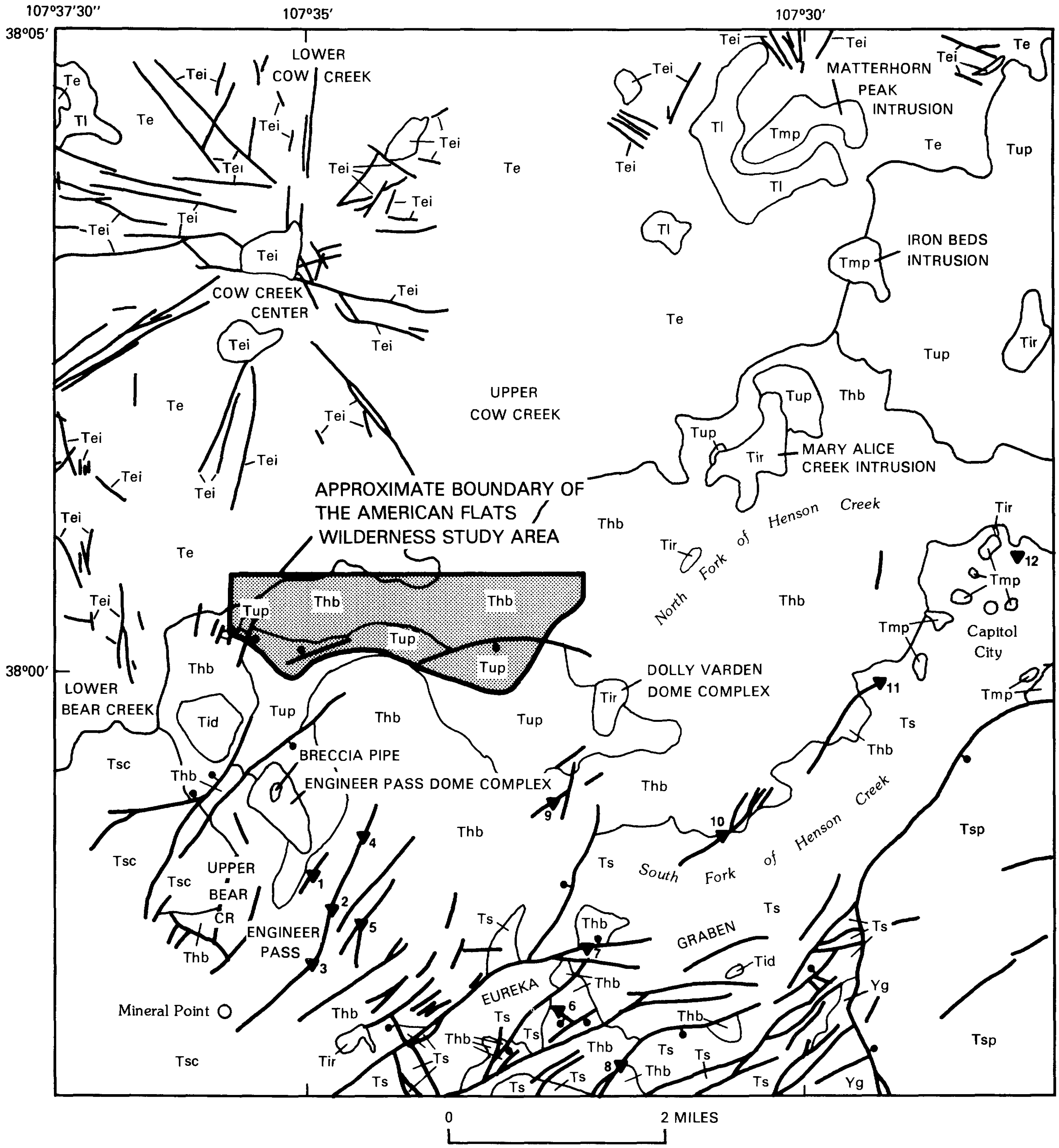


Figure 3 (above and facing page). Generalized geologic map showing the location of principal mines in the vicinity of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colo. (simplified from Lipman, 1976a, with minor additions from Irving and Bancroft, 1911; Brown, 1926; Kelley, 1946; and Luedke, 1972).

the Uncompahgre caldera (25–28 m.y.), and hydrothermal activity along faults of the Eureka graben (fig. 3) that were reactivated during the Miocene (10–20 m.y.) (Lipman and others, 1976). Productive and potential deposit types in the region immediately surrounding the study area include (1) precious- and base-metal vein deposits that formed as open-space fillings of faults; (2) precious- and base-metal vein deposits that formed as replacements of wallrocks adjacent to faults; (3) disseminated porphyry-type copper and molybdenum deposits that are related to precaldera and late-stage caldera intrusions; (4) precious- and base-metal breccia-pipe deposits that are spatially related to Miocene intrusions; and (5) disseminated uranium deposits that formed during the late stages of crystallization of 18- to 19-m.y.-old high-silica rhyolite intrusions.

Mid- to late-Tertiary mineral deposits occur in geologically and temporally distinct settings in the vicinity of the study area. Northeast of the wilderness study area, weak porphyry-type, disseminated mineralization and alteration were associated with the emplacement of a composite central stock late in the development of the 30-m.y.-old Cimarron volcano (fig. 2) (Lipman and others, 1976). Veins and mineralized shears thought to be of about this age also occur along the margins of dikes and in radial fractures related to this volcanic complex (Fischer and others, 1968; Luedke, 1972; Lipman and others, 1976; Steven and others, 1977). Similar disseminated and vein mineralization is also related to the Cow Creek center (Burbank, 1940; Steven and others, 1977), which is about 2–3 mi north of the study area (fig. 3). Anomalous amounts of copper and molybdenum are also associated with monzonitic intrusions that were emplaced late in the Uncompahgre caldera cycle (Steven and others, 1977; Hon and others, 1986). These intrusions extend northward from the Capitol City area to Matterhorn Peak (fig. 3) (Lipman, 1976a), and some of the vein mineralization in the Capitol City area could conceivably be related to these intrusions (Lipman and others, 1976; Steven and others, 1977; Slack, 1980). Northeast-trending veins south of the wilderness study area occupy fracture systems within or subparallel to the Eureka graben that formed during resurgence of the Uncompahgre–San Juan caldera complex (Lipman and others, 1973). However, geologic relations and available age data indicate that most of this mineralization occurred during the late Miocene, some 10–15 m.y. after caldera formation (Lipman and others, 1976). The principal mines south of the study area are shown on figure 3. In the Engineer Pass area (fig. 3), a mineralized breccia pipe associated with a crystal-poor rhyolite intrusion yielded an age of 12–13 m.y. for emplacement and mineralization of the pipe (Hon and Mehnert, 1983; Maher, 1983; Hon and others, 1986). Anomalous concentrations of uranium occur around the margins of 18- to 19-m.y.-old high-silica rhyolite porphyry intrusions; these high uranium concentrations are thought to have formed by expulsion of uranium, beryllium, molybdenum, lithium, and fluorine during the late stages of crystallization and devitrification of these plutons (Steven and others, 1977; Gibbs, 1981).

APPRAISAL OF IDENTIFIED RESOURCES

By Brian J. Hannigan
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The American Flats Wilderness Study Area does not lie within an established mining district, nor does it contain any mines. Several shallow prospect pits were found in the study area, but most of these prospect pits do not lie on any recognizable geologic structures. Abundant stone suitable for aggregate is present throughout the study area. Similar stone is common throughout the San Juan Mountains, and nothing serves to distinguish the stone found within the study area from that found elsewhere in the region. No reserves or resources (either economic or subeconomic) were identified within the American Flats Wilderness Study Area during this investigation.

The peak of prospecting activity in part of the San Juan Mountains occurred in the late 1800's and early 1900's, when the discovery of rich copper-silver ores at the Frank Hough mine (fig. 3) spurred exploration efforts in and around the Mineral Point district (Kelley, 1946). This area also probably experienced a brief renaissance in prospecting activity during the uranium "boom" of the 1950's.

No patented or unpatented claims are located within the American Flats Wilderness Study Area according to records on file with the BLM as of April 1985. One unpatented claim was shown in the area by Fischer and others (1968), but no record of this claim was found during the course of this study. However, there are 47 unpatented claims within 1 mi of the wilderness study area boundary. Numerous patented claims are also present within a 1- to 4-mi radius of the study area, and an outline map of their distribution is included in the report by Fischer and others (1968).

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Ken Hon, V. J. S. Grauch, and Dana J. Bove
U.S. Geological Survey

Geochemistry

Methods

Samples of unaltered and altered rock, vein material, and stream sediments were collected from sites within and immediately adjacent to the American Flats Wilderness Study Area during the course of this study and earlier investigations. Details of sample preparation, analytical techniques, and results are listed in the original reports (Fischer and others, 1968; Weiland and others, 1980; Hannigan, 1985), and the pertinent geochemical data, as well as the sample localities, have been compiled for this investigation in a companion report (Hon, 1986). Most of the samples were analyzed by the direct-current arc and alternating-current spark emission spectrographic method described by Grimes and Marranzino (1968) in the laboratories of the U.S. Geological Survey, Denver, Colo., and the U.S. Bureau of Mines Reno Research Center, Reno, Nev. Six stream-sediment samples collected by Barringer Research, Inc. (Hon, 1986, table 4), were analyzed by a combination of induction-coupled argon plasma spectroscopic (ICP), atomic-absorption, fluorometric, and colorimetric techniques (Weiland and others, 1980). In addition, all of the samples collected by the USBM in and adjacent to the study area (Hannigan, 1985; Hon, 1986) were analyzed for gold and silver by fire assay-ICP, but values were below the detection limits for these elements (silver less than 0.3 ppm (parts per million), gold less than 0.007 ppm). The samples collected by Fischer and others (1968) were also analyzed for gold by atomic-absorption spectroscopy, but none contained gold unequivocally above the reported detection limit (0.02 ppm gold).

The semiquantitative emission spectrographic values are reported to the nearest number in the series 10, 15, 20, 30, 50, 70, 100, and so forth, where these numbers represent the approximate geometric midpoints of the concentration ranges. The best precision to be expected is for replicate analyses to lie within two adjoining intervals 96 percent of the time (Motooka and Grimes, 1976). However, many of the reported values (Hon, 1986) may not represent this level of precision. Because the samples were collected at different times and analyzed by a variety of laboratories, the results are not strictly comparable. The term "anomalous" is used to describe only those levels that exceed levels commonly found in igneous rocks (Turekian and Wedepohl, 1961; Taylor, 1964; Levinson, 1980) and unaltered rocks from the region (Hon, 1986, table 5) by a margin greater than two standard deviations from the mean. Comparison of selected arsenic values given by Hannigan (1985) that were obtained for samples analyzed by emission spectrography and the more reliable atomic-absorption method indicates that the arsenic data listed in table 2 of Hon (1986) are of questionable reliability.

Stream-Sediment Samples

Neither the stream-sediment nor panned-concentrate samples collected from the headwaters of Wildhorse and Cow Creeks, within the wilderness study area (Hon, 1986), contain anomalous amounts of the elements associated with the ore deposits in the surrounding region (Hon and others, 1986). Nearly all of the samples listed in table 2 of Hon (1986) contained elevated levels of zinc; however, these concentrations correlated well with measured abundances of iron, manganese, titanium, and vanadium, as well as with high levels of cobalt, chromium, scandium, and nickel in panned-concentrate samples. This assemblage of elements, including zinc, is associated with iron-titanium oxide minerals (titanomagnetite and ilmenohematite) in igneous rocks and indicates that the zinc anomalies resulted from placer concentrations of rock-forming oxide minerals rather than from the presence of an ore-forming mineral, such as sphalerite. One of the stream-sediment samples (Hon, 1986, table 2, no. 22) had a much higher manganese content (greater than 20,000 ppm) than the others, but this sample also yielded correspondingly high values of iron, titanium, vanadium, and zinc. Again, this association suggests a relationship to the rock-forming oxides, rather than to minerals of hydrothermal origin, such as manganiferous carbonates. Two of the stream-sediment samples (Hon, 1986, table 2, nos. 28 and 63) have reported concentrations of arsenic near the detection limit of the analytical technique. Because of the previously mentioned problems with the arsenic values listed in table 2 of Hon (1986), it is very difficult to assess the validity of these apparent anomalies. Detectable, but not anomalous, molybdenum values (7 ppm and 10 ppm) were reported for only two of the panned-concentrate samples (Hon, 1986, table 2, nos. 56 and 64). One relatively high concentration of barium (2,000 ppm) was present in the panned concentrates (Hon, 1986, table 2, no. 21), but is associated with the highest potassium value and probably represents the presence of potassium feldspar rather than barite of hydrothermal origin. The observed drop in barium values between the paired sediment and panned-concentrate samples listed in table 2 of Hon (1986) undoubtedly reflects a simple decrease in the feldspar content of the heavy-mineral fraction. This relationship is antithetic to that expected if barite were the phase controlling the barium concentration.

Vein and Rock Chip Samples

Twenty-eight rock and "vein" samples were collected within the boundaries of the American Flats Wilderness Study Area (Hon, 1986). These samples are mostly slightly altered (generally iron-stained) or unaltered rock. No true open-space-filling veins were found within the wilderness study area, and the few samples classified as vein material are actually weakly altered and silicified rock that occurs along fractures and faults. The silicified zones are generally narrow, but range from less than 1 in. (inch) to several feet in width and are in places surrounded by envelopes of bleached rock. Most of these zones can be traced for only a few tens of feet along the fracture and fault zones. Only a few of the samples analyzed from the study area contain even slightly anomalous amounts of the elements that are considered to be of economic interest. None of the samples analyzed contains any detectable silver or gold. One sample (Hon, 1986, table 3, no. 700) gave a mildly anomalous lead value of 300 ppm with detectable, but not anomalous, copper (70 ppm). None of the other samples contains lead in excess of 50 ppm. Sample number 906 (Hon, 1986, table 3) has 150 ppm of copper, and several others gave values of 70 ppm copper (Hon, 1986, table 3, nos. 700, 707, 897, 899, 903, and 905). Only the 150-ppm value of copper is considered to be mildly anomalous, but it is not associated with any other elements of economic interest. Molybdenum reached detectable levels in only two of the samples; these contained 50 ppm (Hon, 1986, table 1, no. 101) and 10 ppm (Hon, 1986, table 3, no. 702). No other values for elements indicative of hydrothermal mineralization are associated with the anomalous molybdenum value (50 ppm). Another sample (Hon, 1986, table 2, no. 26), which was taken from near the locality of the anomalous sample, did not contain detectable amounts of molybdenum. These facts suggest that the elevated concentration of molybdenum found in the one sample is an isolated occurrence and is not representative of more widespread mineralization.

Many of the samples collected and analyzed by the USBM from within the wilderness study area (Hon, 1986, table 2) display apparently anomalous amounts of arsenic (300–600 ppm). Relatively high concentrations of iron and manganese in some of these samples suggest that arsenic could have been concentrated in iron-manganese coatings on the rocks. However, leachates of iron-manganese oxides from two samples collected by the USGS (nos. 101 and 102) during this study showed arsenic contents of less than 100 ppm (Hon, unpub. data, 1985), which contradicts the suggestion that arsenic is enriched in iron-manganese coatings. In addition, none of the samples collected by Fischer and others (1968) from within or adjacent to the study area contains greater than 200 ppm of arsenic (Hon, 1986, table 3). Because of the unreliability of the arsenic analyses in table 2 of Hon (1986), as discussed earlier, and because the high arsenic values in this data set were not confirmed by independent sampling (Hon, 1986, table 3), the arsenic anomalies defined by these samples (Hon, 1986, table 2) are regarded as highly suspect.

Geophysics

Scope of Investigations

The American Flats Wilderness Study Area has been included in regional gravity (Plouff and Pakiser, 1972) and aeromagnetic surveys (Steven and others, 1977; U.S. Geological Survey, 1972). The study area also lies within the areas of two much more detailed aeromagnetic and aeroradiometric surveys (High Life Helicopters/QEB, 1981, 1983). The results from less detailed aeroradiometric and aeromagnetic surveys (Geometrics, Inc., 1979; Aero Service, 1979) are available for the area, but were not evaluated during this investigation. The details of the methodology used in collecting and processing the geophysical data for these surveys are given in the individual reports cited above. No additional geophysical studies were done during the course of this investigation.

Gravity Survey

The study area lies along the northwestern edge of a large regional gravity low that probably reflects a major batholith underlying the San Juan Mountains (Plouff and Pakiser, 1972). The regional gravity low has no direct significance for the local evaluation of the resource potential of the study area. Although detailed gravity studies can be useful in detecting density differences that may help locate shallow unexposed plutons or other geologic features of possible significance to mineralization, available gravity data are too sparse to permit this type of interpretation within the study area. In fact, there are no gravity stations in or near the study area.

Aeromagnetic Surveys

Aeromagnetic data from two surveys (High Life Helicopters/QEB, 1981, 1983) were evaluated and were found to show very similar features. One survey was flown north-south at ⅓-mi spacings and the other was flown east-west at ¼-mi spacings. Both were draped at an average of 400 ft above ground. Only the 1981 survey is shown in figure 4; anomalies determined from the 1983 data are so similar that they are not reproduced here.

The aeromagnetic map (fig. 4) shows a small high (H1) in the northeast corner of the study area, a broad boomerang-shaped low (L1) just to the west of H1, a small high (H2) in the southwest corner of the study area, a sharp low (L2) just to the east of this high, and a broad, aeromagnetically nondescript area in between the two

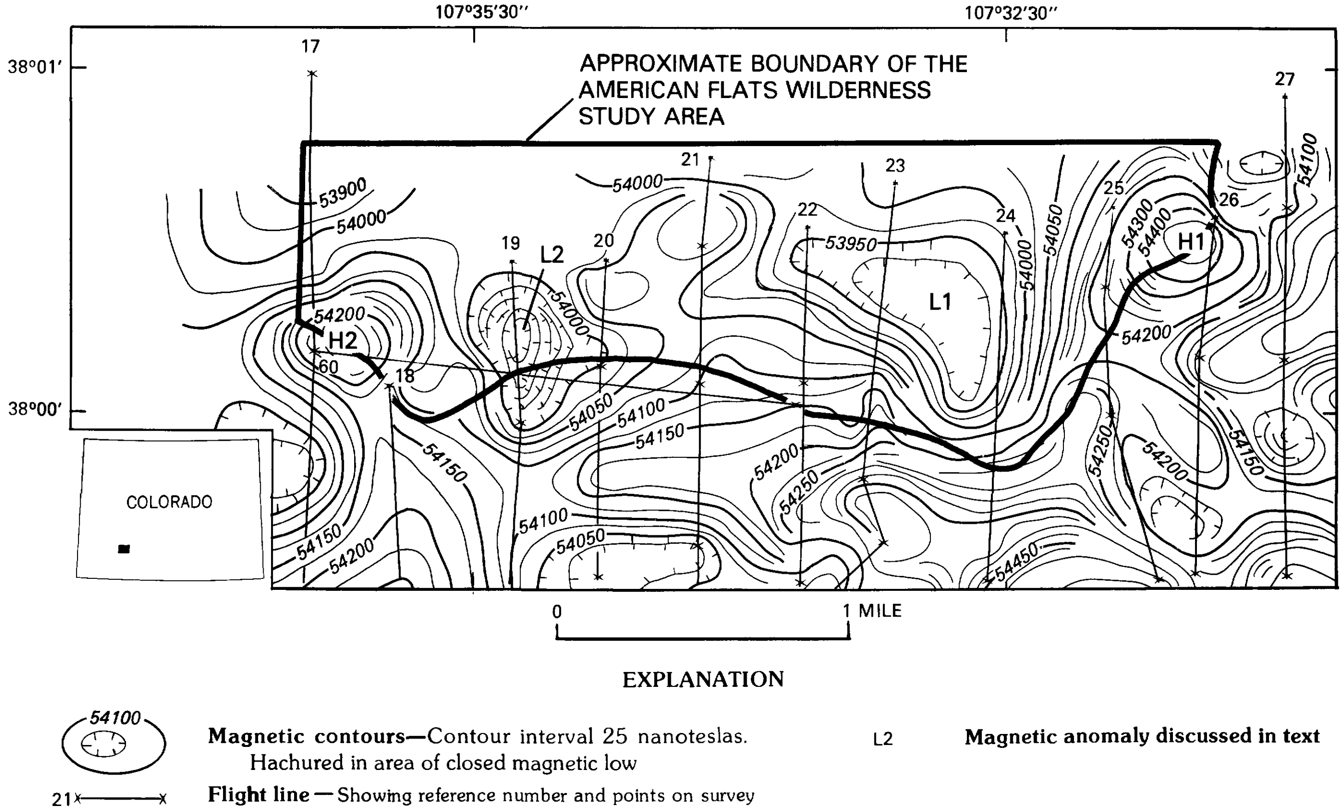

Figure 4. Aeromagnetic map of the American Flats Wilderness Study Area, Ouray and Hinsdale Counties, Colo. (modified from High Life Helicopters/QEB, 1981).

lows. Although these features are correlated to some degree with the topography in the study area, the effects of topography alone are not considered sufficient to produce the observed aeromagnetic features. The aeromagnetic features (fig. 4) may be produced by rock units exposed either at the surface or present in the subsurface that are strongly magnetic in comparison to the surrounding units. Aeromagnetic lows L1 and L2 are probably caused by a polarity effect that occurs on the north side of the corresponding aeromagnetic highs (fig. 4) and by topographic effects due to the survey aircraft flying into a deep valley. The areas of irregular topography without strong aeromagnetic features between L1 and L2 (fig. 4) probably represent rocks that were originally only weakly magnetized or whose magnetic minerals were destroyed by later events, such as oxidation or hydrothermal alteration.

None of the aeromagnetic features observed in the study area can be attributed unambiguously to a particular single geologic source. Interpretation is hindered by the small scale of study, lack of conclusive rock-magnetic data for the various rock types, and non-uniform magnetic character within individual geologic units. The aeromagnetic highs in the northeast and southwest corners of the study area (H1 and H2, fig. 4) are tentatively attributed to buried dacite plutons, although the magnetic characteristics of these intrusions are not well known. However, the implications of this speculation are minor regarding the possible presence or absence of mineral deposits in the study area.

Aeroradiometric Survey

The results of the regional aeroradiometric survey by High Life Helicopters/QEB (1981) have been previously interpreted by Pitkin and Duval (1982). Results of a later survey (High Life Helicopters/QEB, 1983) are nearly identical to those of the earlier investigation. No significant anomalies of any type were detected within the boundaries of the study area, although very weak equivalent uranium and thorium anomalies are associated with exposures of biotite dacite northeast of Wildhorse Peak, outside the study area. The lack of strong anomalies indicates that none of the units exposed within the study area contains elevated concentrations of uranium, thorium, or potassium compared to the surrounding rocks. The absence of anomalies confirms the geologic mapping (pl. 1) (Lipman, 1976a), which shows neither uranium-enriched rhyolites (pl.1, unit Tir) nor evidence for their presence in the shallow subsurface. During this study, no potassium-rich zones were detected that might indicate the presence of regional alteration related to widespread disseminated mineralization of rock in the study area. Surface radiometric traverses of the study area also failed to detect any material above background levels.

Potential for Undiscovered Mineral Resources

Vein Deposits

Polymetallic veins of the western San Juan Mountains have produced large quantities of base and precious metals during the last century and constitute a future source of these metals (Burbank and Luedke, 1968). Vein deposits found in the vicinity, but not within the wilderness study area, contain variable amounts of silver, gold, lead, zinc, and copper; and they may also contain enough bismuth, cadmium, uranium, and tungsten to be recoverable as byproducts (Hon and others, 1986).

The most productive of the mid- to late-Tertiary veins in the western San Juan Mountains are commonly hosted by either early intermediate-composition-assemblage volcaniclastic conglomerates (pl. 1, unit Tec) or dacite lavas (Burns Member of the Silverton Volcanics, pl.1, unit Tbb) (Purington, 1898; Burbank, 1941; Bejnar, 1957; Varnes, 1963; Burbank and Luedke, 1969). However, in the Engineer Pass area the principal mineralized veins occur within the tuffaceous sandstone (Henson Member, pl.1, unit Ths) or the porphyritic andesite (pyroxene andesite member, pl.1, unit Tap) of the Silverton Volcanics (Kelley, 1946). The intracaldera facies of the Sapinero Mesa Tuff (pl. 1, unit Ts) and quartz monzonite intrusions (fig. 3, not shown on pl. 1) are locally important hosts in veins along the South Fork of Henson Creek and at Capitol City (fig. 3). The lithologic and physical characteristics of the host rocks play an important role in the determination of the size and style of open structures suitable for mineralization (Bejnar, 1957). Doe and others (1979) demonstrated that no significant metallic component of the veins was derived from the immediately surrounding wall rocks.

The most important criterion for precious- and base-metal-mineralized vein systems is the presence of large regional structures that were open during the time of mineralization. The highly productive veins of the western San Juan Mountains occupy extensive and complex fault zones that are generally related to caldera formation (Steven and others, 1974), although, in most cases, mineralization postdated formation of the structures (Lipman and others, 1976). Spectacular examples of this type of mineralization occur in the Sneffels–Telluride district, where some veins were mined continuously for as much as 8,000 ft horizontally and 3,000 ft vertically (Burbank, 1941). Around the wilderness study area, however, even the largest and most continuous of the structures contain only sporadic intervals of mineralized vein material (Hon and others, 1986).

Lipman and others (1976) have shown a close relationship between major mineral deposits and Miocene intrusive rocks, particularly quartz-bearing intrusions, in the western San Juan Mountains. Both Kelley (1946) and Maher (1983) noted the presence of altered Miocene rhyolite intrusions associated with veins in the Mineral Point and Engineer Pass areas (fig. 3) to the south of the study area. Near Capitol City (fig. 3), it is possible that some or all of the veins could be related to the alteration and weak disseminated mineralization that was probably produced by late Oligocene quartz monzonite intrusions (Steven and others, 1977; Lipman and others, 1976).

The criteria used to assess the potential for vein deposits within the study area were the presence of (1) suitable host rocks, (2) well-developed fault or fracture zones, (3) quartz veins or mineralized rock, (4) hydrothermally altered rock, (5) geochemical anomalies, and (6) favorable intrusions or geophysical evidence of their presence.

Many of the rock units that are the most favorable host rocks for vein deposits in the region are present within the study area. However, the southern 20–30 percent of the study area is covered by the Fish Canyon Tuff (pl. 1, unit Tf), which is not a favorable host for vein deposits. Where similar outflow sheets are present above productive veins elsewhere in the western San Juan Mountains, the mineralized structure splays upward into thin, weakly mineralized fractures (Purington, 1898; Burbank, 1941). Nowhere in the western San Juan Mountains are these rocks known to host ore deposits. However, the similar outflow-facies ash-flow tuffs that cap the major veins of the Sneffels–Telluride district are commonly weakly mineralized and extensively altered above the deposits (Burbank, 1941), as is the Fish Canyon Tuff that crops out above and adjacent to the Frank Hough deposit on Engineer Pass (Maher, 1983; Hon and others, 1986). Although the Fish Canyon Tuff might prevent veins developed in the underlying units from being exposed at the surface within its outcrop area, alteration associated with any such veins would still be expected to be conspicuous.

The dacite intrusions exposed within the study area are not the type that are known to be associated with mineralization elsewhere in the western San Juan Mountains (Hon and others, 1986). Although the general trend of Miocene intrusions projects through the study area, there is no evidence that any of the quartz-bearing dacites or high-silica rhyolite intrusions crop out or underlie the study area.

Faults exposed within the wilderness study area are not well developed and are defined either by small stratigraphic offsets or by zones of weak hydrothermal alteration. None of these faults or fractures has the size or continuity necessary to host a major polymetallic vein deposit such as those found at the Sunnyside, Idarado, Camp Bird, or Shenandoah-Dives mines (Ransome, 1901; Varnes, 1963; Casadevall and Ohmoto, 1977; Mayor, 1978). However, the structures are of sufficient size to contain smaller vein deposits similar to those found in the vicinity of the study area. The principal products of these veins were silver and gold because the concentrations of the base metals within most of the deposits were generally low (Hon and others, 1986).

No mineralized vein material has been found within the study area either along or away from mapped faults (pl. 1). The only known mineralized structures that trend into the study area are those found in the upper Bear Creek drainage basin (fig. 3), and although they have been prospected fairly extensively, they have not produced any ore (Hon and others, 1986). Samples taken from these faults within 1 mi of the study area do not show any geochemical anomalies (Hon, 1986; Hon and others, 1986). Faults that host the productive deposits of the Engineer Pass area trend parallel to the study area boundary and die out as they get closer to the study area. Similarly, the veins found along the South Fork of Henson Creek are confined to the Eureka graben zone and are oriented parallel to the study area (Hon and others, 1986).

Traces of hydrothermal alteration found in the study area consist of weak, patchy silicification associated with bleaching of the wall rock; the bleached appearance of the rocks was probably produced by minor argillic alteration. Silicification and bleaching were found only along the small, discontinuous faults and fractures on the western edge of the study area. No altered rocks were observed along the larger northeast-trending faults that cut the Fish Canyon Tuff and that appear to be extensions of the structures in the Bear Creek area. Only a few geochemical anomalies, which are defined by single metallic elements, were detected from samples within and immediately adjacent to the American Flats study area (Hon, 1986; Hon and others, 1986). None of the samples displays the suites of elements that were found to be characteristic of the productive vein deposits outside the study area; nor did the stream-sediment samples show any indication of mineralized areas (Hon and others, 1986).

Because the fault and fracture zones identified within the study area are not associated with mineralized rock, significant hydrothermally altered rock, or geochemical anomalies typical of known vein deposits in the region, the mineral resource potential for vein-type deposits is considered to be low (classified according to the system of Goudarzi, 1984). The certainty of this evaluation is good (level C). Within the American Flats Wilderness Study Area, there is virtually no likelihood of large polymetallic vein deposits, like those responsible for most of the metal production in the western San Juan Mountains.

Breccia-Pipe Deposits

Breccia-pipe deposits in the western San Juan Mountains have produced a moderate amount of rich silver-copper-lead ore. Minor amounts of the elements tin, uranium, and bismuth are also associated with these ores (Pierson and others, 1958; Fischer and others, 1968; Burbank and Luedke, 1969). Very little gold was produced from these deposits.

All of the productive breccia-pipe deposits are in a belt that extends from Red Mountain Pass to Ironton, and their emplacement appears to be controlled by ring faults related to the Silverton and San Juan calderas (Burbank, 1941). In contrast, the breccia pipe just south of the study area boundary near Engineer Pass (fig. 3) does not appear to be associated with any regional structures (Maher, 1983). In general, the breccia pipes consist of a silicified and brecciated core surrounded by argillic and phyllic alteration assemblages in the wall rocks (Burbank, 1941; Maher, 1983; Hon and others, 1986). The deposits are commonly zoned from lead-silver to rich copper-silver to pyritic ore with depth (Burbank, 1940). The absence of copper in the breccia pipe near Engineer Pass (Maher, 1983) is probably the result of supergene leaching, because copper is highly mobile under the acidic conditions in the upper, near-surface portions of these breccia pipes (Fisher and Leedy, 1973). Altered rocks around these deposits are commonly enriched in lead and contain small, erratic anomalies of arsenic, bismuth, and silver. Gold and arsenic are the best pathfinder elements within the silicified cores of mineralized pipes, but significant amounts of silver are present as well (Fisher and Leedy, 1973). Intrusive quartz-bearing dacite porphyries and aphyric rhyolites are intimately associated with most of the mineralized breccia pipes (Burbank, 1941; Maher, 1983). However, the relationship of these intrusions to formation of the breccia pipes and their associated ore deposits is not understood.

The characteristics of breccia-pipe deposits that were used to assess potential for their occurrence within the American Flats Wilderness Study Area were (1) evidence of massive silicification and brecciation of country rock or widespread argillic and phyllic alteration, (2) geochemical anomalies similar to those found around known breccia pipes in the region, and (3) the presence of intrusive rocks commonly associated with the breccia pipes near Engineer and Red Mountain Passes.

As was discussed in the preceding section on vein deposits, the altered zones found within the study area are very restricted in size and are not associated with any significant geochemical anomalies. Because of the intense alteration and fracturing that are characteristic of these pipe deposits, it is unlikely that they would occur without some surface expression in the area. In addition, the intrusions exposed within the study area are not of the type known to be associated with breccia pipes in the western San Juans and there is no indication that favorable intrusive rocks might exist at depth. None of the geologic criteria for favorability of this deposit type was met and, accordingly, the resource potential for mineralized breccia pipes within the study area is rated as low with a clearly defined level of certainty (level D).

Porphyry-Type Molybdenum and Copper Deposits

Two environments that have characteristics of porphyry-type molybdenum deposits (with and without copper) are present in the vicinity of the study area. Calc-alkaline monzonitic intrusions near Capitol City, the Iron Beds, and Matterhorn Peak (fig. 3) are associated with anomalous amounts of molybdenum, copper, and several other elements indicative of disseminated mineralization (Steven and others, 1977; Hon and others, 1986). The association of molybdenum with copper and the chemistry of the related plutonic rocks suggest the possibility of weakly developed granodiorite-type molybdenite deposits at these localities, similar to those found in the Canadian Cordillera (Soregaroli and Sutherland Brown, 1976). The high-silica rhyolite associated with the breccia pipe near Engineer Pass might possibly be the surface expression of a granite or "Climax-type" molybdenite deposit (Mutschler and others, 1981; White and others, 1981). This complex has a striking similarity to the composite breccia pipe and related high-silica rhyolite intrusion above the Redwell Basin porphyry-type molybdenum deposit, which is adjacent to the Mount Emmons ore body (Sharp, 1978; Thomas and Galey, 1982). The intrusion on Engineer Pass contains elevated concentrations of molybdenum; however, no molybdenum-mineralized clasts were recognized within the associated breccia pipe (Maher, 1983). The uranium-enriched, high-silica rhyolites also are petrologically similar to the intrusions associated with "Climax-type" deposits (White and others, 1981; Burt and others, 1982) and contain elevated initial concentrations of molybdenum (Steven and others, 1977; K. Hon and R. A. Zielinski, unpub. data, 1985). However, none of these rhyolites in the vicinity of the study area appears to have caused hydrothermal alteration indicative of porphyry-type mineralization (Steven and others, 1977).

Because pervasively altered rocks typical of porphyry-type deposits have not been recognized within or adjacent to the study area, any potential deposits would have to be at relatively great depths. Commonly, the only indications of these deposits are surface exposures of igneous and clastic dikes, the latter of which can carry fragments of mineralized rock. Although no clastic dikes were found, several small plugs of dacite are present along the southwestern side of the study area; however, these are unaltered and are not the same type of intrusions known to be associated with disseminated mineralization elsewhere in the region (Hon and others, 1986). None of the available geophysical data shows any clear indication either of widespread alteration or of plutons, which might be associated with porphyry-type mineralization within the study area.

The mineral resource potential for porphyry-type deposits within the study area is classified as low. Available data only suggest this level of mineral resource potential (certainty level B), because no information about the subsurface is available for evaluating the deeper environments where these deposits might also occur.

Uranium Deposits

Uranium occurs as concentrations at the margins of high-silica rhyolite intrusions east of the study area, which contain elevated magmatic concentrations of uranium, fluorine, beryllium, lithium, and molybdenum (Steven and others, 1977; Gibbs, 1981; Goodknight and Ludlam, 1981). These rhyolites, and similar rocks elsewhere, are referred to as "topaz" rhyolites by Burt and others (1982), who noted their relationship to deposits of uranium, beryllium, tungsten, tin, and molybdenum. In the region including the study area, the only likelihood for uranium deposits is associated with rhyolites of this type. Although two of these rhyolite-related uranium occurrences outside of the study area have been drilled rather extensively, no significant uranium deposits have been delineated (Hon and others, 1986).

There is no geological or geophysical evidence to suggest similar rhyolite intrusions beneath the study area. However, none of the geophysical data available for the study area was adequate to determine if similar intrusions are present at any great depth below the surface. Because no data about the subsurface are available for the study area, the resource potential for uranium deposits related to rhyolite intrusions in the study area is low, with the certainty level of this evaluation only suggested by the data (certainty level B).

Gravel Deposits

No deposits of gravel were noted within the American Flats Wilderness Study Area. The study area is within the headwaters of Wildhorse, Cow, and Henson Creeks, where alluvium consists primarily of poorly sorted, angular to subangular cobbles and boulders that differ little in character from the surrounding colluvial and talus deposits. In addition, no glacial deposits that could have provided a source of gravel are recognized within the area.

On the basis of these observations, the mineral resource potential for unique or easily recoverable deposits of gravel within the wilderness study area is classified as low, with a well-defined level of certainty (level D).

Potential for Undiscovered Energy Resources

Geothermal Resources

No evidence of active geothermal systems was seen within the American Flats Wilderness Study Area. The nearest known hot springs are those at Ouray, which have temperatures that range from 60 °C to 82 °C (Pearl, 1972). The highest measurement of heat flow in the San Juan Mountains was taken near Ouray and the next highest measurements are from the Mary Alice Creek and Nellie Creek areas (Reiter and Clarkson, 1983), which are 2 mi and 8 mi east of the study area, respectively. Although these data indicate that the entire area represents a region of elevated heat flow, there is little evidence to suggest that conditions are favorable for producing geothermal energy anywhere near the study area. This conclusion concurs with that of Steven and others (1977) for the surrounding Big Blue Wilderness. The available data do not completely rule out the possibility that there might be geothermal sources, such as hot, dry rock, at great depth, but this possibility is unlikely. Therefore, the American Flats Wilderness Study Area is assigned a low resource potential for geothermal energy, with a good degree of certainty (level C).

Oil, Gas, and Coal Resources

Geologic data indicate that there are no rock units known to be favorable for the accumulation of oil, gas, or coal within or near the wilderness study area. Thick sequences of Paleozoic and Mesozoic sedimentary rocks, which are known to host such resources elsewhere, are not present underneath the study area. None of the Tertiary volcanic units or Proterozoic metamorphic and igneous rocks in the area is a suitable host for accumulations of fossil fuels. A similar conclusion was reached by Spencer (1983) for the American Flats Wilderness Study Area. There is no resource potential for oil, gas, or coal within the wilderness study area; the certainty of this assessment is clearly defined (level D).

Conclusions

The geologic evidence available at the time of this evaluation indicates that the American Flats Wilderness Study Area has a low mineral resource potential for all metals and nonmetals, and for geothermal energy. The certainty of this assessment ranges from clearly defined (level D) to good (level C) to suggested (level B); see explanation for figure 1 for specific commodities. There was no past mining activity; nor is there evidence of extensive prospecting within the study area. Although some moderately productive mineral deposits occur within 2–4 mi of the study area boundary, little geologic or geochemical evidence of mineralized rock was found within the study area. Conditions favorable for the accumulation of energy resources are neither known nor postulated to occur within the wilderness study area. Nothing of sufficient geologic interest was found during the course of this surface investigation to warrant further study of the 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.

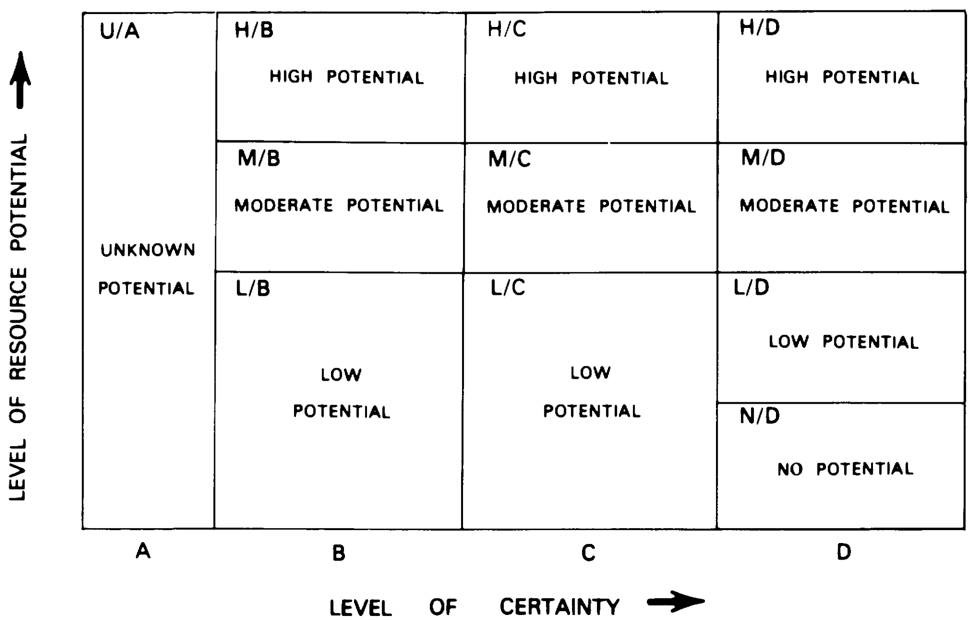
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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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 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
			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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