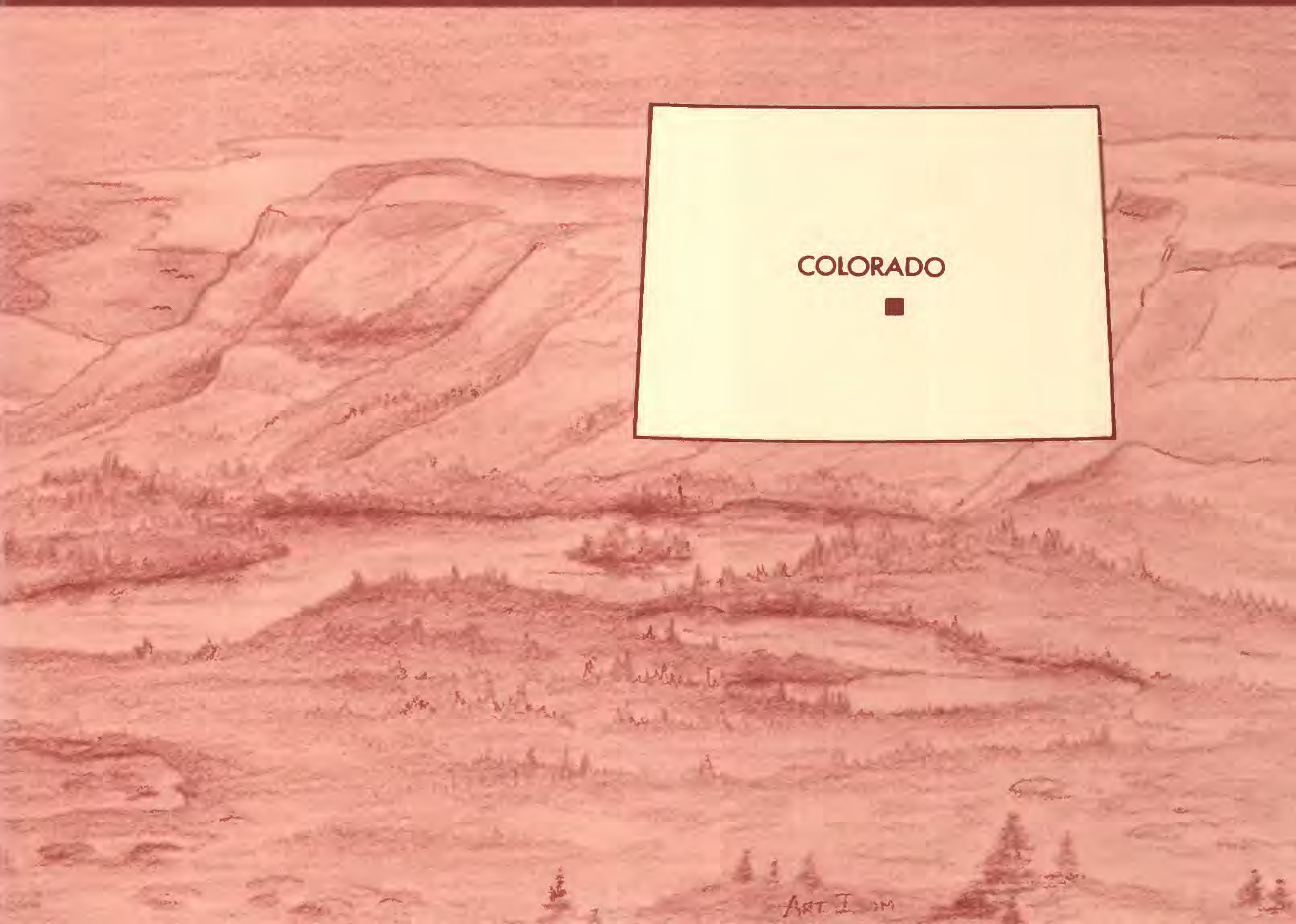
Mineral Resources of the Beaver Creek Wilderness Study Area, Fremont, El Paso, and Teller Counties, Colorado

U.S. GEOLOGICAL SURVEY BULLETIN 1716–B



DEFINITION OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

Definitions of Mineral Resource Potential

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

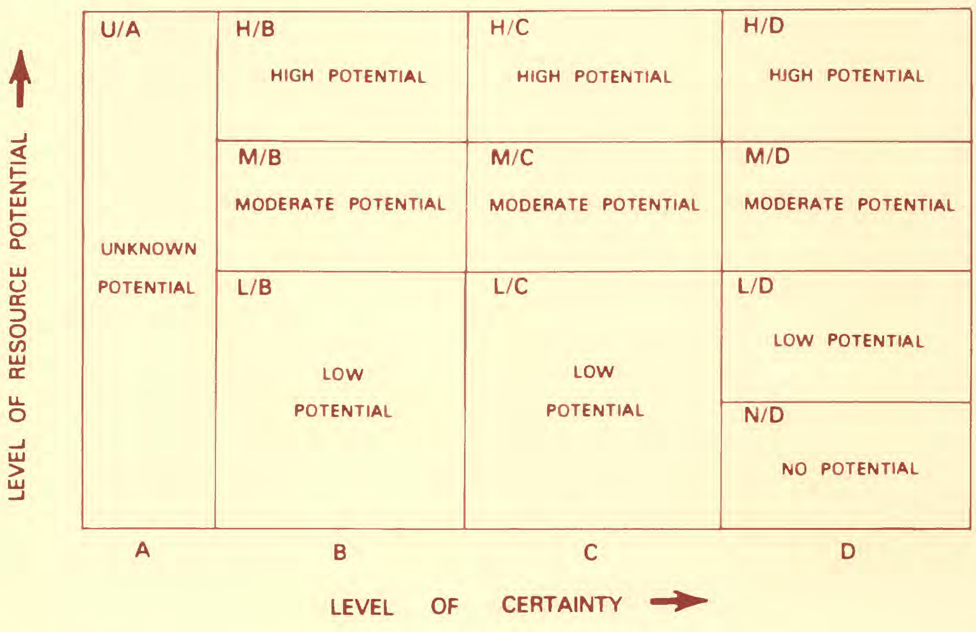
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



A. Available information is not adequate for determination of the level of mineral resource potential.

B. Available information suggests the level of mineral resource potential.

C. Available information gives a good indication of the level of mineral resource potential.

D. Available information clearly defines the level of mineral resource potential.

Abstracted with minor modifications from:

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

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

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Chapter B

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTH-CENTRAL COLORADO

Mineral Resources of the Beaver Creek Wilderness Study Area, Fremont, El Paso, and Teller Counties, Colorado

By David A. Lindsey, Jerry R. Hassemer, Ronny A. Martin, and Richard B. Taylor, U.S. Geological Survey, and Terry J. Kreidler, U.S. Bureau of Mines

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94–579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the results of a mineral survey of the Beaver Creek (CO–050–016) Wilderness Study Area, Fremont, El Paso, and Teller Counties, Colorado.

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(In pocket)

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Mineral Resources of the Beaver Creek Wilderness Study Area, Fremont, El Paso, and Teller Counties, Colorado

By David A. Lindsey, Jerry R. Hassemer, Ronny A. Martin, *and* Richard B. Taylor,
U.S. Geological Survey *and*
Terry J. Kreidler,
U.S. Bureau of Mines

SUMMARY

The Beaver Creek (CO–050–016) Wilderness Study Area has identified resources of dolomite and small identified resources of fluorite and pegmatite minerals (fig. 1). Construction stone is quarried nearby, east of the study area. No geologic terrane having high or moderate potential for undiscovered mineral resources was found in the study area. The potential for undiscovered resources of metals, pegmatite minerals, and oil and gas is considered low. This conclusion is based on field studies done in 1984 and on analysis of previous geologic mapping.

The Beaver Creek Wilderness Study Area (20,750 acres) is south of Pikes Peak and north of the Arkansas River, about 8 mi (miles) northeast of Canon City and 12 mi southwest of Colorado Springs, in Fremont, El Paso, and Teller Counties, Colorado. The northern boundary of the study area is from 1.5 to 4 mi south of the Pike National Forest. The study area is accessible on foot from the gravel road in Phantom Canyon (Eightmile Creek) and by trails that extend from the ends of gravel roads at Beaver Creek, Red Creek Canyon, and Turkey Creek. The wilderness study area covers rugged terrain that ranges in elevation from about 6,200 ft (feet) to 9,922 ft.

The wilderness study area is in the southernmost part of the Front Range, a geologic terrane that has been uplifted repeatedly in the geologic past. Faults that trend northeast and north across the study area probably formed in Precambrian time. These faults were probably reactivated during uplift of the ancestral Rocky Mountains about 280–320 million years ago, again during the Laramide uplift about 50–70 million years ago, and finally during uplift from about 30 million years ago to the present. During the last period of uplift, the Arkansas River eroded the broad Canon City embayment from soft sedimentary rocks south of the study area.

Proterozoic igneous and metamorphic rocks (1,400–1,800 million years old) are exposed over much of the wilderness study area. They include a batholith of granodiorite, which has intruded slightly older quartzite and gneiss of Early Proterozoic age, and a stock of Middle Proterozoic quartz monzonite, which has intruded both granodiorite and gneiss. The marginal zone of the granodiorite batholith contains small, sparse dikes of pegmatite that have been prospected for mica and fluorspar.

Paleozoic sedimentary rocks (250–500 million years old) are exposed in remnants of synclines north of major faults and in an east-dipping sequence that extends along the southeastern margin of the wilderness study area. Paleozoic sedimentary rocks consist of the Ordovician Manitou Limestone, the Ordovician Harding Sandstone, the Ordovician Fremont Dolomite, and the Pennsylvanian and Permian Fountain Formation. The Fremont Dolomite has been quarried near Canon City for use in the steel mills at Pueblo. It is as much as 55 ft thick about midway along the southeastern margin of the study area but is absent to the southwest and northeast. The gypsum-bearing Permian and Triassic Lykins Formation is outside the study area, to the southeast.

The Beaver Creek Wilderness Study Area contains identified resources of high-purity dolomite in the Fremont Dolomite. About 40 million tons of metallurgical-grade dolomite may exist mostly outside but near the southeastern boundary of the study area. Dolomite along the boundary of the study area may not be developed because the only local market for metallurgical dolomite, the CF&I Steel Corp. blast furnaces at Pueblo, was closed in 1982.

A small identified resource of fluorite occurs in veins in granodiorite on West Mill Creek. Pegmatites in the wilderness study area have been prospected for mica and fluorspar, and small identified resources of mica and feldspar in pegmatites occur in Trail Gulch. In Turkey Creek, east of the study area, quartz monzonite of Middle Proterozoic age is quarried for construction stone.

The Beaver Creek Wilderness Study Area has a low mineral resource potential for undiscovered metals, pegmatite minerals (and rare metals associated with them), and oil and gas. Except for pegmatite dikes, no evidence of mineralization or related alteration was observed at the surface in the study area. Geochemical anomalies that would indicate stratabound or other metal deposits

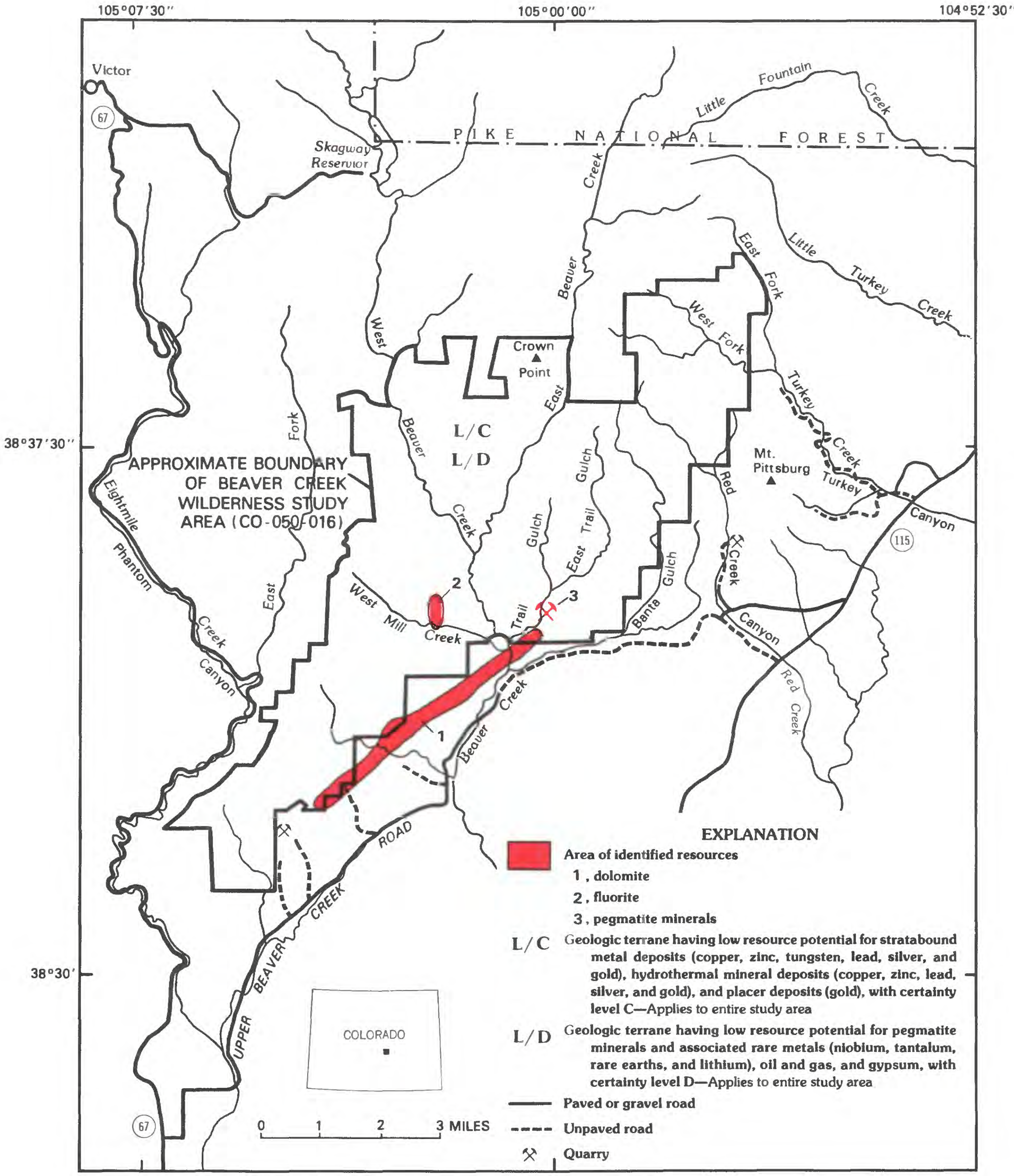


Figure 1. Summary map showing mineral resource potential and mineral occurrences of the Beaver Creek Wilderness Study Area.

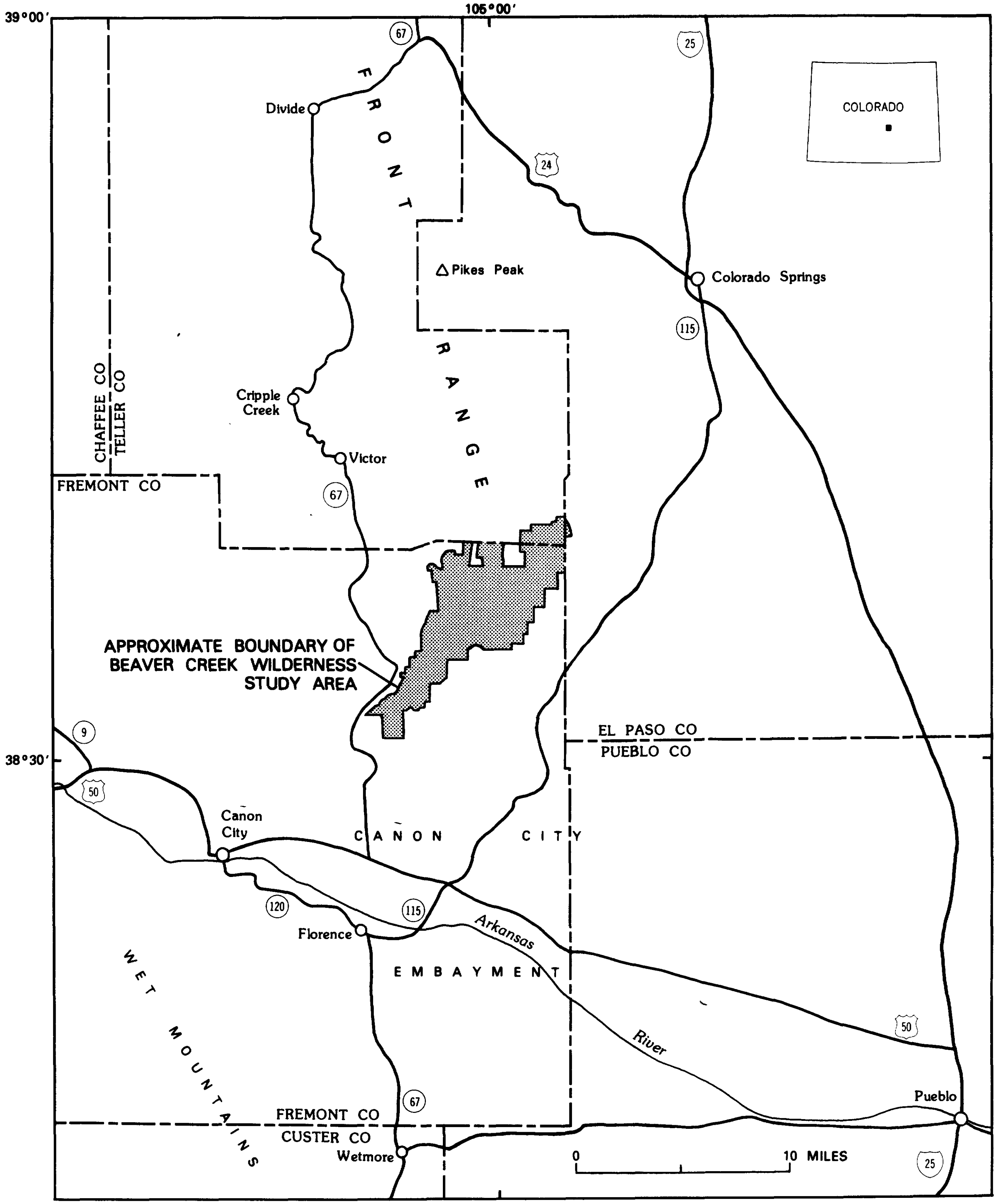


Figure 2. Index map showing location of the Beaver Creek Wilderness Study Area.

were not found. Geochemical anomalies of molybdenum and tungsten in stream sediments of the study area are probably derived from scattered pegmatite dikes because intrusive rocks generally favorable for stockwork deposits are not known in the area. Pegmatite dikes are small and sparse in the marginal zone of Precambrian intrusions. No magnetic anomalies indicating buried mineral deposits or alteration zones were located. The geologic environment is not favorable for oil and gas.

INTRODUCTION

The U.S. Geological Survey and the U.S. Bureau of Mines studied 20, 750 acres of the Beaver Creek (CO–050–016) Wilderness Study Area. The study of this acreage was requested by the U.S. Bureau of Land Management. In this report, the studied area is called "wilderness study area" or simply the "study area".

The Beaver Creek Wilderness Study Area is south of Pikes Peak and north of the Arkansas River, about 8 mi northeast of Canon City and 12 mi southwest of Colorado Springs, in Fremont, El Paso, and Teller Counties, Colorado (fig. 2; pl. 1). The northern boundary of the study area is 1.5 to 4 mi south of the Pike National Forest. The study area is accessible on foot from the unpaved gravel road in Phantom Canyon (Eightmile Creek) and by trails that extend from the ends of gravel roads at Beaver Creek, Red Creek Canyon, and Turkey Canyon (Turkey Creek); the latter two roads pass through private property. The roads connect with U.S. Highway 50 to the south and Colorado State Highway 115 to the east. The wilderness study area has rugged terrain and ranges in elevation from about 6,200 ft where a trail enters the study area along Beaver Creek to 9,922 ft at Crown Point in the northern part of the study area.

Investigations by the U.S. Bureau of Mines

The Beaver Creek Wilderness Study Area was examined by the U.S. Bureau of Mines in 1984 (Kreidler, 1985; pl. 1*A*, this report). Prior to the field investigation, a detailed literature search was made for pertinent geologic and mining information. U.S. Bureau of Land Management records were checked for the location of patented and unpatented claims, and oil and gas, geothermal, and other mineral leases in or near the study area. Field studies by Bureau of Mines personnel included investigation of mines, prospects, and mineralized areas in and within 1 mi of the study area. Forty samples were collected from 12 pits, 7 dumps, 5 adits, 3 shafts, 2 quarries, 1 vein, and 1 outcrop. All samples were analyzed by a semiquantitative optical emission spectrographic method for 40 elements; additionally, 33 samples were analyzed by fire assay for gold and silver, 15 were analyzed for copper by atomic absorption, and 7 were analyzed for uranium by fluorimetry and for fluoride by selective-ion electrode analysis. Sample descriptions and analytical results are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Building 20, Denver Federal Center, Denver, CO 80225.

Investigations by the U.S. Geological Survey

A geologic map of the Beaver Creek Wilderness Study Area and vicinity (pl. 1*B*) was prepared by D. A. Lindsey from: mapping of the Phantom Canyon quadrangle (Wobus and others, 1985); mapping of the Cripple Creek-Pikes Peak area (Wobus and others, 1976); an unpublished thesis map of the Mount Pittsburg quadrangle (Orr, 1976); unpublished mapping of the Mount Pittsburg and Mount Big Chief quadrangles by R. B. Taylor, G. R. Scott, and R. A. Wobus of the U.S. Geological Survey; and new field mapping in July 1984 by D. A. Lindsey and R. B. Taylor. Sampling for a stream-sediment geochemical survey was done in July 1984 (Detra and others, 1985), and the geochemical data were interpreted by J. R. Hassemer for this report. An existing aeromagnetic survey of the western half of the study area and adjacent terrain was analyzed by R. A. Martin. Mineral resources of the wilderness study area are classified by potential and level of certainty (see inside of front cover), and by types of deposits.

Acknowledgments.—We thank employees of the Bureau of Land Management in Canon City, Colo., for providing information on mineral resources from their files.

APPRAISAL OF IDENTIFIED RESOURCES

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

Mining History

Bureau of Land Management records show 63 patented lode claims in the area, 7 of which are wholly or partly within the study area (pl. 1*A*). As of September 1984, there were 63 unpatented mining claims recorded with the Bureau of Land Management, all at least 1 mi southeast of the study area (Kreidler, 1985, pl. 1) in a geologic terrane that does not occur in the wilderness study area. There are no oil and gas leases in or near the study area.

The first claims, presumably for gold and silver, were located near the wilderness study area in the late 1880's, when prospectors arrived from the Cripple Creek district to the northwest. They found the geologic terrane of the study area to be completely different from that of Cripple Creek; their efforts went unrewarded. Three poorly defined mining districts were established near the study area at about this time: the McCourt (or Eightmile), the Wilbur, and the Turkey Creek (pl. 1*A*). Part of the Cripple Creek mining district, which was defined by Henderson (1926) as including the area of T. 14–16 S. and R. 68–70 W., is within the northwestern part of the study area, although the nearest workings in the district are a group of prospects 3–4 mi northwest of the study area. The only recorded production in or near the study area was during World War I, when 1,800 lbs (pounds) of ore averaging 58 percent WO_3 was shipped from the Presidents group of patented claims about 2 mi west of the study area in the Holbert cabin area (Belser, 1956, p. 8).

Appraisal of Sites Examined

Six mineralized areas were identified during the field examination (pl. 1*A*): (1) Pecks Camp area, (2) Northwest area, (3) Holbert cabin area, (4) McCourt area, (5) Southeast area, and (6) Mill Creek fluorite area (Kreidler, 1985). Of these areas, only the Mill Creek fluorite area has identified resources as defined by the U.S. Bureau of Mines and the U.S. Geological Survey (1980). Salient characteristics of the other areas are summarized in table 1. No workings or evidence of mineralization were found in the Turkey Creek district. Other identified resources include the Fremont Dolomite, which occurs in a narrow band along the southeastern boundary, and pegmatite minerals in pod-shaped veins. At least two pegmatite veins have been quarried to a limited extent (one within the study area and one about 1 mi west). The pegmatites are also summarized in table 1.

Mill Creek Fluorite Area

Fluorite is a mineral with the composition CaF_2; fluorspar is its commercial name. Fluorspar has many industrial applications, the most important of which is in the manufacture of hydrofluoric acid, used extensively in the aluminum, fluorochemical, and uranium industries. It is also used in the making of iron and steel and specialized types of glass (Fulton and Montgomery, 1983, p. 724–725). Acid-grade fluorspar must be 98 percent CaF_2, and metallurgical grade at least 85 percent (Bates, 1969, p. 277–278). Estimated domestic production for 1985 is 70,000 tons, only about 8 percent of estimated consumption; the rest is imported primarily from Mexico and the Republic of South Africa. Domestic fluorspar demand is forecast to increase at a rate of about 2.7 percent per year through 1990. The average price of domestically produced fluorspar in 1984 was $170 per ton (U.S. Bureau of Mines, 1985, p. 50–51).

In the study area, fluorite occurs in veins and pods about 1.25 mi upstream on Mill Creek from its junction with Beaver Creek. Workings include two adits, 73 and 53 ft long, an inaccessible adit estimated at about 30 ft, a 15-ft-deep shaft, and a pit. The prospect was developed in the mid-1950's, but there are no known production records. According to Joseph Lackey (oral commun., 1984), former miner at Canon City, the ore was hand sorted to upgrade it to metallurgical grade. However, ore reserves were small and mining costs were high; operations ceased in 1958.

The veins are in Early Proterozoic granodiorite on the northern side of West Mill Creek; the ridge on the southern side of the creek is Early Proterozoic gneiss. The granodiorite is pink to pale pink, medium grained, and biotite rich. Movement on the Adelaide fault, about 0.5 mi to the northwest, probably produced faulted and sheared zones in the granodiorite; the fluorite veins occupy one of these zones. The fluorite is clear to deep purple. Seven samples were taken at the site, three from the lower two adits and four from a series of prospects on a single vein farther up the ridge. The lower adit has a well-defined 7-in.(inch)-thick vein striking northeast and dipping 15° SE., but it is mostly quartz, and the two samples from it contained only 0.52 and 1.7 percent CaF_2. The vein in the upper adit was poorly defined and discontinuous; a sample from the one place where the vein was easily distinguished contained 33.0 percent CaF_2. The samples also contained minor amounts of uranium (37–167 ppm, or parts per million) in too low a concentration to be of economic interest (Kreidler, 1985, fig. 2).

The fluorite vein exposed in the upper series of prospects is more consistent in size and mineral content, and it may be the same as the vein at the higher of the two adits, although the two cannot be visually connected. The vein, averaging about 20 in. thick, strikes N. 15° W., dips 80° N., and contains a varying amount of quartz, as much as 50 percent. Four samples from the vein contained an average of 63.5 percent CaF_2, with values ranging from 38 to 82 percent. The surface exposure of the vein is traceable for about 60 ft (Kreidler, 1985, fig. 3). Assuming that the vein extends both laterally and vertically a distance equal to one-half its exposed length and that it contains 11 ft^3 (cubic feet) of rock per ton, an identified resource of approximately 400 tons averaging 63.5 percent fluorspar is left in the upper vein. However, the pinching nature of the vein makes this an optimistic estimate. The ore would have to be concentrated to at least metallurgical grade (85 percent CaF_2) prior to shipment. The likelihood of any further development is low because of the low grade and tonnage, discontinuous nature, high transportation costs, and low unit value of the deposit.

Fremont Dolomite

Dolomite rock is composed of at least 50 percent calcite and dolomite, dolomite being more abundant. It has many of the industrial uses of limestone, such as aggregate for construction applications, fluxing agent in

Table 1. Miscellaneous mineral occurrences in and near the Beaver Creek Wilderness Study Area, Colorado

Sample No. (pl. 1A)	Name (commodity)	Description	Workings	Sample and resource data
1-6	Pecks Camp*-	Quartz veins and diorite dikes in granodiorite, minor pyrite, chalcopyrite, and possibly fluorite. Structures not exposed, but trend of workings suggests they do not extend into study area.	Two shafts, four caved adits.	Of six samples, one contained 0.02 oz gold/ton and five contained minor amounts of copper (0.001-0.138 percent); no resource identified.
7-9	Northwest--	Quartz veins, 7 and 20 in. wide, strike N. 15° W., and diorite dike in granodiorite. Veins have minor iron and manganese staining, no other visible minerals.	One shaft, 7x10x20 ft, two prospect pits.	Three samples contained no detectable concentrations of metallic minerals.
10-13, 17-21	Holbert cabin* (copper, tungsten).	Quartz veins and diorite dikes in fault zones in quartz monzonite. No metallic minerals seen in workings or outcrop but moderately abundant on dumps. Strikes of structures vary between N. 10° W. and N. 25° E. Doubtful if they extend into the study area.	Caved shaft, caved adit, five prospects. 1,800 tons of ore averaging 58 percent WO_3 was shipped from adit during World War I.	Minor copper detected in samples 10, 11, 13, 17, 18; 3.8 percent in sample 12. No copper resource identified. Tungsten not suspected at time of field study, and no analysis was requested.
22-26	McCourt area*	Pink to white quartzite, very clean except for iron staining. Quartzite occurs in study area but is not mineralized.	One prospect adit, 38 ft long, two prospect pits.	No metals detected in five samples.
27-30	Southeast area* (manganese, clay).	Pennsylvanian and Permian Fountain Formation, manganese on fractures as thick as 1 in., appears to be limited to this exposure. Clay beds as thick as 30 ft currently (1985) mined by Summit Brick Co., who has no plans for expansion of present pit into study area.	One trench 50x35 ft; an operating clay pit.	Samples 28 and 29 contained 3.1 and 9.8 percent manganese, respectively. Exposure of deposit too limited to determine size of resource. Clay is stratigraphic unit in Fountain Formation, which may occur in extreme southern end of study area.
14-16	Pegmatite, Holbert cabin Area*.	Pegmatite pod in Early Proterozoic granodiorite.	Open cut, 150x50x 23 ft.	Outer zone of massive orthoclase and muscovite, mica books as large as 3x6 in. and massive-quartz inner zone. Unable to calculate size of remaining resource due to limited exposure; rough estimate of 200-300 tons based on observation. Further development unlikely due to lack of local market.
38-40	Pegmatite, Trail Gulch.	Pegmatite pod in Early Proterozoic granodiorite.	Open cut, 70x 15x13 ft.	Outer zone of massive orthoclase and muscovite, mica books as large as 4x9 in. and clusters to 18 in., quartz inner zone not exposed. Unable to calculate remaining resource due to limited exposure; rough estimate of 100-200 tons of material based on observation. Further development unlikely due to lack of local market.

*Outside the wilderness study area.

the smelting and refining of iron and other metals, soil conditioner, manufacture of glass, and dimension stone. Dolomite is also utilized as a refractory in lining metallurgical furnaces (Bates, 1969, p. 156–157).

The Fremont Dolomite is a high-purity dolomite and has been quarried southwest of Canon City by CF&I Steel Corp. for making iron and steel (Carter, 1968, p. 205). The Fremont Dolomite crops out inside and along the southeastern boundary of the study area (pl. 1*A*) for a distance of about 5 mi; it has an average thickness of about 35 ft. Assuming down-dip continuity to a minable depth of 500 ft and 11.5 ft^3 of dolomite per ton, a resource of 40 million tons exists mostly outside the wilderness study area boundary. Although the dolomite dips away from the study area at an average of 45°, any development of the deposit would start in or adjacent to the study area. The deposit is close to existing roads; only short access roads of 1 mi or less would be needed. Development of the resource is not likely, though, because the primary consumer of metallurgical dolomite in Colorado, CF&I Steel Corp., permanently closed the blast furnaces at its smelter in Pueblo in 1982 and sold its interest in the dolomite quarry near Canon City.

Conclusions and Recommendations for Further Study

A fluorite resource of approximately 400 tons averaging 63.5 percent CaF_2 occurs in the wilderness study area in West Mill Creek in a fluorite-quartz vein in granodiorite. The low tonnage and grade of the resource and high mining costs preclude any future development at current or foreseeable prices. An exploration program consisting of trenching across the upper vein as well as along strike may locate extensions of the veins or discover other veins, perhaps larger and of higher grade.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By David A. Lindsey, Jerry R. Hassemer, Ronny A. Martin, and Richard B. Taylor, U.S. Geological Survey

Geology

Geologic Setting

The Beaver Creek Wilderness Study Area is just north of the Canon City embayment, at the southern end of the Front Range uplift (fig. 2, pl. 1*B*). The study area contains igneous and metamorphic rocks of Precambrian age and sedimentary rocks of Paleozoic age. Southeast of the study area, outcropping sedimentary rocks of Mesozoic age form the margin of the Canon City embayment. Rocks of the study area are cut into a steplike series of blocks by north- and northeast-trending fault zones, each upthrown on the southeastern side.

The Precambrian rocks of the Beaver Creek area consist of Early Proterozoic gneiss, quartzite, and granodiorite, and Middle Proterozoic quartz monzonite (pl. 1*B*). East and west of Phantom Canyon, gneiss of Early Proterozoic age forms a steeply dipping southeast-facing sequence that mostly overlies a thin marker unit of Early Proterozoic quartzite. Below the level of the quartzite marker, the gneiss has been intruded by the Phantom Canyon batholith of Early Proterozoic granodiorite. The quartzite marker extends east along the intrusive contact to near Red Creek Canyon, where a stock of Middle Proterozoic quartz monzonite has intruded the granodiorite-gneiss contact. East of Red Creek Canyon, remnants of the quartzite marker indicate the approximate position of the former contact between the gneiss and granodiorite. This intrusive contact is significant because, elsewhere in Colorado, the marginal zones of Early Proterozoic granodiorite batholiths contain pegmatite dikes having resources of feldspar, mica, beryl, and rare-metal minerals (Taylor and others, 1984, p. 28–30). Pegmatite dikes occur in the outer zone of the granodiorite batholith in the Beaver Creek Wilderness Study Area, but they are small and sparse. No other indication of mineralization has been observed in the Proterozoic rocks of the study area.

Paleozoic rocks of the Beaver Creek Wilderness Study Area include the Manitou Limestone, Harding Sandstone, and Fremont Dolomite of Ordovician age, and the Fountain Formation of Pennsylvanian and Permian age (pl. 1*B*). These rocks occur locally in synclines within the study area and crop out extensively in a southeast-dipping homoclinal sequence along the southeastern margin of the study area, where the Fremont Dolomite is present locally. The Fremont Dolomite was mined for high-purity dolomite southwest of the study area near Canon City (Carter, 1968, p. 205). The gypsum-bearing Triassic and Permian Lykins Formation, as well as younger Mesozoic formations, crop out to the southeast, outside the study area.

The north- and northeast-trending fault zones of the study area (pl. 1*B*) probably date from Precambrian time. The nature of motion along the faults during Precambrian time is unknown, but the geometry of the fault zones is compatible with strike-slip movement. Where the fault zones traverse Proterozoic rocks, they are defined by a brecciated and mylonitized zone as much as 500 ft wide and are intruded by dikes of mafic rock (not shown on pl. 1*B*). The fault zones dip nearly vertically and, where mapped in detail, split into many strands. The Adelaide fault zone tends to follow major lithologic boundaries, but it does not delineate these boundaries precisely. In the northeastern part of the study area, the Adelaide fault zone approximately follows the contact between large intrusions of Early Proterozoic granodiorite and Middle

Proterozoic quartz monzonite, but the fault zone has left thin intervals of quartz monzonite in apparent intrusive contact with granodiorite northwest of the fault. To the southwest, the Adelaide fault zone splits into two branches that diverge gradually from the contact between Early Proterozoic granodiorite and gneiss.

Some of the fault zones may have been active during Pennsylvanian and Permian time, when the Front Range was first uplifted as part of the ancestral Rocky Mountains (Mallory, 1972). At that time, the site of the Beaver Creek Wilderness Study Area was at the southern end of the ancestral Front Range. Sedimentary rocks of Ordovician age were partly removed by erosion of the flanks of the uplift, and rocks of Proterozoic age were eroded from the core of the uplift. Detritus from the Front Range uplift was deposited on alluvial fans around the margin of the uplift. These alluvial deposits make up most of the Pennsylvanian and Permian Fountain Formation, now exposed around the margins of the Canon City embayment and in the foothills of the Beaver Creek area. By Late Triassic time, the Front Range uplift had been reduced to a low plain.

The Adelaide and other fault zones to the southeast show evidence of reverse movement where they cut sedimentary rocks of Paleozoic age. At the surface, these fault zones dip moderately (45–55°) southeast and override west-facing synclines of Paleozoic rocks. Steeply dipping to overturned beds of Paleozoic rocks make up the footwall of the faults. Although they dip moderately near the surface, at depth the faults probably have near-vertical attitudes inherited from Proterozoic movement (sections *A–A′*, *A″–A‴*, pl. *1B*). The reverse-fault style probably represents movement during the Laramide orogeny, perhaps in response to poorly understood northwest-directed stresses within the southern part of the Front Range uplift.

After a long interval of erosion during the Eocene and Oligocene Epochs, the southern Front Range was uplifted again during Miocene time and later (Taylor, 1975). The third uplift of the Front Range was accompanied by normal faulting outside the study area, but direct evidence for normal faulting is lacking in the Beaver Creek Wilderness Study Area. Possibly, some of the faults in the study area may have moved as normal faults, with downthrown sides on the southeast, during late Cenozoic time. Normal faulting has been recognized in the Canon City area, southwest of the study area, and near Cripple Creek, north of the study area, and is considered to have been partly responsible for the great contrast in elevation between the Cripple Creek area and the Canon City embayment (Taylor, 1975, p. 221–223). Also, in late Tertiary and Quaternary time the Arkansas River eroded soft sedimentary rocks, forming the present topographic reentrant (Canon City embayment) that borders the southeastern side of the Beaver Creek Wilderness Study Area.

Description of Rock Units

Except where noted, the following description of rock units on pl. *1B* is modified from Wobus and others (1985).

Early Proterozoic quartzite (unit Xq).—White to light-gray, well-bedded quartzite is well exposed along the road in Phantom Canyon. The quartzite is pure, mostly thin bedded, and contains locally preserved crossbedding and ripple marks that indicate stratigraphic tops to the southeast. Quartzite overlies gneiss locally, but at most localities this contact has been obscured by intrusion of granodiorite. The quartzite is interlayered with overlying gneiss through an interval of 10 to 20 ft. The thickness of the quartzite is as much as 100 ft in the study area.

Early Proterozoic biotite gneiss (unit Xgn).—The unit is composed of dark-gray, layered, well-foliated biotite-quartz-plagioclase gneiss and schist, and minor interbedded hornblende gneiss and calc-silicate gneiss. The gneiss contains sillimanite and microcline locally.

Early Proterozoic granodiorite of Routt Plutonic Suite (unit Xgd).—Medium- to coarse-grained biotite granodiorite to quartz monzonite composes the Phantom Canyon batholith. The granodiorite commonly contains large ovoid to euhedral crystals of pink microcline in a gray groundmass and contains foliation parallel to that of adjacent gneiss. Marginal zones of the batholith contain small pegmatite dikes composed of quartz, potassium feldspar, and mica, and inclusions of gneiss and quartzite. Granodiorite is interleaved with gneiss and quartzite along the walls of the batholith. The batholith is dated at 1,670 m.y. (Hutchinson and Hedge, 1967) and assigned to the Routt Plutonic Suite (Tweto, in press) of about 1,700 m.y. age.

Middle Proterozoic quartz monzonite of Berthoud Plutonic Suite (unit Yqm).—Gray, fine- to medium-grained quartz monzonite forms a stock centered near Mt. Pittsburg. The stock intrudes older gneiss, quartzite, and granodiorite. At the walls of the stock, the quartz monzonite is interlayered with gneiss and quartzite. In Turkey Creek canyon, the wall of the stock is granodiorite; there, a marginal zone of the stock contains abundant inclusions of gneiss. The quartz monzonite is assigned to the Berthoud Plutonic Suite (Tweto, in press) of about 1,400 m.y. age.

Cambrian(?) sandstone (unit Ꞓs).—A dike of red-brownto gray quartz sandstone, about 30 ft wide, was emplaced along a fault in Early Proterozoic granodiorite in the northeastern part of the study area. The dike, and others like it west of Colorado Springs, may be a remnant of Cambrian Sawatch Quartzite (Ross and Tweto, 1980, p. 50). Sandstone filling the dike does not contain material indicative of Ordovician or younger rocks.

Undivided Ordovician sedimentary rocks (unit Ou).—In ascending order, this unit consists of the Manitou Limestone, Harding Sandstone, and Fremont Dolomite. The following description is modified from Gerhard (1967). (1) The Manitou Limestone (Early Ordovician) is composed of pink to gray cherty dolomite in the lower part and pink to gray massive limestone in the middle and upper parts. The Manitou Limestone is 50–100 ft thick and unconformably overlies Proterozoic rocks. (2) The Harding Sandstone (Middle Ordovician) is composed of quartz- or chert-pebble conglomerate over a disconformable base; red sandy shale and interbedded white sandstone in the lower and middle parts; and white, yellow, pink, and green quartz sandstone in the upper part. The Harding is about 100 ft thick. (3) The Fremont Dolomite (Late Ordovician) is composed of light-gray, massive to thin-bedded, fossiliferous dolomite; it is locally cherty, stained red, and contains solution breccia. A widespread unconformity at the top records pre-Pennsylvanian erosion. The Fremont Dolomite is absent along much of the mountain front but is as much as 55 ft thick in a lens that extends along the front near Beaver Creek from sec. 25, T. 17 S., R. 69 W. to sec. 9, T. 17 S., R. 68 W. (Gerhard, 1967, p. 2275); the Fremont may be as much as 150 ft thick in the syncline northwest of the Adelaide fault zone.

Pennsylvanian and Permian Fountain Formation (unit PPf).—The Fountain is composed of reddish-brown arkosic sandstone and conglomerate, yellowish-gray arkosic sandstone, and thin beds of pale-green and dark-red-brown siltstone and shale; it is about 1,200 to 1,400 ft thick. According to Schultz (1984), the Fountain Formation in the Beaver Creek area contains a basal member, 100 to 300 ft thick, distinguished from the rest of the Fountain by abundant quartz sand and generally finer grain size, and unconformably overlain by conglomerate and arkose of the upper member. Besides abundant conglomerate and arkose, the upper part of the Fountain near Phantom Canyon contains many beds of dark-red mudstone and nodular limestone.

Triassic and Permian Lykins Formation (unit ŦPl).—The Lykins Formation consists of maroon and green silty shale; white, maroon, and pink fine-grained sandstone; and limestone and gypsum. Thickness is as much as 130 ft.

Middle and Late Jurassic Ralston Creek and Late Jurassic Morrison Formations (unit Jmr).—In ascending order: (1) The Ralston Creek Formation consists of sandstone, siltstone, gypsum, and beds of limestone containing red jasper grains; it is about 150 ft thick. (2) The Morrison Formation consists of varicolored gray, maroon, and green siltstone and claystone and thin beds of sandstone, limestone, and conglomerate; it is about 320 ft thick.

Early Cretaceous Purgatoire Formation and Dakota Sandstone (unit Kdp).—In ascending order: (1) The Purgatoire Formation consists of the Lytle Sandstone Member, composed of fine- to coarse-grained sandstone and pebbly sandstone, and the Glencairn Shale Member, composed of shale, claystone, and gypsum; the Purgatoire is 200–250 ft thick. (2) The Dakota Sandstone consists of yellowish-brown, fine-grained, crossbedded sandstone and, in the upper middle part, lesser shale; it is about 115 ft thick.

Quaternary alluvium (unit Qal).—The Beaver Creek Wilderness Study Area contains three units of alluvium, described in order of decreasing age: (1) The Verdos Alluvium (Pleistocene) is composed of brown, poorly sorted, stratified gravel having sandy and silty matrix, about 20 ft thick; the upper part contains strongly developed calcareous brown soil. (2) The Slocum Alluvium (Pleistocene) is composed of medium-reddish-brown, poorly sorted, moderately compacted, stratified gravel, clay, silt, and sand. The Slocum is about 20 ft thick and forms alluvial terraces and pediments about 80–120 ft above major streams. (3) The Piney Creek Alluvium (Holocene) is composed of gray to brown, humic-rich, compacted clayey silt and sand, and gravel lenses in the lower part. It is as thick as 20 ft and forms terraces about 20 ft above major streams.

Quaternary landslide deposits (unit Qls).—Landslide deposits are composed of reddish- to yellowish-brown debris slides and earthflows in the Dakota Sandstone on the valley walls of Beaver Creek. The upper surface is hummocky; thickness is about 30 ft.

Geochemistry

Analytical Methods

Fifty stream-sediment samples were collected from first- and second-order drainages in and near the Beaver Creek Wilderness Study Area (pl. 1*B*). A heavy-mineral concentrate and a minus-100-mesh sample were collected at each locality.

Each heavy-mineral concentrate was collected by panning a composite sample of stream sediment to an approximate composition of half dark minerals and half light minerals using a 16-in.-diameter gold pan. The panned concentrate was then processed through bromoform and an isodynamic separator to obtain nonmagnetic heavy-mineral concentrates for analysis.

All samples were analyzed for 31 elements by a semiquantitative six-step, direct-current arc, optical-emission spectrographic method (Grimes and Marranzino, 1968). Rock samples were also analyzed for arsenic, antimony, bismuth, and cadmium by an atomic-absorption method (Viets, 1978). The minus-100-mesh stream sediments were analyzed for uranium and thorium by a neutron activation method (Millard and Keaton, 1982). Of the elements analyzed, barium, beryllium, boron, copper, gold, lead, molybdenum, niobium, silver, tin, tungsten, and zinc probably are the best indicators of the types of deposits that could be anticipated in the study area. Selected data for the stream-sediment samples are presented in tables 2 and 3. A few rock samples were also analyzed (table 4). All of the data are reported by Detra and others (1985).

Results of Study

Low-level geochemical anomalies in the Beaver Creek Wilderness Study Area are difficult to interpret because they do not present clear patterns of element enrichment. In part, this is due to the reconnaissance nature of the sampling (pl. 1*B*). Although individual drainage basins are small (generally less than 1 square mile), most are narrow and long (generally 1½–3 mi). Most streams run perpendicular, or nearly so, to the strike of geologic contacts; hence they commonly cut across more than one rock unit. Element enrichments are generally low and sporadic and are best seen in the heavy-mineral concentrates.

Low-level anomalous concentrations of molybdenum and tungsten are widespread; anomalous concentrations of lead, tin, beryllium, and copper are sporadically associated with molybdenum and tungsten. No individual sample has all of these elements in anomalous amounts. This enrichment occurs in stream sediments derived from Proterozoic rocks, especially the Early Proterozoic gneiss (unit Xgn, pl. 1*B*) and in that part of the Phantom Canyon batholith (unit Xgd) lying south of the Skagway fault. Molybdenum and tungsten anomalies are due to the presence of scheelite and powellite, which were identified by examining the heavy-mineral concentrates under ultraviolet light. Anomalous concentrations of lead, niobium, and tin occur sporadically throughout the same general area as molybdenum and tungsten. Beryllium (in concentrates only) and copper (in sieved sediments only) are only weakly anomalous. A rough anomaly pattern is defined by beryllium in samples from the western part of the study area (near Phantom Canyon) and copper in samples from the eastern part (near Red Creek Canyon and Turkey Creek). The element suite is compatible with derivation both from Precambrian stratabound sulfide deposits containing tungsten and from rare-metal pegmatite deposits (Taylor and others, 1984). The low-level geochemical anomalies suggest that any deposits in the study area are either small or are not exposed, or that mineralization was weak and insufficient to form a large mineral deposit. Based only on intensity of anomalies, the best chance for a tungsten-bearing deposit is in the Red Creek Canyon area. However, a large tungsten deposit near the surface would be expected to produce a stronger geochemical anomaly than that observed at Red Creek Canyon.

Low-level anomalous concentrations of beryllium in stream sediments in much of the study area suggests the presence of beryllium minerals in zoned pegmatites. However, lack of beryllium in stream sediments of West Mill Creek and Trail Gulch, where small pegmatite dikes are known, argues against its presence in pegmatites there. A grab sample of mica pegmatite from Trail Gulch contained only 10 ppm beryllium (BE105R2, table 4), and a grab sample of fluorite-bearing pegmatite on West Mill Creek (BE112R, table 4) showed a strong enrichment of barium but not of beryllium. Heavy-mineral concentrates containing anomalous amounts of barium were checked under the microscope for fluorite, but none was found.

Barium (as barite) was enriched in heavy-mineral concentrates from streams draining Paleozoic rocks. Barite is a common trace constituent in sandstones and is readily concentrated in nonmagnetic fractions. Hence the occurrence of anomalous barite in Paleozoic terrane probably does not indicate the presence of mineral deposits.

Manganese, possibly in manganese-rich calc-silicate minerals, is present in anomalous amounts in all heavy-mineral concentrates of stream sediments. The common manganese minerals were not seen under the microscope. The significance of manganese-enriched stream sediments is not known.

The minus-100-mesh fraction of stream sediments in the Beaver Creek Wilderness Study Area is slightly enriched in uranium (table 3). High values are in sediments derived from Proterozoic source areas, a relationship that is typical of stream sediments throughout the Colorado Front Range. Scattered values as high as 30–40 ppm probably indicate local precipitation of uranium in organic-rich stream sediments. Although uranium deposits can form by precipitation in organic matter, uranium values in the Beaver Creek Wilderness Study Area are probably too low to indicate the presence of uranium deposits.

Geophysics

Methods

Aeromagnetic data for the Beaver Creek Wilderness Study Area were taken from surveys flown at 1- and 2-mi flight-line spacing, projected to 14,500 ft barometric elevation and contoured at 20-gamma intervals (Klein, 1983). The high-altitude regional aeromagnetic data delineate the Pikes Peak batholith, the Phantom Canyon batholith, sedimentary rocks, possibly the northeast-trending Mountaindale fault east of the study area, possibly a northwest-trending fault mapped between Phantom Canyon and the northern side of the study area, and possibly an extension of the north-trending fault that may extend approximately east of the Crown Point peak (compare fig. 3 with pl. 1*B*). The regional data are not sufficient to delineate the northeast-trending faults or contacts between rock units within the study area.

Table 2. Concentrations of selected elements in heavy-mineral concentrates, Beaver Creek Wilderness Study Area

[Concentrations in parts per million. All samples analyzed by six-step spectrographic method by D. E. Detra; L, less than; N, not found; >, greater than; number in parentheses, lower limit of detection]

Sample No.	Mn (20)	Ba (50)	Be (2)	Mo (10)	Nb (50)	Pb (20)	Sn (20)	W (100)	Cu (10)	Zn (500)
BE001	5,000	1,000	7	N	L	50	1,500	100	10	N
BE002	5,000	500	7	10	L	20	N	500	N	N
BE003	7,000	150	7	N	L	30	N	N	N	N
BE004	3,000	3,000	7	N	L	20	N	N	N	N
BE005	500	2,000	5	N	L	20	N	N	N	N
BE006	1,000	1,500	5	N	N	N	N	L	N	N
BE007	5,000	500	3	100	L	N	N	1,500	N	N
BE008	5,000	300	5	N	N	150	N	N	N	N
BE009	2,000	300	7	N	L	50	N	N	N	N
BE010	3,000	700	3	200	L	70	N	5,000	N	N
BE011	7,000	500	3	200	L	3,000	N	5,000	10	N
BE012	5,000	1,500	5	70	N	100	N	2,000	L	N
BE013	7,000	10,000	3	N	N	20	N	L	N	N
BE014	5,000	5,000	5	50	50	200	N	L	N	N
BE015	10,000	2,000	10	N	N	300	N	100	10	N
BE016	2,000	700	5	100	L	150	N	300	N	N
BE018	2,000	150	5	N	L	30	N	N	N	N
BE019	2,000	500	5	N	N	50	N	N	N	N
BE020	7,000	2,000	3	N	N	30	N	N	N	N
BE021	2,000	1,000	5	N	N	30	N	N	N	N
BE022	2,000	700	5	N	N	30	N	N	N	N
BE023	2,000	2,000	2	N	200	700	N	N	N	N
BE024	700	2,000	7	N	N	N	N	N	N	N
BE025	3,000	5,000	3	N	200	300	150	N	N	N
BE026	7,000	>10,000	5	N	50	50	N	N	N	N
BE027	2,000	>10,000	2	70	500	50	150	500	N	N
BE028	1,000	1,000	7	N	L	50	N	N	N	N
BE029	1,000	>10,000	5	N	N	30	N	N	N	N
BE030	1,500	700	5	N	N	30	N	N	N	N
BE031	500	500	5	N	N	50	N	N	N	N
BE032	3,000	>10,000	5	N	N	30	N	N	N	N
BE033	2,000	7,000	5	N	N	30	N	N	N	N
BE034	5,000	5,000	3	N	N	20	N	N	N	N
BE035	1,500	3,000	3	N	L	N	N	L	N	N
BE036	2,000	150	L	N	N	N	N	N	N	N
BE037	2,000	150	2	N	N	N	N	N	N	N
BE101	2,000	5,000	2	N	500	300	100	L	20	N
BE102	1,000	3,000	3	N	N	20	N	N	N	N
BE103	2,000	1,500	2	N	L	50	N	N	N	N
BE107	7,000	2,000	3	N	L	30	N	L	10	N
BE108	3,000	150	5	N	N	30	N	L	N	N
BE109	1,000	1,000	5	70	L	50	N	1,000	N	N
BE110	2,000	>10,000	5	N	N	50	N	N	20	N
BE111	1,000	2,000	5	N	50	70	N	N	N	N
BE113	10,000	>10,000	5	N	L	50	N	100	10	N
BE114	5,000	1,000	7	N	70	2,000	50	N	L	N
BE115	3,000	2,000	5	N	L	30	N	150	N	N
BE116	2,000	>10,000	10	N	50	70	N	N	10	N
BE117	1,500	>10,000	2	300	N	70	N	1,000	N	N
BE118	1,500	500	3	N	N	N	N	150	N	N

Table 3. Concentrations of selected elements in minus-100-mesh fraction of stream-sediment samples, Beaver Creek Wilderness Study Area

[Concentrations in parts per million. Cu, Mo, Nb, Pb, Sn, and Zn analyzed by six-step spectrographic method by M. J. Malcolm and N. M. Conklin; U and Th analyzed by neutron activation method by R. B. Vaughn and D. M. McKown; L, less than; N, not found; number in parentheses, lower limit of detection]

Sample No.	Cu (5)	Mo (5)	Nb (20)	Pb (10)	Sn (10)	Zn (200)	U (0.01)	Th (7)
BE001	50	N	L	30	N	N	10.9	33
BE002	70	N	20	50	N	N	43.6	73
BE003	50	N	20	70	N	N	43.5	110
BE004	50	N	20	70	N	N	30.4	82
BE005	30	N	30	50	N	N	24.4	87
BE006	50	N	20	50	N	N	27.9	100
BE007	50	N	20	50	N	N	21.7	L
BE008	30	N	20	50	N	N	11.5	53
BE009	50	N	30	100	N	N	25.7	45
BE010	70	N	L	50	N	N	24.1	51
BE011	70	N	L	70	N	N	30.7	34
BE012	70	N	L	70	N	N	38.0	47
BE013	50	N	30	70	N	N	17.0	28
BE014	20	N	L	50	N	N	9.5	22
BE015	30	N	L	50	N	N	10.5	23
BE016	30	N	L	50	N	N	12.3	21
BE018	30	N	50	30	N	N	31.5	91
BE019	70	N	50	70	N	N	28.0	48
BE020	50	N	30	70	N	N	19.0	37
BE021	70	N	30	70	N	N	25.2	62
BE022	30	N	30	50	N	N	23.9	100
BE023	50	N	20	50	N	N	34.0	66
BE024	70	N	30	30	N	N	21.7	39
BE025	10	N	20	20	N	N	9.2	34
BE026	20	N	L	30	N	N	9.8	89
BE027	30	N	30	50	N	N	27.7	100
BE028	30	N	L	30	N	N	16.9	33
BE029	15	N	L	50	N	N	12.7	68
BE030	20	N	L	30	N	N	12.3	28
BE031	20	N	20	30	N	N	6.5	20
BE032	20	N	L	30	N	N	9.6	41
BE033	20	N	L	50	N	N	9.9	46
BE034	30	N	L	30	N	N	4.9	18
BE035	150	N	L	30	N	N	13.8	32
BE036	70	N	20	30	N	N	10.8	62
BE037	70	N	20	30	N	N	25.1	180
BE101	15	N	20	30	N	N	11.0	42
BE102	15	N	20	20	N	N	9.7	35
BE103	20	N	20	30	N	N	11.2	43
BE107	30	N	L	30	N	N	8.3	25
BE108	20	N	20	30	N	N	28.7	58
BE109	15	N	20	30	N	N	17.4	96
BE110	50	N	20	50	N	N	17.3	76
BE111	15	N	L	30	20	N	23.7	54
BE113	20	N	30	30	N	N	19.6	64
BE114	10	N	L	30	15	N	6.6	22
BE115	20	N	L	30	15	N	5.4	20
BE116	20	N	L	50	15	N	8.9	44
BE117	20	N	L	30	15	N	7.4	38
BE118	70	N	20	20	15	N	14.0	90

Table 4. Concentrations of selected elements in rock samples, Beaver Creek Wilderness Study Area

[Rocks analyzed are representative of map units (pl. 1*B*) unless noted. Concentrations in parts per million. Mn, Ba, Be, Cu, Pb, and Sn analyzed by six-step spectrographic method by M. J. Malcolm and P. H. Briggs; As and Zn analyzed by atomic-absorption method by M. J. Malcolm and P. H. Briggs; L, less than; N, not detected; number in parentheses, lower limit of detection]

Sample No.	Mn (10)	As (5)	Ba (20)	Be (1)	Cu (5)	Pb (10)	Sn (10)	Zn (2)
BE007R	50	L	1,000	1	15	70	L	4
BE008R[1]	700	L	1,500	3	100	30	L	86
BE014R	150	6	70	1	15	L	L	7
BE017R[1]	1,500	L	500	2	7	10	10	190
BE025R	300	L	200	2	7	10	L	15
BE026R	20	L	30	L	7	L	L	L
BE104R	50	L	15	L	5	L	L	L
BE105R1[2]	200	L	100	10	7	L	L	3
BE105R2[2]	30	L	10	L	7	L	L	L
BE106R	300	L	150	L	7	L	L	8
BE112R[3]	200	L	2,000	L	30	20	L	3
BE115R	100	32	50	L	7	L	L	4
BE005R[4]	1,500	L	300	L	10	10	L	49

[1]Mafic dike rock.
[2]Pegmatite.
[3]Fluorite-bearing pegmatite.
[4]Quartz vein.

Results of Study

Low magnetic intensity southeast of the Beaver Creek Wilderness Study Area is caused by sedimentary rocks of Mesozoic and Paleozoic age (fig. 3, feature A); magnetic intensity increases to the northwest over granodiorite of the Phantom Canyon batholith of Early Proterozoic age. The magnetic-low contour embayment extends from the sedimentary terrane across the study area into the granodiorite terrane. Although the magnetic-contour embayment could be caused by sedimentary rocks beneath the Early Proterozoic rocks of the study area, this interpretation is unlikely because of the near-vertical attitude of major faults in Early Proterozoic rocks. More likely, the embayment in the magnetic-contour pattern may indicate an extension of the northwest-trending fault mapped between Phantom Canyon and the northern boundary of the study area (pl. 1*B*); the fault strike aligns with the magnetic contours in the embayment.

The magnetic high over Crown Point at the northern end of the study area is probably primarily caused by the granodiorite and high topography (fig. 3, feature B). The steep magnetic gradient outside the study area on the eastern side of the Crown Point magnetic high can probably be related to magnetic-susceptibility contrasts caused by fault offset of the merging Mountaindale and Adelaide fault zones. The magnetic ridge extending southeast from the Crown Point magnetic high is possibly caused by faulting; the ridge could represent an extension of the Mountaindale fault or an extension of the north-trending fault questionably located just east of Crown Point, or extensions of both.

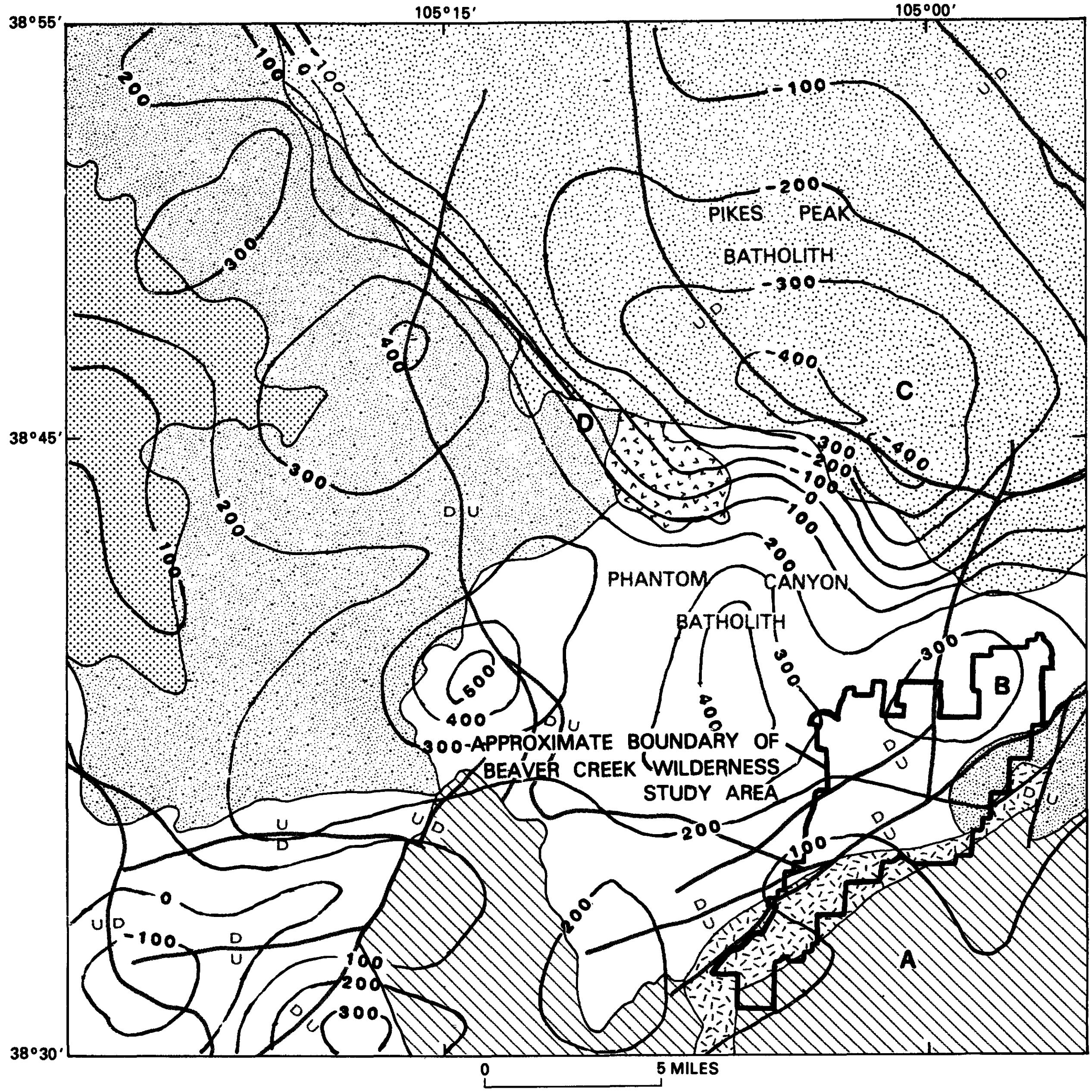
Low magnetic intensity delineates granite of the Pikes Peak batholith of Middle Proterozoic age north of the Beaver Creek Wilderness Study Area (fig. 3, feature C). A steep northwest-trending magnetic gradient (feature D) marks the southwestern edge of the granite along its contact with the granodiorite of Early Proterozoic age, and with the quartz monzonite of Middle Proterozoic age and alkalic igneous rocks of Miocene and Oligocene age near Cripple Creek. The Beaver Creek Wilderness Study Area lies south of the granite-granodiorite contact zone.

A regional northwest-trending gravity low extends across the wilderness study area (Klein, 1983). Although no gravity data points are within the study area, gravity data from points both southeast and northwest of the study area do not permit distinction between the sedimentary terrane to the southeast and the granodiorite terrane northwest of the study area.

Mineral and Energy Resource Potential

Precambrian Stratabound Metals

The model.—Stratabound metal deposits containing copper, zinc, tungsten, lead, silver, and possibly gold



EXPLANATION

Alkalic igneous rocks (Miocene and Oligocene)

Thirtynine Mile Andesite (Oligocene)

Sedimentary rocks (Mesozoic and Paleozoic)

Granite of Pikes Peak batholith (Middle Proterozoic)

Quartz monzonite of Berthoud Plutonic Suite (Middle Proterozoic)

Granodiorite of Routt Plutonic Suite (Early Proterozoic)

Gneiss (Early Proterozoic)

U/D Fault—U, upthrown side; D, downthrown side

—100— Magnetic contour—Contour interval 100 gammas

A Magnetic feature discussed in text

Figure 3. Map showing geologic setting and magnetic anomalies in the vicinity of the Beaver Creek Wilderness Study Area (geology simplified from Scott and others, 1978). Flight-line spacing 1 and 5 miles. Flight elevation 14,500 ft barometric.

occur in gneiss of Early Proterozoic age in other parts of Colorado (Taylor and others, 1984, p. 14–16). The most favorable host rocks are interlayered feldspathic, calc-silicate, and hornblende gneiss. The deposits tend to occur near one another and at specific stratigraphic levels.

The stratabound metal deposits of Colorado range in size from small pods, irregular masses, and lenses a few feet across to lenses tens of feet thick and thousands of feet long. The deposits vary considerably in mineralogy and metal content but are mainly zinc-copper or tungsten-copper deposits; most have been metamorphosed. Ore minerals are mainly sphalerite, chalcopyrite, galena, gahnite, scheelite, powellite, and molybdenite. Gangue minerals include amphibole, pyroxene, garnet, pyrite, pyrrhotite, and common rock-forming minerals. Anomalous concentrations of copper, lead, tungsten, and tin occur in sediment of streams draining areas of stratabound deposits.

Resource potential.—The resource potential for stratabound metal deposits in the wilderness study area is regarded as low. Early Proterozoic gneiss (unit Xgn, pl. 1*B*) in the study area is composed mainly of biotite schist, whereas the most favorable terranes are composed of interlayered feldspathic, calc-silicate, and hornblende gneiss (Taylor and others, 1984, p. 15). Geochemical analyses of stream sediment from the study area indicate that stratabound deposits are unlikely to be found there. Weak tungsten anomalies may indicate weakly mineralized gneiss but may also be derived from small pegmatites along the margin of the Phantom Canyon batholith. No surface evidence of alteration or mineralization was found during mapping, but small stratabound deposits are difficult to locate unless a target area has been identified by geochemical or other means.

Assignment of mineral resource potential for stratabound metal deposits in gneiss is made with a certainty level of C (pl. 1*B*). Geological and geochemical criteria generally indicate low resource potential for stratabound metal deposits in the study area, but the typically small size of these deposits makes their presence difficult to exclude.

Pegmatite minerals

The model.—A model for the occurrence of feldspar, beryl, mica, and byproduct rare metals (niobium, tantalum, rare earths, and lithium) is summarized here from Taylor and others (1984, p. 28–30). These elements are concentrated in Precambrian pegmatites that intrude rocks of the Routt Plutonic Suite and adjacent gneiss. Although the marginal zones of plutons belonging to the Routt Plutonic Suite are the most favorable for pegmatite emplacement, not all marginal zones contain abundant pegmatites. Pegmatite dikes having the most resource potential are large and strongly zoned. Elsewhere in Colorado, pegmatite dikes that have been explored extensively are tens of feet thick and have an exposed length of hundreds or thousands of feet. Most are zoned, having a biotite-rich zone in the wall rock, an outer zone of quartz and feldspar, and an inner quartz-rich zone. If present, beryl and other rare-metal minerals tend to be concentrated separately from the major-mineral zones. Stream-sediment samples from pegmatite terrane commonly have anomalous concentrations of tin and tungsten. Although some marginal zones of Routt Plutonic Suite plutons are evident on aeromagnetic maps, the pegmatite dikes themselves are too small to be detected on regional geophysical maps.

Resource potential.—The Beaver Creek Wilderness Study Area has a low mineral resource potential for pegmatite minerals and associated rare metals. Although the study area contains the marginal zone of a large batholith assigned to the Routt Plutonic Suite, no large pegmatite bodies have been discovered. Those pegmatites that have been prospected and observed during mapping are small and sparse. Rare-metal minerals have not been observed in the pegmatites of the Beaver Creek Wilderness Study Area. The only evidence of zoning is the presence of a small fluorite vein in a pegmatite on West Mill Creek (Kevin Anderson, U.S. Bureau of Land Management, written commun., 1982).

Assignment of low potential for pegmatite minerals and associated rare metals is made with a certainty level of D (pl. 1*B*). The geologic environment for resources of pegmatite minerals is well defined in the study area. Large zoned pegmatites have not been found by prospecting and mapping in the study area; only small, unzoned pegmatites have been found.

Oil and gas

The model.—Oil and gas may occur in sedimentary rocks in the footwalls of mountain-front reverse and thrust faults, in the manner proposed for the Rocky Mountain foreland by Gries (1981) and for the Front Range and Wet Mountains by Jacob (1983). In the mountain-front thrust model, oil and gas is trapped in permeable reservoir rocks beneath the thrust. Entrapment may occur beneath impermeable beds in folds and faults beneath the main thrust or beneath gouge in the thrust. In the Canon City embayment, the most likely reservoir rocks are the Early Permian Lyons Sandstone, the Early Cretaceous Dakota Sandstone, the Codell Sandstone Member of the Late Cretaceous Carlile Shale, and fractured Late Cretaceous Pierre Shale (Donaldson and MacMillan, 1980; Jacob, 1983).

Resource potential.—The oil and gas potential of the Beaver Creek Wilderness Study Area is rated as low, in accordance with the findings of earlier appraisals of the region (Spencer, 1983). The faults that extend through the study area are not mountain-front thrusts but instead are interpreted as complex reverse faults that flatten upward and that formed by reactivation of near-vertical Precambrian faults (sections *A–A′*, *A″–A‴*, pl. 1*B*). The principal time of flattening and reverse movement was probably during the Laramide orogeny, when mountain-front thrusts were also formed. No reservoir rocks are known to be present in the subsurface of the synclines that adjoin faults in the study area. The stratigraphic section preserved in the synclines does not include rocks younger than the Pennsylvanian and Permian Fountain Formation; the best reservoir rocks of the Canon City embayment lie above the Fountain.

A low resource potential for oil and gas is assigned with a certainty level of D; the geologic structure of the study area is defined well enough to exclude the conditions necessary for oil and gas occurrence beneath mountain-front thrusts.

Other Resources

No signs of hydrothermal alteration or of geochemical anomalies indicating hydrothermal mineral deposits were observed in the wilderness study area. No concentrations of placer minerals were noted in the Early Proterozoic quartzite (unit Xq, pl. 1*B*) or in alluvial sediment along streams in the study area. Gypsum in the Lykins Formation is wholly outside the study area. The resource potential for all these commodities in the study area is low. A certainty level of C is assigned to the resource assessment for hydrothermal mineral deposits and placers; a level of D is assigned to the resource assessment for gypsum.

Recommendations for Further Study

North of Salida, stratabound sulfide deposits occur in gneiss near a quartzite bed that is preserved only as xenoliths in younger intrusive rock (Van Alstine, 1969, p. 43–47). Such quartzite beds are so rare in Early Proterozoic gneiss of south-central Colorado that they may represent a single stratigraphic marker. If the quartzite north of Salida correlates with that of the Beaver Creek Wilderness Study Area, and if stratabound sulfide deposits tend to occur near the quartzite marker, then such deposits should be sought in gneiss terranes having quartzite beds, such as those of the study area. A relationship between stratabound sulfide deposits and quartzite beds is so speculative that it cannot be used with confidence for mineral resource assessment. Research should be done to test the possible relationship between the occurrence of stratabound sulfide deposits and quartzite beds or other stratigraphic markers in Early Proterozoic gneiss of Colorado.

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