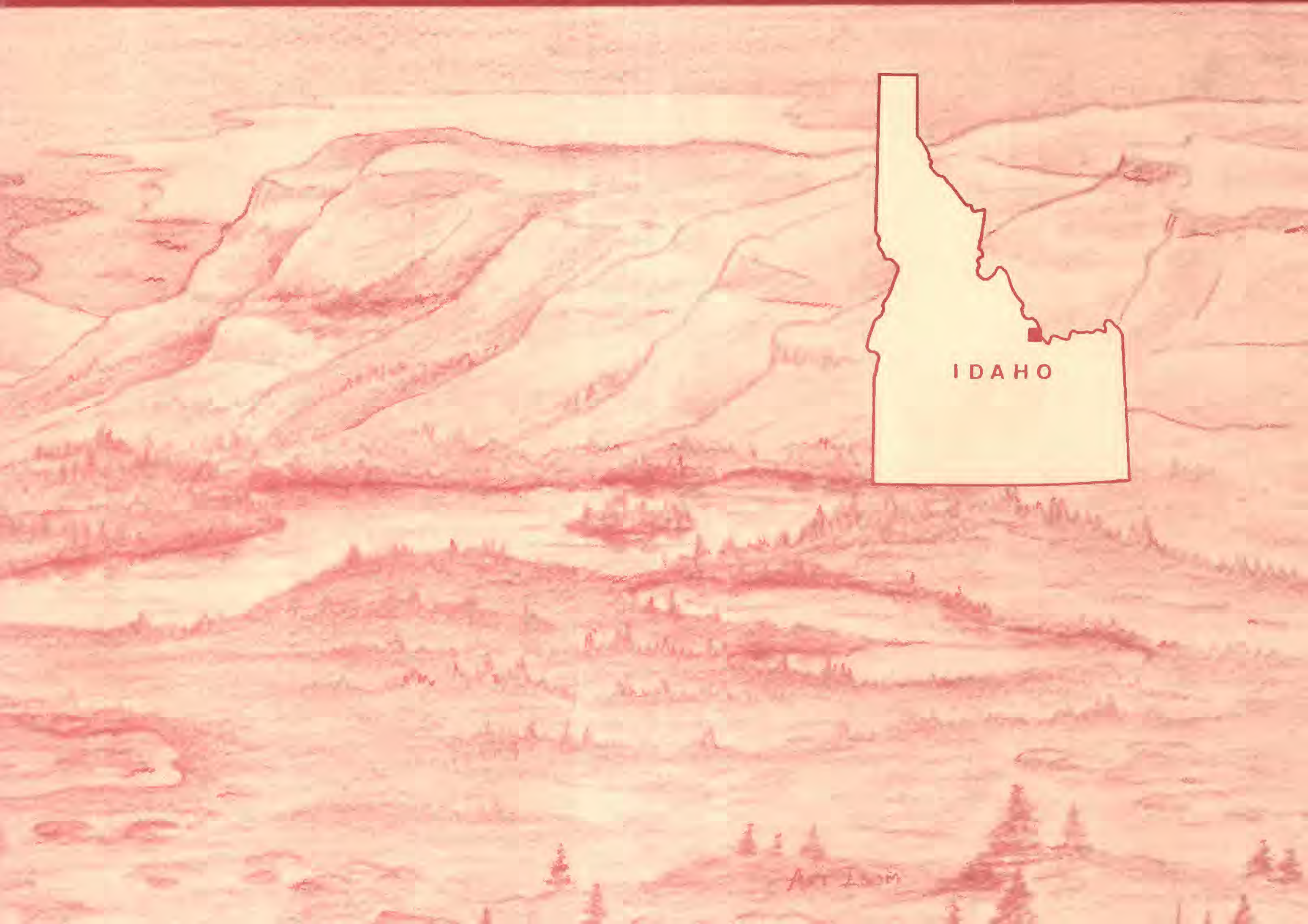
Mineral Resources of the Eighteenmile Wilderness Study Area, Lemhi County, Idaho

U.S. GEOLOGICAL SURVEY BULLETIN 1718–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

LEVEL OF RESOURCE POTENTIAL ↑

U/A UNKNOWN POTENTIAL	H/B HIGH POTENTIAL	H/C HIGH POTENTIAL	H/D HIGH POTENTIAL
	M/B MODERATE POTENTIAL	M/C MODERATE POTENTIAL	M/D MODERATE POTENTIAL
	L/B LOW POTENTIAL	L/C LOW POTENTIAL	L/D LOW POTENTIAL
			N/D NO POTENTIAL
A	B	C	D

LEVEL OF CERTAINTY →

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

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

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

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

Abstracted with minor modifications from:

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

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

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

Chapter B

Mineral Resources of the Eighteenmile Wilderness Study Area, Lemhi County, Idaho

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U.S. GEOLOGICAL SURVEY BULLETIN 1718

MINERAL RESOURCES OF WILDERNESS STUDY AREAS—
SOUTHEASTERN IDAHO

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 Eighteenmile (ID-043-003) Wilderness Study Area, Lemhi County, Idaho.

RESOURCE / RESERVE CLASSIFICATION

	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range	
	Measured	Indicated		Hypothetical (or)	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.

CONTENTS

PLATE

[Plate is in pocket]

FIGURES

Mineral Resources of the Eighteenmile Wilderness Study Area, Lemhi County, Idaho

By Betty Skipp, Jerry R. Hassemer,
Dolores M. Kulik, *and* Don L. Sawatzky,
U.S. Geological Survey, and

Andrew M. Leszcykowski *and* Richard A. Winters,
U.S. Bureau of Mines

ABSTRACT

At the request of the U.S. Bureau of Land Management, 18,700 acres of the Eighteenmile Wilderness Study Area (ID–043–003) were studied by the U.S. Bureau of Mines and the U.S. Geological Survey. In this report the area studied is called the "wilderness study area" or simply the "study area." There are no identified resources within the study area; however, according to a U.S. Bureau of Land Management examination report, there are approximately 13 million tons of gypsum reserves at the E.J. Wilson and Sons mine just outside the northwest boundary of the study area, on Clear Creek. The northern part of the study area has a moderate mineral resource potential for undiscovered deposits of hydrothermal gypsum in the Clear Creek area and a low potential for associated lead, silver, copper, molybdenum, and zinc in the vicinity of Clear Creek (fig. 1). The central part of the study area and other areas to the south underlain by the Jefferson Formation have a moderate mineral resource potential for undiscovered stratabound lead, zinc, and silver resources in dolomite of the Jefferson Formation. The southern part of the study area has a low potential for undiscovered silver, copper, lead, molybdenum, and zinc resources in fractures in the Beaverhead Mountains pluton and a low potential for tin, niobium, uranium, thorium, and rare-earth element resources in granites and sediments derived from the granites of the Beaverhead Mountains pluton. The northern part of the area has a low resource potential for undiscovered phosphate resources. The entire study area has a low and moderate potential, respectively, for undiscovered oil and gas at depths as great as 10,000 ft (feet) beneath the surface. An unknown potential for oil and gas exists below 10,000 ft.

SUMMARY

Character and Setting

The area studied is on the steep western flank of the central Beaverhead Mountains of east-central Idaho, 12 mi (miles) southeast of Leadore (fig. 2), in Lemhi County. Parts of the eastern border of the study area lie on the Continental Divide, along which peaks rise to more than 11,000 ft. Total maximum relief is about 4,000 ft. Access to the western side of the study area is provided by gravel roads that exit from paved Idaho State Highways 28 and 29.

The wilderness study area is within the Cordilleran overthrust belt, which has been pulled apart by extensional (normal) faults, some of which are still active. Thrust plates present in the area probably moved into place during Cretaceous time (for geologic ages, see geologic time chart on last page of report) along folded, low-angle, west-dipping thrust faults. The first normal faults formed between about 65 and 50 million years ago, and basin-range normal faults have been active ever since. The northwest-trending, narrow, high mountain ranges and intervening deep, elongate valleys that are characteristic of south-central Idaho and the study area were formed in the latest episode of basin-range extension.

Mineral Resource Potential

Middle and Late Proterozoic marine sedimentary rocks are exposed in two small areas in the wilderness study area, but no mineral deposits are known to be associated with them. Paleozoic sedimentary rocks make up the north half of the area and are present in limited outcrops along north-trending normal faults in the south half. They consist of

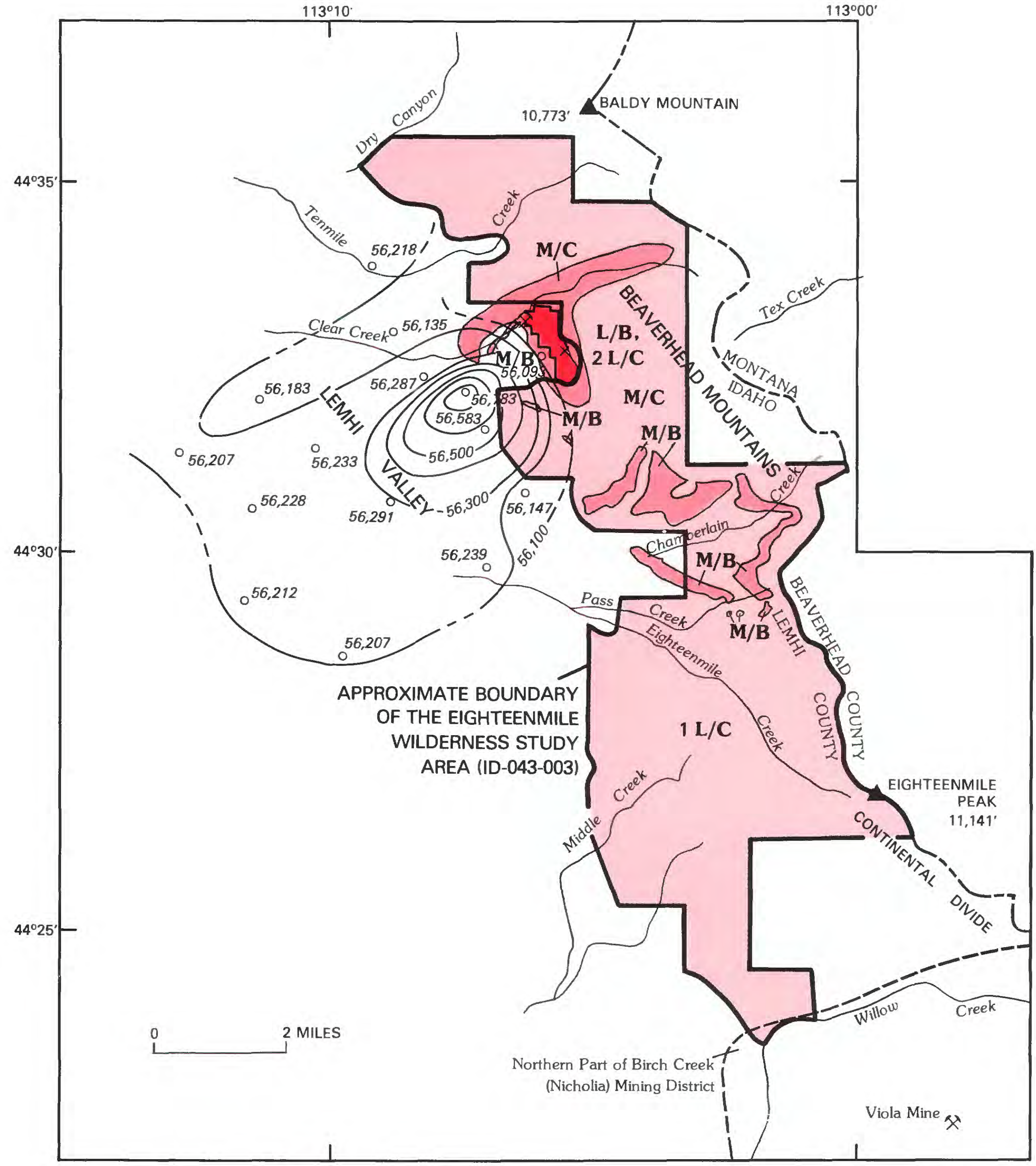


Figure 1 (above and facing page). Summary map showing identified resources, mineral resource potential, principal mines and prospects, and a local magnetic anomaly in the Eighteenmile Wilderness Study Area and vicinity, Lemhi County, Idaho.

Ordovician Kinnikinic Quartzite, Devonian Jefferson and Three Forks Formations, Mississippian McGowan Creek, Middle Canyon, Scott Peak, South Creek, Surrett Canyon, and Railroad Canyon Formations, Pennsylvanian to Mississippian Bluebird Mountain Formation, and Permian to Pennsylvanian Snaky Canyon Formation. The Permian Phosphoria Formation, which has been mined for phosphate 5 mi north of the study area, is not present in the study area. Scattered phosphate anomalies identified in the study area in other upper Paleozoic rocks are not indicative of a phosphate resource, and thus the northern part of the area has a low mineral resource potential for undiscovered phosphate.

EXPLANATION

[Down to a depth of 10,000 ft, the entire study area has low resource potential for oil, at certainty level D. Below a depth of 10,000 ft, the entire study area has an unknown resource potential for oil and gas, at certainty level A]

(red box)	Area of identified resources of gypsum
M/B	Geologic terrane having moderate mineral resource potential for silver, lead, and zinc, at certainty level B
M/C	Geologic terrane having moderate mineral resource potential for gypsum, at certainty level C
M/C	Geologic terrane having moderate resource potential for dry gas (methane), and possibly wet gas, at certainty level C, down to a depth of 10,000 ft—Applies to entire study area
L/B	Geologic terrane having low mineral resource potential for lead, silver, copper, molybdenum, and zinc, at certainty level B—Applies to Clear Creek area and vicinity in northern part of study area
1L/C	Geologic terrane having low mineral resource potential for silver, copper, lead, molybdenum, and zinc in fractures, and for tin, niobium, uranium, thorium, and rare-earth elements in granite, both groups at certainty level C—Applies to Beaverhead Mountains pluton and sediments derived from the pluton in south half of study area
2L/C	Geologic terrane having low mineral resource potential for phosphate, at certainty level C—Applies to north half of study area, north of Pass Creek
56,287 ○	Ground magnetic station and total-intensity magnetic value
—56,300—	Contours of total-intensity magnetic values from ground survey—Contour interval 100 gammas
⚒	Mine—Gypsum mine on Clear Creek
×	Prospect

Levels of certainty

A	Available data not adequate to assign potential
B	Data indicate geologic environment and suggest level of resource potential
C	Data indicate geologic environment, but do not establish activity of resource-forming processes
D	Data define geologic environment and level of resource potential and indicate activity of resource-forming processes in all or part of the area

Dolomite of the Devonian Jefferson Formation is the host for stratabound silver-lead-zinc ores in the Nicholia mining district 2 mi southeast of the study area, and a moderate mineral resource potential exists for undiscovered silver, lead, and zinc in deposits of a similar type in the central part of the wilderness study area, near Clear Creek.

Presence of minor amounts of base and precious metals (copper, lead, zinc, molybdenum, and silver) in fractures in granite of the Ordovician Beaverhead Mountains pluton indicates a low potential for undiscovered resources of these metals in the southern part of the wilderness study area. That part of the study area has a low resource potential for tin, niobium, uranium, thorium, and rare-earth elements in the granite itself and in sediments derived from the granite.

A deposit of gypsum is present adjacent to the northern part of the study area, along Clear Creek (fig. 1), and according to the BLM contains approximately 13 million tons of gypsum reserves. Therefore, parts of the Clear Creek area in the vicinity of the gypsum reserves have a moderate mineral potential for similar, undiscovered resources of gypsum. A positive magnetic anomaly centered west of the study area (fig. 1) in the vicinity of the mine on Clear Creek indicates the presence of a subsurface magnetic body. The body probably is a Pliocene or early Pleistocene intrusion localized along the Crooked Creek range-front normal-fault zone. The proposed intrusive body may have been a source for heat and metals prerequisite to hydrothermal ore deposits, and, therefore, parts of the Clear Creek area have a low resource potential for lead, silver, copper, molybdenum, and zinc. There is no evidence for a Holocene source of geothermal energy in the study area.

The entire wilderness study area has a low resource potential for undiscovered oil down to 10,000 ft beneath the surface. Rocks above this level have been subjected to temperatures in excess of 100 °C, as indicated by conodont color alteration index (CAI) values of 2.5–4.5 in the limestones, and any contained liquid hydrocarbons (oil) would have been destroyed. A moderate resource potential for undiscovered dry gas (methane), and possibly for wet gas, exists above 10,000 ft. An unknown potential resource potential for both oil and gas exists below 10,000 ft.

These conclusions are based partly on earlier reports on the mineral resources and geochemistry of the Italian Peak and Italian Peak Middle Roadless Areas (Skipp and others, 1983; Hopkins and others, 1984) and partly on new field and laboratory studies done in 1983 through 1986.

INTRODUCTION

At the request of the U.S. Bureau of Land Management (BLM), 18,700 acres of the Eighteenmile Wilderness Study Area (ID–043–003) was studied by the U.S. Bureau of Mines and the U.S. Geological Survey. In this report the area studied is called the "wilderness study area" or simply the "study area." The study area lies along the steep western flank of the central Beaverhead Mountains. The northern border of the area is 12 mi southeast of Leadore, Idaho, and the area extends an

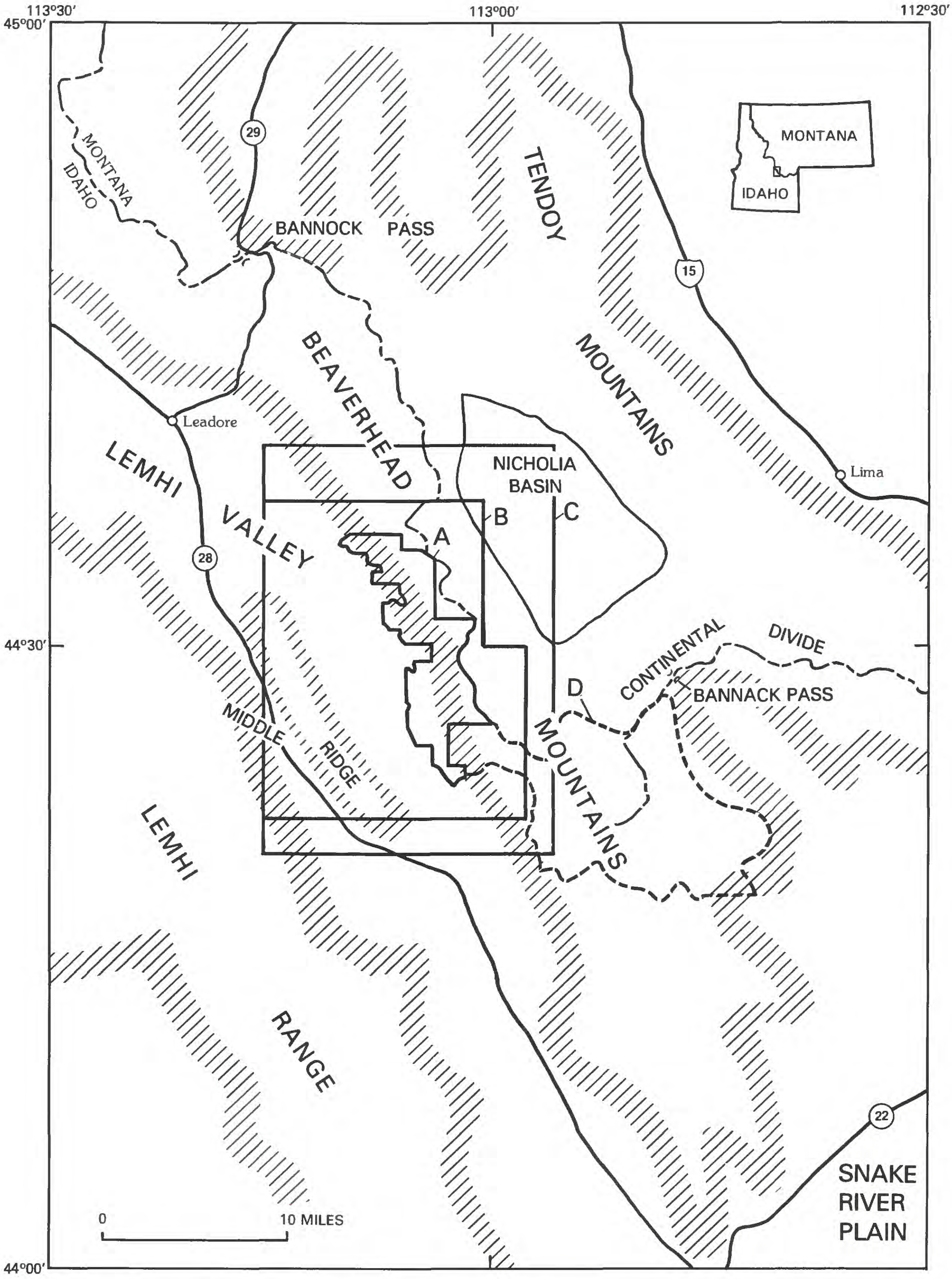


Figure 2. Index map showing (A) area of the Eighteenmile Wilderness Study Area, Lemhi County, Idaho; (B) area of figure 1 and plate 1, (C) area of figures 4, 5, and 6, and (D) approximate boundary of contiguous Italian Peak and Italian Peak Middle Roadless Areas.

additional 14 mi to the south-southeast. The study area is just 5 mi wide at its widest point. Elevations range from 7,100 ft at the northwest corner to 11,141 ft at Eighteenmile Peak along the Continental Divide in the southeastern part (pl. 1). The deep valleys and canyons of the area were sculptured by Pleistocene alpine glaciers, their meltwaters, and fast-flowing streams following a steep gradient. These valleys and canyons are now either dry or are occupied by intermittent or relatively small perennial streams that reflect the drier Holocene climate. The western border of the study area is flanked by large aprons of alluvial gravels that fill much of the Lemhi Valley.

Access to the western side of the study area is provided by graded gravel roads that exit from Idaho State Highways 28 and 29. The road into Clear Creek is well traveled. Less well traveled jeep and pack trails within the northern part of the study area include those in Dry Canyon, Powderhorn Canyon, Tenmile Creek, Horsethief Canyon, and Pass Creek (pl. 1). The gravel road up Willow Creek provides the best access to the southern part of the area, and jeep trails along Eighteenmile Creek and the minor creeks in between are passable in dry weather.

This report presents an evaluation of the mineral endowment (identified resources and mineral resource potential) of the study area and is the product of several separate studies by the U.S. Bureau of Mines (USBM) and the U.S. Geological Survey (USGS). Identified resources (studied by the USBM) are classified according to the system of the USBM and USGS (1980), which is shown in the appendix of this report. Mineral resource potential (studied by the USGS) is the likelihood of occurrence of undiscovered metals and nonmetals, 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), which is also shown in the appendix.

The Eighteenmile Wilderness Study Area is contiguous on the southeast with the Italian Peak Middle Roadless Area, for which a report on the mineral resource potential was completed earlier by the USGS and the USBM (Skipp and others, 1983).

Investigations by the U.S. Bureau of Mines

USBM personnel completed prefield, field, and report preparation phases of the Eighteenmile Wilderness Study Area in 1985 and 1986. Prefield studies included library research and perusal of Lemhi County and BLM mining and mineral lease records. USBM and Idaho state records also were searched. Reconnaissance of the area on foot and by four-wheel-drive vehicle was undertaken in a search for evidence of mining activity that may not have been recorded.

Seventeen samples were taken during field work (11 rock samples and 6 alluvial samples). Most of the rock samples were taken from outside the study area at the gypsum mine on Clear Creek (fig. 1) and from the gypsum prospect on the ridge southeast of the mine. Alluvium was sampled in several stream drainage basins.

The rock samples were crushed and sent to the USBM analytical laboratory in Reno, Nev. Seven samples were analyzed for gold and silver by fire assay–inductively coupled plasma methods having detection limits of 0.007 and 0.3 ppm (parts per million) for gold and silver, respectively. Eight samples were assayed for a broad spectrum of elements by inductively coupled plasma or semiquantitative spectrographic methods. Three samples were analyzed for $CaSO_4$ (gypsum) by wet-chemical methods.

Six grab samples of alluvium filling two 14-in. (inch) pans each were taken from the major drainage basins during this study. The grab samples were concentrated by hand panning in the field and further concentrated in the laboratory on a Wilfley table. The concentrates were examined microscopically for gold and other heavy minerals. Detailed analyses are available from the U.S. Bureau of Mines, Western Field Operations Center, E. 360 Third Avenue, Spokane, WA 99202.

Investigations by the U.S. Geological Survey

Data for assessing the mineral resource potential of the Eighteenmile Wilderness Study Area were collected during the summers of 1983, 1984, and 1985. A preliminary report on the mineral resource potential of the study area (Skipp and others, 1984) was based on (1) a new geologic map at a scale of 1:62,500 prepared by Betty Skipp; (2) a geochemical survey that utilized rock, stream-sediment, soil, and water samples collected by J.R. Hassemer and Betty Skipp and analyzed by D.E. Detra, supplemented by geochemical data from the Italian Peak Middle Roadless Area (Hopkins and others, 1984); and (3) an aeromagnetic survey of the Italian Peak Middle Roadless Area (U.S. Geological Survey, 1981). Since publication of the preliminary report, additional geologic mapping was completed in 1984 by Betty Skipp, and gravity and magnetic surveys were completed by D.M. Kulik. Conodont samples were collected by D.M. Kulik in 1985 and identified by Kirk Denkler in 1986. A remote-sensing study by D.L. Sawatsky was completed in 1986. The present report summarizes only the most important findings of the geochemical survey. Analytical data and maps showing distributions of anomalous metal concentrations in the wilderness study area are given in Skipp and others (1984).

Acknowledgments.—We thank George F. Babits, Jr., of the BLM in Salmon, Idaho, who provided the information on the status of claims and estimates of gypsum reserves in the Clear Creek area. We also thank Jean M. LaDue, who assisted in the USGS field studies, and the people of Leadore whose hospitality and knowledge of local road conditions proved very valuable during the field investigations.

APPRAISAL OF IDENTIFIED RESOURCES

By Andrew M. Leszcykowski and Richard A. Winters
U.S. Bureau of Mines

Mining History

There has been considerable mining activity in the nearby northern part of the larger Birch Creek mining district (Nicholia district) (fig. 1). Production of lead, zinc, silver, copper, and gold from the Nicholia district was valued at $2.5 to $5 million (Anderson and Wagner, 1944). Most of the activity was in the late 1800's and early 1900's, and the primary producer was the Viola mine (fig. 1). According to an unpublished BLM mineral patent application[1], the E.J. Wilson and Sons gypsum mine on Clear Creek (fig. 1) has produced about 120,000 tons of gypsum. Most of it (93,000 tons) was sold to the Idaho Portland Cement Company at Inkom, Idaho, for use as a cement retarder, and the remaining 27,000 tons was used as soil conditioner. Ore was mined from 1964 to 1977, the last 2 years' production being used as soil conditioner. In 1984, mineral patents were approved for three claims encompassing the mine and vicinity (see next paragraph).

Mining Claims and Leases

County, state, and federal records indicate that no mines, mining claims, or mineral leases exist in the study area, but there are three patented claims immediately adjacent to the boundary of the study area.[1]

[1]Babits, G.F., Jr., 1983, Mineral Patent Application of E.J. Wilson and Sons: U.S. Bureau of Land Management Mineral Report, 36 p., appendixes A–L.

Reserves and Exploration

According to a BLM examination report, there are approximately 13,100,000 tons (8,700,000 cubic yards) of gypsum classified as reserves just outside the northwest boundary of the study area at the mine on Clear Creek (Leszcykowski and Winters, 1986, fig. 2). The deposit is characterized as an alteration product of limestone, and most of the mined portion was part of a landslide derived from nearby bedrock. It is possible that shallowly buried deposits or extensions are present in the study area as described in the section concerning mineral resource potential; however, no gypsum resources were identified within the study area.

Industry interest in the study area will probably be low because known resources outside the area at the E.J. Wilson and Sons mine are sufficient to meet current and projected long-term needs of the Idaho Portland Cement Company and local agriculture well into the next century. No increase in demand for gypsum from either the cement plant or for agricultural use is foreseen that could warrant increasing the reserve base. Use of the gypsum as feed stock for a wallboard plant would be improbable because existing wallboard plants in this area are capable of supplying all foreseen market demands. A plant would have to be constructed at or near the deposit site to minimize the costs of handling the raw ore. A plant at this location would be too far from present rail facilities to make shipping the wallboard competitive.

ASSESSMENT OF POTENTIAL FOR UNDISCOVERED RESOURCES

By Betty Skipp, Jerry R. Hassemer, Dolores M. Kulik, and Don L. Sawatzky
U.S. Geological Survey

Geology

Geologic Setting

The Eighteenmile Wilderness Study Area is on the steep western slope of the central Beaverhead Mountains. The Beaverhead Mountains are separated from the Lemhi Valley on the west by a series of normal faults, including the Crooked Creek and Beaverhead fault zones, which pass immediately west of the study area (fig. 3; pl. 1). These zones are basin-range faults along which both mountain blocks and adjacent valleys have been tilted to the east-northeast. Strands of the Beaverhead fault zone offset upper Pleistocene glacial deposits near the mouth of Willow Creek south of the study area (Skipp, 1984) and are considered active (Scott and others, 1985). Upper Pleistocene glacial deposits also are offset by faults in the vicinity of Eighteenmile Creek (pl. 1).

The Beaverhead Mountains are a part of the Mesozoic Cordilleran thrust belt, and the Proterozoic and Paleozoic rocks of these mountains have been moved many miles northeastward on a series of folded moderate- to low-angle thrust faults that bound major thrust plates (Scholten and others, 1955; Scholten, 1983; Skipp, 1985 and in press). Two major thrusts, the Hawley Creek and Fritz Creek, and three major thrust plates, the Hawley Creek, Fritz Creek, and Cabin, are present in the Eighteenmile Wilderness Study Area (fig. 3). Rocks of the Hawley Creek thrust plate, including the Ordovician Kinnikinic Quartzite and the Beaverhead Mountains pluton, make up the southern part of the study area and are present in isolated patches along the western front of the mountains, to the north. Rocks of the underlying Fritz Creek plate, which range in age from Proterozoic to Mississippian, constitute most of the northern part of the study area. Large Cenozoic gravity slide blocks derived from Mississippian limestones of this plate have slid westward toward and into the Lemhi Valley. The Clear Creek slide block is the largest of these. In addition, a large elliptical keystone graben formed in rocks of the Fritz Creek plate southeast of the Clear Creek slide block (fig. 3). Rocks of the Fritz Creek thrust plate overlie Mississippian to Permian rocks of the underlying Cabin thrust plate in the northernmost part of the study area. Older Proterozoic rocks of the Cabin thrust plate are exposed east of the Continental Divide and east of the study area in the vicinity of Tex Creek (pl. 1).

Conodonts recovered from carbonate rocks of the Fritz Creek and Cabin plates and identified by Kirk Denkler (written commun., 1986) indicate that Mississippian rocks of the Fritz Creek plate have been subjected to higher temperatures than approximately coeval rocks of the Cabin thrust plate; a similar relationship was noted previously in the adjacent Italian Peak area (Skipp, 1984). Conodont color alteration index (CAI) values determined for samples from the Cabin thrust sheet in the northern part of the study area range from 2.5 to 3.5 (fig. 3), which indicates temperatures greater than about 100 °C (Epstein and others, 1977). CAI values on the Fritz Creek plate range from 4 to 6 (fig. 3), indicating temperatures greater than 190 °C (Epstein and others, 1977). A single sample from the Clear Creek slide block has a CAI value range of 4.5 to 7; this unusually wide range of values can result from either hydrothermal alteration or contact metamorphism (Rejebian and others, 1987). The corroded and fractured nature of the conodonts in this sample indicates alteration by hydrothermal processes (Anita Harris, oral commun., 1987). The Clear Creek slide block therefore was emplaced before or during such thermal activity.

Any liquid hydrocarbons contained in rocks of the Cabin plate that underlie the study area to depths around 10,000 ft would have been destroyed (Perry and others, 1983). Dry gas (methane), and possibly wet gas, would be the only hydrocarbons present to that depth. Basement, however, is projected to lie at a depth of more than 30,000 ft beneath the surface of the study area, and rocks of a structurally lower thrust sheet beneath the Cabin thrust plate may not have been heated to such high temperatures (Perry and others, 1983; Skipp, 1984).

Eocene Challis Volcanics of intermediate composition unconformably overlie rocks of all three thrust plates regionally and are themselves overlain by younger Tertiary and Quaternary sedimentary deposits. Intermediate to basic dikes and sills (Chamberlain Canyon sheet of Scholten and Ramspott, 1968) that intrude rocks of the thrust sheets may have been feeders to the Eocene Challis Volcanics.

A positive magnetic anomaly (see following section on geophysics) near the gypsum mine on Clear Creek is centered above the projected buried trace of the Crooked Creek fault zone (pl. 1). Other normal faults also can be projected into the Crooked Creek fault zone near this position. Multiple fault intersections commonly form conduits for rising magma. Young basalt flows 20 mi south of the study area have yielded a Neogene K-Ar (potassium-argon) age of about 5.5 million years (Mitchell and others, 1985) and may be similar in age to (or older than) the interpreted intrusion at Clear Creek. A late Pliocene or Pleistocene age for the intrusion is postulated because the body does not appear to be offset by the Pliocene to Pleistocene Crooked Creek fault zone. Geologic relations also suggest that hydrothermal activity in the Clear Creek area was younger than 5.5 million years old and at least partly postdated emplacement of the Clear Creek slide block over the same Pliocene to Pleistocene Crooked Creek fault zone (Skipp, 1984) (fig. 3).

Description of Rock Units

The following rock units were mapped in the study area (pl. 1):

Late and Middle Proterozoic sandstone (unit ZYs*).*—This unit consists of medium- to thick-bedded, locally crossbedded or laminated, pale-red, grayish-green, and light- to dark-gray, fine- to coarse-grained sandstone and minor siliceous mudstone. The sandstone is quartzose, feldspathic, and micaceous in places, and it consists of angular to subrounded grains of quartz, altered feldspar, some calcic plagioclase, and lithic

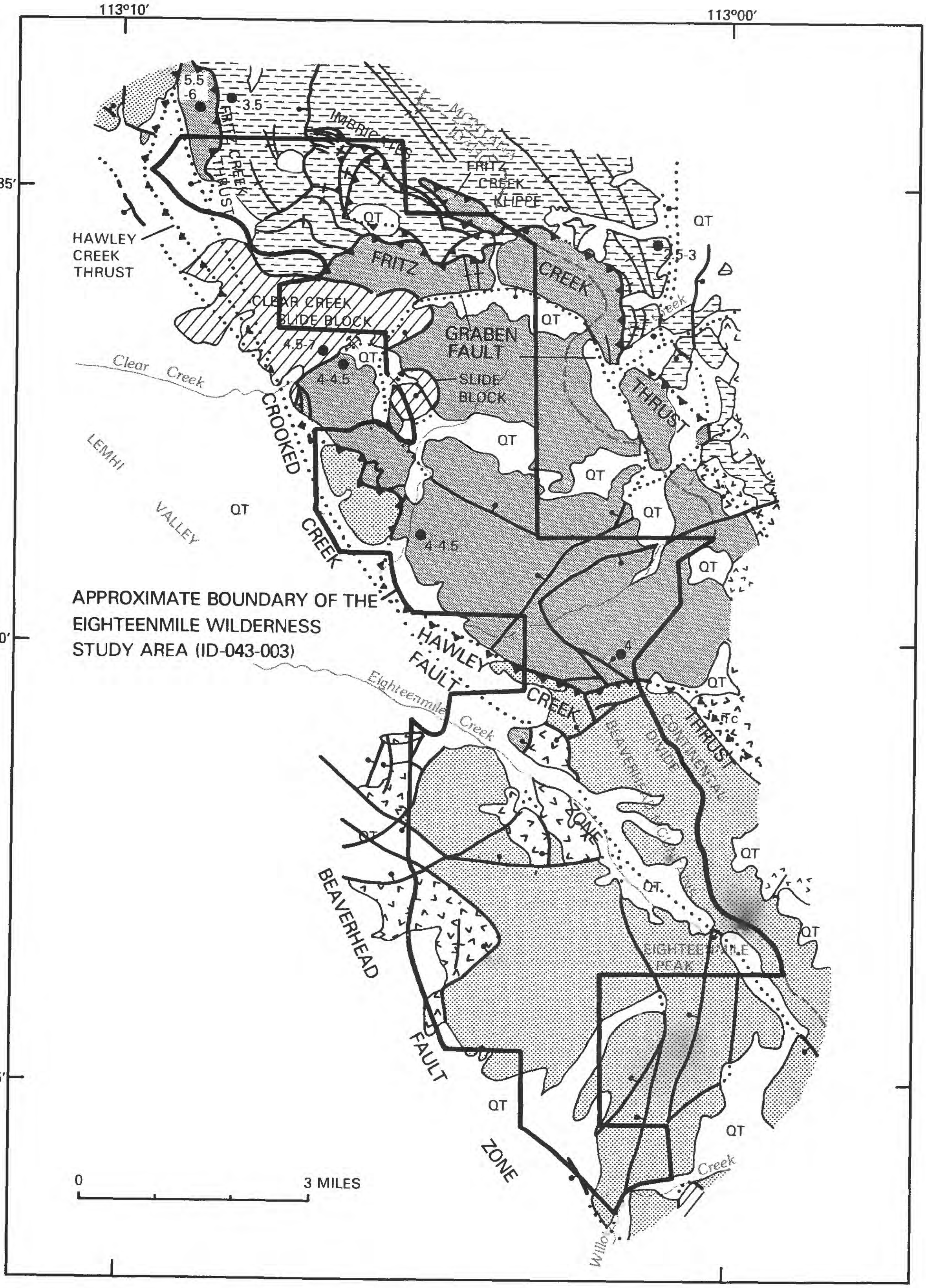


Figure 3 (above and facing page). Distribution of major thrust plates and faults, conodont sampling sites, and CAI values in vicinity of the Eighteenmile Wilderness Study Area, Lemhi County, Idaho.

LIST OF MAP UNITS

QT Quaternary and Tertiary rocks and sediments, undivided

Tc Eocene Challis Volcanics

LIST OF THRUST PLATES

Rocks of Hawley Creek thrust plate

Rocks of Fritz Creek thrust plate

Slide blocks from Fritz Creek(?) thrust plate

Rocks of Cabin thrust plate

Contact

Fold axis

Fault—Dotted where concealed. Bar and ball on downthrown side where mostly normal slip

Thrust fault—Dotted where concealed. Sawteeth on upper plate

● 4.5 Conodont sampling site, showing CAI value

⚒ Mine

× Prospect

---

fragments including chert, quartzite, and gneiss (Scholten and Ramspott, 1968). The base of the unit is not exposed; the unit is more than 1,500 ft thick.

Middle Ordovician Kinnikinic Quartzite (unit Ok*).*—This unit consists of medium- to thick-bedded, locally crossbedded, light-gray to yellowish-gray, medium- to fine-grained pure orthoquartzite composed of subrounded to well-rounded vitreous quartz grains largely cemented by authigenic quartz overgrowths and minor calcite. Spotty brown limonitic stains and blotches are common. The quartzite is brecciated in much of the outcrop area, where it forms cliffs and ledges. This unit is at least 1,000 ft thick (Skipp, 1984) and is present only on the Hawley Creek thrust plate.

Syenite of Ordovician Beaverhead Mountains pluton (unit Obs*).*—Syenite or leucosyenite present above Willow Creek at the south end of the study area is pale red and weathers to shades of brown. It is medium to coarse grained, holocrystalline, and phaneritic, and it is composed of 80–95 percent feldspar, 0–16 percent quartz, less than 5 percent biotite, opaque minerals, zircon, apatite, and as much as 10 percent altered actinolitic amphibole (Ramspott, 1962; Scholten and Ramspott, 1968). Both the granite and syenite are intruded by numerous aplite bodies.

Granite of Ordovician Beaverhead Mountains pluton (unit Obg*).*—Granite makes up most of the craggy ridges and grus-covered slopes above Eighteenmile Creek. It is grayish orange to light brown, holocrystalline, and medium to coarse grained, and it consists of both one- and two-feldspar rocks. Unaltered rocks contain more than 23 percent quartz and 65 percent alkali feldspar; in two-feldspar rock, albite commonly makes up less than one-third of the total feldspar. Biotite, opaque minerals, zircon, and apatite constitute 5 percent of the rock (Ramspott, 1962; Scholten and Ramspott, 1968). Fine-grained, dusky-yellow-green chill-zone facies are present next to Kinnikinic Quartzite on Eighteenmile Peak. Strongly altered rocks of the pluton are made of quartz, sericite, and magnetite and show no relict structures.

Middle and Upper Devonian Jefferson Formation (unit Dj*).*—The shallow marine Jefferson Formation depositionally overlies either Kinnikinic Quartzite on the Hawley Creek thrust plate or Proterozoic sandstone on the Fritz Creek and Cabin plates. Near Pass Creek it is in apparent fault contact on granite. The unit consists of a basal conglomeratic sandstone overlain by limestone-dolomite breccia, limestone, and dolomite. The dolomite is thin to medium bedded, light gray to medium dark gray, and finely crystalline. The limestone is medium gray and porous, locally containing cubic solution cavities filled with a silty, limy matrix. Both the angular solution cavities and the limestone-dolomite breccia are evaporite solution features (Poole and others, 1977). The unit ranges in thickness from a zero erosional edge to 200 ft.

Lower Mississippian McGowan Creek Formation and Upper Devonian Sappington Member of the Three Forks Formation (unit MDmt*).*—The Sappington Member of the Three Forks unconformably overlies the Jefferson Formation and consists of 75–100 ft of grayish-black to yellowish-brown laminated siltstone and mudstone. The basal dark-gray, silty, even-bedded limestone of the McGowan Creek Formation unconformably overlies the Sappington Member and contains common trace fossils and Kinderhookian (Early Mississippian) conodonts (B.R. Wardlaw, written commun., 1982). The limestone is 150–400 ft thick and is overlain by 150–250 ft of siltstone and mudstone like that of the underlying Sappington Member. Calcareous siltstone of the McGowan Creek Formation is reported to contain broken plates of phosphorite (Sandberg, 1975). These siltstones and mudstones were erroneously assigned to the Upper Mississippian Big Snowy Formation in Scholten and Ramspott (1968).

Lower Mississippian McGowan Creek Formation, Upper Devonian Sappington Member of the Three Forks Formation, and Upper and Middle Devonian Jefferson Formation, undivided (unit MDmj*).*—This unit is used wherever the Jefferson Formation was not mapped separately.

Upper to Lower Mississippian carbonate bank deposits (units Mm, Ms, Msc, Msu, *and* Mr*).*—In ascending stratigraphic order, the formations comprising the Mississippian carbonate bank are Middle Canyon

(Mm), Scott Peak (Ms), South Creek (Msc), Surrett Canyon (Msu), and Railroad Canyon (Mr). The Upper to Lower Mississippian Middle Canyon Formation, made up of about 500 ft of medium- to dark-gray, cherty, thin- to medium-bedded limestone, phosphatic in places, gradationally overlies the McGowan Creek Formation and is gradational with the overlying Scott Peak Formation. The Scott Peak and Surrett Canyon Formations, about 2,000 ft and 100–400 ft thick, respectively, consist mostly of medium-dark-gray, medium- to thick-bedded, fossiliferous (corals, brachiopods, and mollusks), relatively pure limestone of Late Mississippian age that locally has been altered hydrothermally to gypsum. The South Creek Formation is a thin (200 ft), silty thin-bedded Upper Mississippian limestone that separates the Scott Peak from the Surrett Canyon Formation. The Railroad Canyon Formation (formerly Big Snowy Formation) is about 800 ft thick and also of Late Mississippian age. This formation contains some sandy limestone and limestone conglomerate beds, but about half the formation is medium-gray and grayish-black mudstone containing scattered limestone concretions and calcareous sandstone in which phosphatic brachiopods are common (Skipp, 1985; Wardlaw and Pecora, 1985).

Lower Pennsylvanian to Upper Mississippian Bluebird Mountain Formation (unit ℙMb*).*—This unit gradationally overlies the Railroad Canyon Formation and consists of 300–500 ft of medium-gray, very fine grained to medium-grained, thick- to medium-bedded sandstone and minor thin beds of dolomite and limestone.

Lower Permian to Lower Pennsylvanian Snaky Canyon Formation (unit Pℙs*).*—This unit gradationally overlies the Bluebird Mountain Formation and consists of about 2,000 ft of thin- to thick-bedded, light- to dark-gray limestone and dolomite, much of it very sandy.

Permian Phosphoria Formation (unit Pp*).*—This unit is present north of the wilderness study area (pl. 1), where it disconformably overlies the Snaky Canyon Formation and consists of dolomite, sandstone, phosphatic siltstone, and bedded chert (Lucchitta, 1966; Oberlindacher and Hovland, 1979).

Eocene Challis Volcanics (unit Tc*).*—These intermediate volcanics consist of rhyodacite tuff and volcanic breccia, tuffaceous sandstone and conglomerate, and latite flows.

Eocene(?) dike or sill (Challis Volcanics) (unit Td*).*—Dikes and sills are of intermediate to basic composition and include the Chamberlain Canyon sheet of Scholten and Ramspott (1968).

Eocene(?) jasperoid (unit Tj*).*—Dark-gray silicified limestone makes up this unit, which is present only in one small outcrop north of Pass Creek (pl. 1).

Lower Pleistocene to Pliocene gravel (units QTg, QTfo*).*—Undifferentiated gravels (QTg) and older alluvial fan gravels (QTfo) constitute this unit.

Quaternary surficial deposits (units Qlo, Qfy, Qb, Qrg, Qto, Qop, Qtp, Ql, Qc, *and* Qa*).*—These deposits include landslide deposits (Qlo), alluvial fan gravels (Qfy), boulder trains (Qb), rock glacier deposits (Qrg), and pre-Pinedale glacial till (Qto) of Pleistocene age, outwash deposits (Qop) and glacial till (Qtp) of Pleistocene Pinedale age, and landslide deposits (Ql), colluvial deposits including small fan deposits (Qc), and alluvial deposits (Qa) of Holocene age.

Geochemistry

Introduction

The reconnaissance geochemistry of the wilderness study area is based on two studies. In the first study, 34 sieved-sediment samples, 32 nonmagnetic heavy-mineral-concentrate samples, and 79 rock samples (fig. 4) were collected, analyzed, and described in Skipp and others (1984). An additional 21 water and 7 soil samples (not shown in fig. 4) were also collected but provided only supplemental information. For the second study, 29 sieved-sediment, 13 panned-concentrate, and 102 rock samples (also shown in fig. 4) were collected during the course of a USGS investigation of the contiguous Italian Peak and Italian Peak Middle Roadless Areas. Complete analytical data from that study are presented in Hopkins and others (1984). Selected data from the Italian Peak study also are presented in Skipp and others (1984).

Analytical Methods

Heavy-mineral concentrates were collected by panning a composite sample of stream sediment to an approximate composition of half dark minerals and half light minerals with a 16-in.-diameter gold pan and standard gold-panning techniques. The panned concentrate was then processed through bromoform (specific gravity 2.8) and a magnetic separator to obtain nonmagnetic heavy-mineral concentrates for analysis.

In the Italian Peak survey, heavy-mineral concentrates were obtained by panning until the sample was reduced to approximately 10 grams of material. A small "split" of sample material weighing approximately 0.1 gram or less was taken for spectrographic analysis. The remainder of the sample was analyzed for gold by atomic-absorption spectroscopy.

In both studies, stream-sediment material was passed through U.S. Standard #80 stainless steel screens. The fine fraction was retained for analysis. Rock samples were crushed, pulverized, and then analyzed.

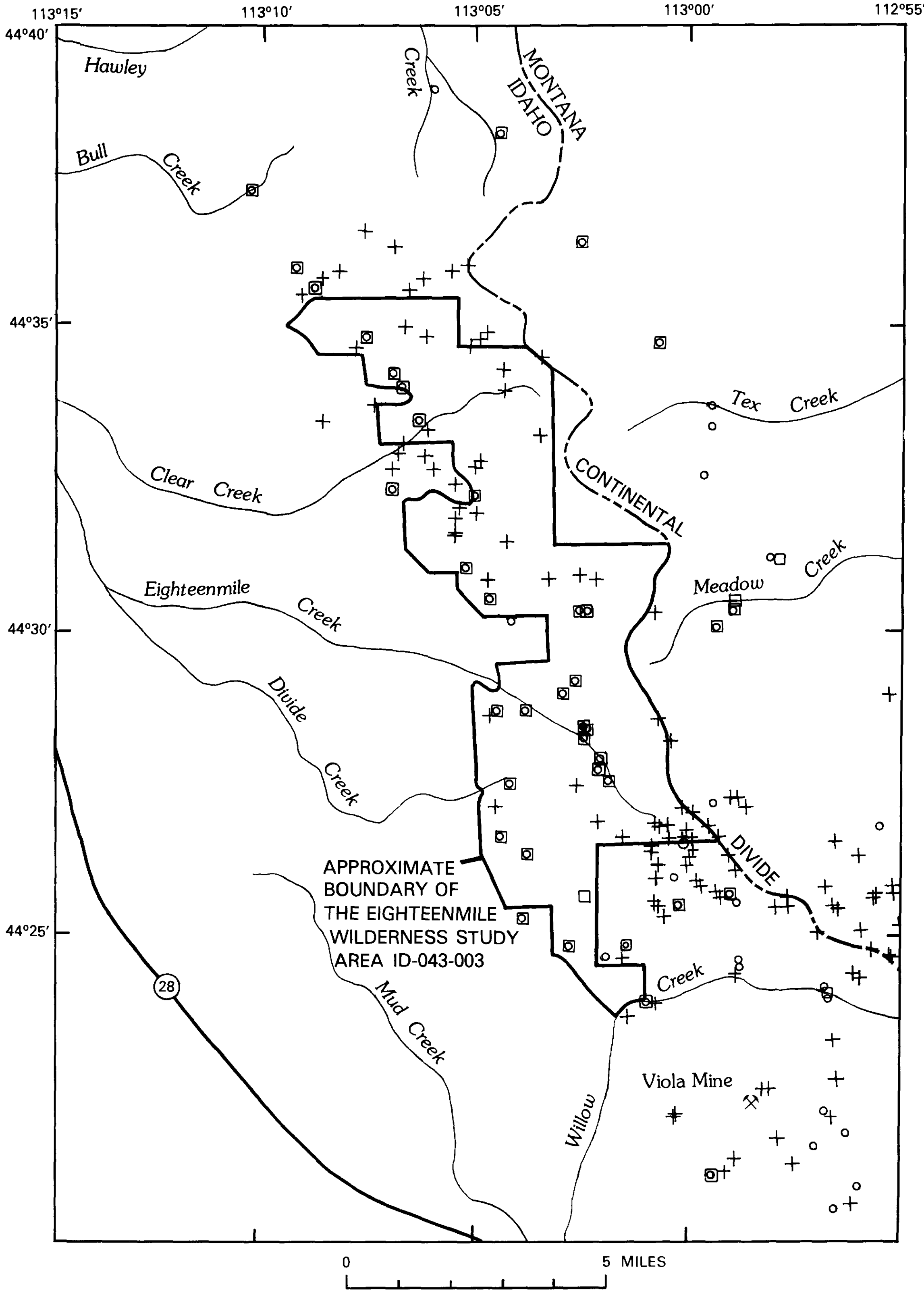


Figure 4. Map showing distribution of geochemical sampling sites for rocks (crosses) and stream sediments (circles indicate sieved-sediment samples; squares are panned nonmagnetic heavy-mineral concentrates), Eighteenmile Wilderness Study Area, Lemhi County, Idaho.

Panned-concentrate, sieved-sediment, and rock samples were analyzed for 31 elements by a semiquantitative optical-emission spectrographic method. In the Eighteenmile survey, sieved stream sediments were also analyzed for uranium by a laser-activated fluorometric method. In the Italian Peak survey, rocks were analyzed for uranium by the same method. Details of analytical procedures are described in Skipp and others (1984) and Hopkins and others (1984).

Water samples were analyzed for major anions (chlorine, fluorine, nitrate, and sulphate) by ion chromotography; for major cations (sodium, magnesium, potassium, and calcium) and trace metals (copper and molybdenum) by atomic-absorption spectroscopy; for uranium by laser-activated fluorimetry; and for other characteristics such as alkalinity, specific conductance, pH, and temperature by standard methods of water analysis. Soil samples were analyzed by semiquantitative spectrography (Skipp and others, 1984).

Results of Study

The entire study area appears to be enriched in a wide variety of elements resulting from several geochemical processes. Distributions of many of the anomalous elements are given in Skipp and others (1984, figs. 3–13). A summary of the anomalies with respect to geologic units follows:

Anomalies in Proterozoic Sedimentary Rocks

Three Proterozoic rock samples were analyzed, one of which (a brecciated quartzite marked with stringers of hematite) contained 30 ppm (parts per million) gold (pl. 1, sample MLO15R). This was the only sample of any type from the study area in which gold was found. Although sediments from streams draining Proterozoic rocks contained anomalous amounts of silver and copper, among other elements, a Proterozoic source cannot be established because those streams also drain Paleozoic rocks.

Anomalies in Paleozoic Sedimentary Rocks

Paleozoic rock units and the stream sediments derived from them contain anomalous amounts of silver, boron, barium, chromium, copper, manganese, molybdenum, nickel, lead, and zinc. Geologic, stratigraphic, and structural complexities and the reconnaissance nature of the geochemical data gathering combine to make interpretations difficult. Most stream-sediment, concentrate, and water samples are composite samplings of many stratigraphic and structural units. Rock samples, in general, are representative of unaltered parts of a stratigraphic unit. For example, the highest silver value determined for a rock sample, 10 ppm (excluding samples from mining areas), was obtained from a Mississippian or Devonian siltstone. Siltstones and mudstones of the Devonian Three Forks Formation and the Mississippian McGowan Creek and Railroad Canyon Formations were found to be anomalous in a number of elements, including silver and molybdenum, at several localities (Skipp and others, 1984, figs. 3 and 7). These data suggest the siltstones may have been pathways for the metal-bearing fluids that transported and deposited the anomalous concentrations of metals in the Paleozoic carbonate rocks. Metals could have been transported by several types of fluids: (1) hydrothermal fluids or enriched ground waters that may have moved through the siltstones because they were the most permeable units; and (2) metal-rich formation brines or sedimentary exhalative fluids for which the siltstones may have been both the source and the pathway.

Alternatively, the siltstones and mudstones may have acted as caprocks for fluid movement through a stratigraphically lower permeable unit and may have residual metal concentrations (Lambeth and Mayerle, 1983). The data from the geochemical survey are insufficient to distinguish between these possibilities.

The highest molybdenum value, 300 ppm, was determined for an altered and brecciated carbonate rock sample found in a tributary to Chamberlain Creek (pl. 1, sample MLO16R1). The brecciation of the rock suggests that anomalies may have resulted from movement of hydrothermal fluid through permeable fault breccias. There appears to be a spatial relationship between faults and anomalous concentrations of metals in rocks throughout the Eighteenmile Wilderness Study Area, and a tendency exists for higher anomalous concentrations to be present near fault intersections. However, the spatial association may reflect only sampling bias and secondary distribution of pre-existing metal enrichment.

Very high chromium and nickel concentrations in many of the rock and stream-sediment samples (Skipp and others, 1984, figs. 8 and 11) may be interpreted as evidence of magmatic activity. Altered Paleozoic limestones and dolomites, in many cases, have much higher concentrations of chromium and nickel than do samples of the mafic dikes of probable Eocene age. Interpretation of the geochemical data is complicated by the nearly certain presence of a subsurface pluton emplaced along the range-front fault near Clear Creek (see following section on geophysics). This body could have been the source for the anomalous metal concentrations, but the case is not clear. At the very least, this body acted either as a source for magmatic fluids or as a heat pump for cells of circulating meteoric waters. This activity appears to have resulted in the formation of the gypsum deposits in the Clear Creek area (see discussion in a following section) and probably caused local redistribution of elements.

The presence of a subsurface igneous body and anomalous molybdenum values suggests the possiblity of a porphyry molybdenum system. The data, however, are sufficient only for speculation. Geologic relationships indicate the subsurface body is late Tertiary or early Pleistocene in age, and most porphyry molybdenum systems in Idaho and Montana are Late Cretaceous or early Tertiary in age (Armstrong and others, 1978; Hall and others, 1984). Only trace amounts of fluorite were found in a few nonmagnetic concentrate samples in the study area, indicating that if a molybdenum system were present, it probably would be deficient in fluorine. If emanations from the subsurface body were the source of the high chromium and nickel contents in the rocks and stream sediments, a basaltic composition for the body would be indicated. Most fluorine-deficient molybdenum systems are associated with granites and granodiorites (Theodore and Menzie, 1984; Hall and others, 1984). Samples of Eocene dikes, however, also contain weakly anomalous concentrations of molybdenum, but these levels may have resulted from a later enrichment. Fractures formed during emplacement of dikes may have provided solution pathways for metal-rich fluids.

Dolomite of the Devonian Jefferson Formation is the host for stratabound silver-lead-zinc ores in the northern part of the Birch Creek (Nicholia) mining district (Viola mine) (fig. 1) south of the study area (Lambeth and Mayerle, 1983; Skipp and others, 1983). Only weakly anomalous concentrations of silver and lead were noted in rock samples of Devonian dolomite from the study area, but some concentrate samples were very strongly anomalous in lead. Scattered samples of Mississippian carbonate rocks are enriched in lead, copper, and molybdenum. Comparison of data from the study area and from the Nicholia district (Skipp and others, 1983) suggests that similar processes affected both areas, but that the study area is less enriched in metals than the area of the Viola mine.

Many of the nonmagnetic-concentrate samples collected between Dry Canyon and Pass Creek (pl. 1) contained large amounts of phosphatic material, which indicates that there are phosphate-bearing beds in upper Paleozoic rocks other than the Phosphoria Formation.

Anomalies in the Ordovician Beaverhead Mountains Pluton

The Beaverhead Mountains pluton is a geochemically specialized granitoid containing anomalous amounts of boron, beryllium, lanthanum, niobium, molybdenum, tin, and uranium in addition to base and precious metals (copper, lead, zinc, and silver). Many of the rock samples (Hopkins and others, 1984) contain tin concentrations and zirconium-to-tin and vanadium-to-niobium ratios that meet the criteria for recognizing granitoid complexes as sources of deposits of rare metals (Beus and Grigorian, 1977, tables 20 and 21). The base- and precious-metal concentrations show a close spatial relationship to fractures and faults in the granite, whereas tin-rich rock samples show no such relationship. In addition, a tendency for tin-rich rocks not to be enriched in either base or precious metals suggests that silver, copper, lead, and zinc anomalies in the pluton are not genetically related to the granite, but are a later superimposed enrichment.

Moderately high uranium values (Skipp and others, 1984, fig. 13) determined for sieved sediments definitely are associated with the pluton; however, none of the 30 rock samples collected contained as much as 5 ppm uranium when analyzed (Hopkins and others, 1984). The source for the anomalous uranium concentrations in the sediments is not known, but precipitated uranium on organic matter in small, localized boggy areas in the stream drainages is the probable cause.

A few selected paramagnetic heavy-mineral concentrates also were analyzed by semiquantitative-emission spectrography. This concentrate fraction contains mafic minerals and iron and manganese oxides. Results of the analyses yielded virtually the same interpretations as the other sample types, although anomalous concentrations of lanthanum, yttrium, and thorium for one site (pl. 1, sample NI001NM1), suggests the possibility of fine-grained thorite inclusions in some of the hematite grains observed in the paramagnetic fractions. Hematite-thorite minerals are present in the Lemhi Pass district north of the study area (Staatz, 1972, 1979) and at a thorite prospect (Staatz, Bunker, and Bush, 1972) at Bull Creek about 3 mi northwest of the study area (fig. 4; Skipp and others, 1984). These deposits also contain significant amounts of rare-earth lanthanides (neodymium, gadolinium, dysprosium), and yttrium, which is not a lanthanide (Staatz, Shaw, and Wahlberg, 1972). Data from all three areas are similar (Skipp and others, 1984; J.R. Hassemer, 1984, unpub. data) and suggest that the anomaly in the study area may represent an occurrence similar to, but weaker than, the two known occurrences. It is possible, then, that rocks of the Beaverhead Mountains pluton contain a southward extension of the Lemhi Pass–type of enrichment.

Geophysics

Introduction

Magnetic and gravity studies were undertaken as part of the mineral resource evaluation of the Eighteenmile Wilderness Study Area. The geophysical data provide information on subsurface structure and distribution of rock types that may have associated mineral resource potential.

Gravity

Methods

The gravity data were obtained in the study area and surrounding areas during the summers 1982–85 and were supplemented by data maintained in the files of the Defense Mapping Agency of the U.S. Department of Defense. Stations obtained by the author were established using Worden[2] gravimeter W–177. The data were tied to the International Gravity Standardization Net 1971 (U.S. Defense Mapping Agency Aerospace Center, 1974) at base station ACIC 3945–1, Grant, Mont. Station elevations were obtained from bench-marks, spot elevations, or estimates from topographic maps at 1:24,000 and 1:62,500 scales, and are accurate to ±20–40 ft. The error in the Bouguer anomaly is less than 2.5 mGal (milligals) for elevation control. Bouguer anomaly values were computed according to the 1967 gravity formula (International Association of Geodesy, 1967) and a reduction density of 2.67 gm/cm^3 (grams per cubic centimeter). Mathematical formulas are given in Cordell and others (1982). Terrain corrections were made by computer for a distance of 167 km from the station according to the method of Plouff (1977). The data are shown contoured at a 5-mGal interval in figure 5.

Results of Study

Moderately high gravity values (–215 to –205 mGal) (fig. 5) are produced by the Ordovician, Devonian Mississippian, Pennsylvanian, and Permian rocks of the Hawley Creek, Fritz Creek, and Cabin thrust plates (fig. 3). A major low-gravity anomaly trending N. 25° W. is centered over Tertiary and Quaternary sedimentary rocks in the Lemhi Valley, west of the study area (fig. 5). The gravity gradient west of the northern part of the study area corresponds to the Crooked Creek normal fault. In the southwestern part of the area, the major gradient swings southward at Eighteenmile Creek parallel to the Beaverhead fault, whereas a minor trend defined by the termination of anomalies is associated with the southwestward continuation of the Crooked Creek fault zone.

Magnetics

Methods

The regional aeromagnetic data of figure 6 are from two sources: (1) Zietz and others (1980) for Montana and (2) U.S. Geological Survey (1978) for Idaho. Both maps are contoured at 20-gamma intervals.

The southern part of a local magnetic-high anomaly that exceeds 500 gammas in magnitude was identified by an aeromagnetic survey of the Italian Peak and Italian Peak Middle Roadless Areas adjacent to the study area (U.S. Geological Survey, 1981). The area of the anomaly is indicated by the auxiliary contours and letter A in figure 6. A ground magnetic survey was completed in 1985 to determine the extent of the anomaly. The locations of measurements made in that survey are shown on plate 1. The ground measurements were made with a GeoMetrics proton magnetometer, and the values shown on plate 1 are uncorrected total-magnetic-intensity values obtained in the field.

Results of Study

On the regional map (fig. 6), moderately low magnetic values are associated with Paleozoic rocks of the Hawley Creek, Fritz Creek, and Cabin thrust plates in the study area. Slightly higher values are associated with the sedimentary rocks of the Lemhi Valley west of the study area. Rocks and deposits of the Lemhi Valley are derived partly from the Lemhi Range to the west, where the rocks have higher magnetic susceptibilities than those east of the valley. The magnetic high in the southwestern corner of the area shown in figure 6 is part of a broad anomaly produced by the Lemhi Range. The positive magnetic nose (B) east of the central part of the study area (fig. 6) is the terminus of a major magnetic-high anomaly. It is interpreted to be associated with Archean basement rocks beneath the study area, a southwestern projection of the Blacktail-Snowcrest uplift that crops out east of the Tendoy Mountains (Perry and others, 1981; Kulik and Perry, in press).

The local magnetic anomaly, partly within the wilderness study area (pl. 1, fig. 1), probably indicates the presence of a Neogene subsurface magnetic body intruded along the range-front (Crooked Creek) fault. Estimates based on the half-width of the anomaly suggest that the magnetic body lies at a depth of 10,000–15,000 ft below the surface.

Landsat Multispectral-Scanner Linear Features

Linear features in Landsat multispectral-scanner (MSS) images at a scale of 1:800,000 were mapped by photogeologic interpretation for southern Idaho. Linear features are the topographic and spectral expression primarily of rock-fracture patterns and other structural and lithologic lineaments. These expressions can be enhanced or subdued by scanner resolution, sun orientation, atmospheric phenomena, and vegetation. Analysis of linear features in conjunction with geologic and geophysical maps may reveal new relationships such as fracture control of mineralization.

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

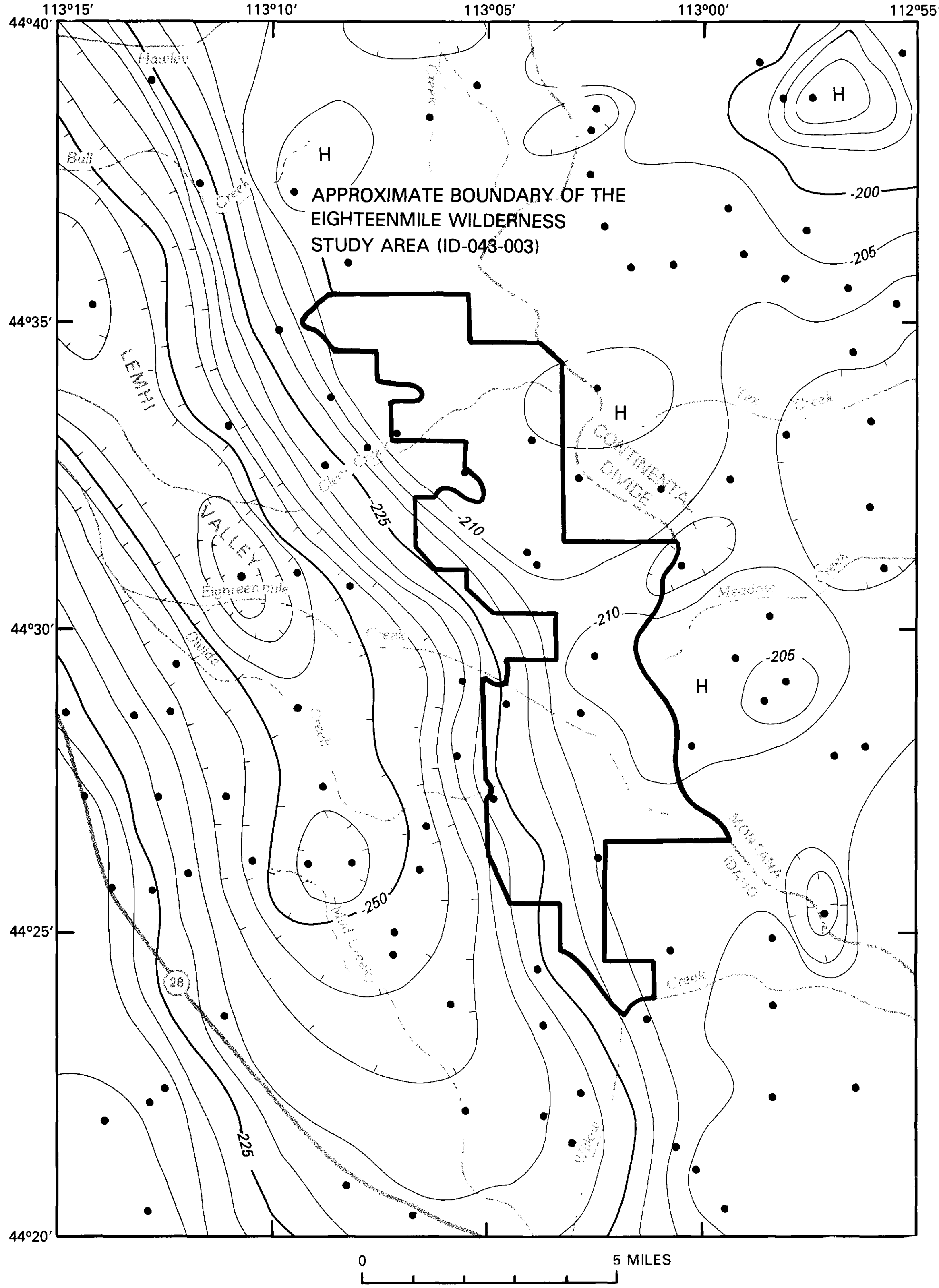
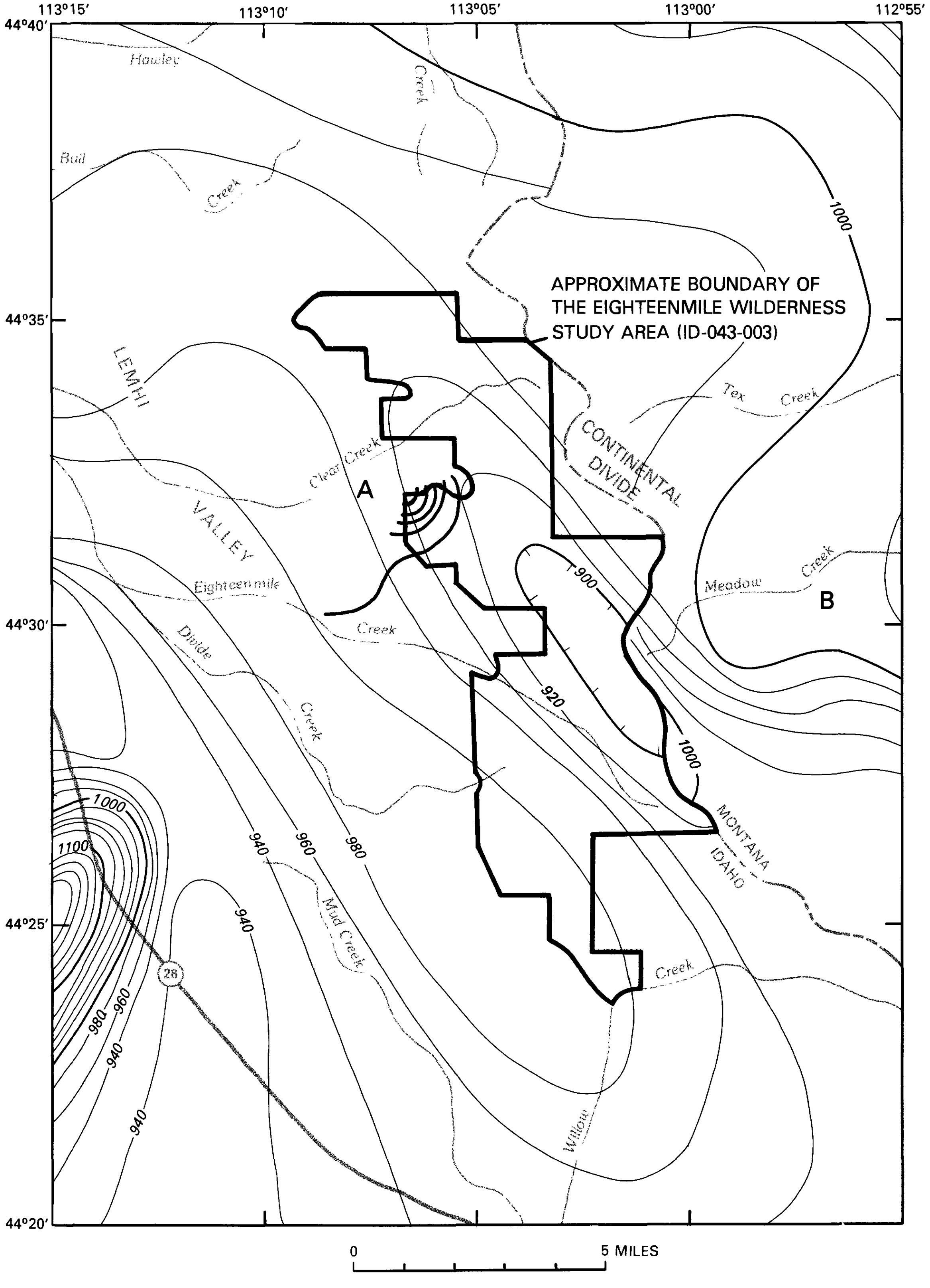


Figure 5. Regional complete Bouguer gravity anomaly map of area encompassing the Eighteenmile Wilderness Study Area, Lemhi County, Idaho. Contour interval is 5 milligals; small dots indicate locations of gravity stations. H indicates gravity high. Hachured line indicates closed gravity low.


113°15′
113°10′
113°05′
113°00′
112°55′
44°40′
44°35′
44°30′
44°25′
44°20′
APPROXIMATE BOUNDARY OF THE EIGHTEENMILE WILDERNESS STUDY AREA (ID-043-003)
Hawley
Bull
Creek
Clear Creek
Eighteenmile
Divide
Mud Creek
Tex Creek
Meadow Creek
Willow
LEMHI
VALLEY
CONTINENTAL DIVIDE
MONTANA
IDAHO
A
B
900
920
940
960
980
1000
1100
28
0
5 MILES

Linear features of every orientation are expressed well on the surface in east-central Idaho. The dominant trend in and adjacent to the study area is N. 5°–35° W. This is the strike of the basin-range type of normal faults in the wider area. West of the study area, the Crooked Creek and Beaverhead frontal faults, which separate the Beaverhead Mountains and Lemhi Valley, are local examples (fig. 3, pl. 1). On the Bouguer anomaly map (fig. 5), a major gravity low is shown to underlie the Lemhi Valley and to follow this trend. On the total-intensity magnetic map (fig. 6), the contours parallel the trend.

A major broad trend, N. 5°–55° E., is well expressed in the region around the study area. Little has been reported on other major fault trends or pervasive fracture patterns.

Mineral and Energy Resource Potential

Hydrothermal Gypsum and Associated Base and Precious Metals

The Model

The presence of a projected buried stock intruded along an extensional fault zone and the presence of a keystone graben are two characteristics of epithermal deposits containing silver and base metals (copper, lead, and zinc) that are found in other parts of the world (Barton and others, 1982). The majority of these deposits, however, are located in thick intermediate to felsic volcanic rocks deposited on the stable craton rather than in folded and faulted carbonate rocks in a mobile thrust belt environment such as that of the wilderness study area.

Gypsum that has been mined at Clear Creek appears to be part of a fault-controlled hydrothermal deposit developed in fractured limestone of the Upper Mississippian Scott Peak Formation. The gypsum recovered from the Clear Creek mine was part of a Holocene landslide deposit (pl. 1). Scott Peak limestone altered to gypsum is exposed at the patented prospect southeast of the mine and probably was a major source for the landslide material. Limestone at the prospect is thick-bedded, pure, fossiliferous Scott Peak Formation that grades into pure gypsum along the cliff face. No anhydrite has been described for the area, but it is possible that the gypsum is a product of hydration of hydrothermal anhydrite in the zone of weathering. The disruption of bedding that would accompany the volume change from anhydrite to gypsum is not obvious at the prospect, but the main deposit is in a landslide. The spread of CAI values and the corroded and fractured nature of conodonts recovered from the adjacent Clear Creek slide block indicate the presence of hydrothermal activity in the area (Rejebian and others, 1987).

It is also possible that the limestone was altered directly to gypsum by sulfur-enriched ground waters (P.K. Theobold, oral commun., 1987). Oxidation of sulfides present in the vicinity of the gypsum deposit could have provided the sulfur source. Minor amounts of iron oxides and sulfides in gossan selvages containing anomalous amounts of lead, silver, zinc, and molybdenum are associated with the gypsum in the Clear Creek and adjacent areas (see section on geochemistry).

The keystone graben just east of the Clear Creek mine and prospect may have provided conduits for heat and fluids emanating from the intrusion inferred to be present in the Lemhi Valley (see section on geophysics), and a hydrothermal system may have developed above the intrusion soon after its emplacement in late Pliocene to early Pleistocene time.

Resource Potential

The wilderness study area is judged on the basis of the following factors to have areas of moderate resource potential for hydrothermal gypsum in the Clear Creek area: (1) nearby recognized deposits, (2) Pliocene or Pleistocene hydrothermal alteration, (3) abundant fractured limestone host, (4) a buried Neogene stock intruded along an extensional fault, and (5) a fault defining a keystone graben. Assignment of moderate resource potential for gypsum in the Clear Creek area in the vicinity of the projected buried stock is made with a certainty level of C. More detailed geochemical sampling is required to define the extent of areas having moderate resource potential for metals, and shallow drilling would identify gypsum resources.

Stratabound Silver, Lead, and Zinc in Dolomite of the Devonian Jefferson Formation

Erosional remnants of the Devonian Jefferson Formation are present throughout the central part of the study area on both the Fritz Creek and Hawley Creek

Figure 6 (facing page). Regional total intensity aeromagnetic map of area encompassing the Eighteenmile Wilderness Study Area, Lemhi County, Idaho, showing southern part of a local anomaly, A, identified in an aeromagnetic survey of the Italian Peak Middle Roadless Area (U.S. Geological Survey, 1981). B is the terminus of a major magnetic high anomaly (see text). Data in Montana from Zietz and others (1980). Flightlines were east-west at 2.5-mi spacing (not shown). Flown at 12,000–12,500 ft barometric elevation. Data in Idaho from U.S. Geological Survey (1978). Flightlines were east-west at 5-mi spacing (not shown). Flown at 12,500 ft barometric elevation. Contour interval is 20 gammas.

thrust plates and in the southern part of the area on the Hawley Creek plate. Although only weakly anomalous concentrations of silver and lead were noted in three of four rock samples of Devonian dolomite, one sample from the Hawley Creek plate contained an anomalous concentration of lead even though the sample presented no outward appearance of alteration or mineralization. Some concentrate samples also were strongly anomalous in lead.

The Model (Viola Mine)

The Viola mine, about 2.5 mi southeast of the study area (fig. 1, pl. 1), the most productive mine in the northern part of the Birch Creek mining district, is discussed here as a potential model for stratabound silver-lead-zinc deposits in dolomite of the Devonian Jefferson Formation in the study area. The following discussion is modified from Lambeth and Mayerle (1983) and Skipp and others (1983).

Descriptions of mineralized bodies in the Viola and adjacent mines by Shenon (1928) and Anderson and Wagner (1944) indicate that the bodies had the characteristics of stratabound deposits. These authors, however, described the deposits as derived from magmatic hydrothermal fluids that migrated from depth along the range-front fault system. As a result of the study of the Italian Peak and Italian Peak Middle Roadless Areas (Lambeth and Mayerle, 1983; Skipp and others, 1983), the deposits were reclassified as possible basin-margin, carbonate-hosted, lead-silver-zinc deposits stratabound within the Devonian sedimentary rocks.

> The requirements for basin-margin, carbonate-hosted deposits are (1) a basinward metal source; (2) permeable migration conduits; (3) a basin-margin host rock; and (4) an impermeable cap. A metal source could have been provided by the destruction of the western, metal-rich arc terrain supplemented by cratonic erosion sources and concentration in the adjacent back-arc basin. The migration conduit may have been the Kinnikinic Quartzite before secondary silicification, and the principal host rock is the craton-margin Devonian dolomite. An impermeable cap could have been provided by the low-permeability shale and silicified siltstone of the Sappington Member of the Three Forks Formation and the shale and siltstone of the upper part of the McGowan Creek Formation. During lithification of the back-arc basin sediments, the metal ions may have been mobilized, and then migrated as acidic chloride complexes up the hydraulic gradient toward the cratonic platform along faults and permeable formations. The metal-rich fluids may have traveled cratonward through permeable sandstones of the Kinnikinic Quartzite and deposited their metals upon contact with the overlying Devonian carbonate rocks. Reductive sulfide ions could have been provided by evaporites in the Devonian Jefferson Formation [Skipp and others, 1983, p. 7, 8].

Because there is no evidence of a buried intrusion along the Beaverhead fault zone west of the Nicholia mining district, and because many of the prospects in that district are related spatially to the Jefferson Formation, a stratabound genesis for the ore bodies of the Viola mine seems reasonable.

Resource Potential

The wilderness study area has areas of moderate resource potential for silver, lead, and zinc in stratabound deposits similar to those of the Viola mine (pl. 1). Dolomite of the Jefferson Formation on the Hawley Creek thrust plate has the same depositional environment as that of the Viola mine. Dolomite of the Jefferson Formation on the Fritz Creek thrust plate is a more easterly facies, but has many of the sedimentary characteristics of the formation on the Hawley Creek plate.

Assignment of moderate resource potential for silver, lead, and zinc is made with a certainty level of B. In many places the Jefferson Formation has not been mapped separately, but has been included with the Upper Devonian Sappington Member of the Three Forks Formation and the Lower Mississippian McGowan Creek Formation. Detailed mapping and geochemical sampling are required to better define areas having moderate resource potential. Exploration would be required to identify resources.

Oil and Gas

The Model

Oil and gas has been found in structural traps such as frontal ramp anticlines in the Idaho-Wyoming thrust belt southeast of the Snake River Plain. Thrust-belt structures in the study area are similar in some respects to those to the southeast (Skipp, 1985). Abundant thermally mature source rocks and thick, permeable reservoir rocks characterize the productive parts of the Idaho-Wyoming belt (Powers, 1977). However, source rocks of the Fritz Creek and Cabin plates in the study area have been heated to more than 100 °C, as indicated by CAI values (fig. 3); thus they are thermally post-mature with respect to oil generation, and liquid hydrocarbons would have been destroyed.

Resource Potential

The oil potential of the entire wilderness study area is rated as low to a depth of 10,000 ft beneath the surface, the estimated thickness of the Hawley Creek, Fritz Creek, and Cabin thrust plates. The dry gas (methane), and possibly wet gas, potential is rated as moderate over the same area.

The low resource potential for oil is assigned with a certainty level of D. The moderate resource potential for gas is assigned with a certainty level of C. The thermal history of rocks of the three thrust plates precludes the presence of oil, although lack of subsurface data precludes assigning the area a rating of "no resource potential" for oil. Dry or wet gas may be present, but only exploratory drilling could raise the level of certainty.

An unknown resource potential for oil and gas, at certainty level A, exists at depths below 10,000 ft where thermally mature source rocks and favorable structures may be present in a lower thrust plate in areas not affected by an inferred buried stock (Skipp, 1984). However, only drilling could verify a deep resource or better define a potential resource at that depth.

Other Resources

A low mineral resource potential (certainty level B) for hydrothermal metal deposits (copper, zinc, lead, molybdenum, and silver) in small veins and replacement deposits associated with the hydrothermal gypsum is assigned to the north half of the study area, in the vicinity of Clear Creek and the magnetic anomaly. High chromium and nickel concentrations in many rock and stream-sediment samples may be evidence of extensive magmatic activity, but the reconnaissance geochemical survey did not pick up consistently anomalous concentrations of the above metals in any one area. Anomalous molybdenum values were determined for samples from localities scattered throughout the northern part of the study area (Skipp and others, 1984, fig. 7), but evaluation of the resource potential is difficult. Known fluorine-deficient porphyry molybdenum deposits in Idaho and Montana are associated with early Tertiary to Late Cretaceous I-type granitoid plutons (Armstrong and others, 1978; Hall and others, 1984; Theodore and Menzie, 1984). Hall and others (1984) note one case in which the hydrothermal solutions that formed the molybdenite converted magnetite to a nonmagnetic phase that is detectable by a low in the field magnetic measurement. Though the composition of the inferred stock at 10,000–15,000 ft beneath the surface of the Lemhi Valley is unknown, high chromium and nickel contents in surface rocks may indicate a basaltic composition, and the stock has a positive magnetic signature: magnetite has not been converted. The resource potential for molybdenum in a porphyry deposit in the vicinity of Clear Creek is considered to be low on the basis of the young age of the inferred intrusive body and its positive magnetic signature.

A low resource potential for metals (silver, copper, lead, molybdenum, and zinc) in faults and fractures in the Beaverhead Mountains pluton, and for metals (tin, niobium, uranium, thorium, and rare-earth elements) in granite of the same pluton and in sediments derived from the granite is assigned to the south half of the study area, south of Pass Creek, at certainty level C.

A low resource potential for phosphate, at certainty level C, is assigned to the northern part of the study area because the Phosphoria Formation is not present. Phosphate-rich zones are present in other upper Paleozoic formations but are of low grade. Though there is some evidence that late Tertiary, and possibly Pleistocene, geothermal activity affected the area, no Holocene activity is evident.

Recommendations for Further Study

Detailed geologic mapping to determine the extent of the Devonian Jefferson Formation and more thorough geochemical sampling of that unit are needed to raise the level of assessment of the potential for silver, lead, and zinc in stratabound deposits. More detailed geochemical studies and selected shallow drilling are needed in the vicinity of the magnetic anomaly, the keystone graben fault, and the Clear Creek mine to better assess the mineral resource potential for gypsum and to better evaluate speculations on the presence or absence of a subsurface porphyry molybdenum system.

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GEOLOGIC TIME CHART

Terms and boundary ages used in this report

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

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

[2] Informal time term without specific rank.

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