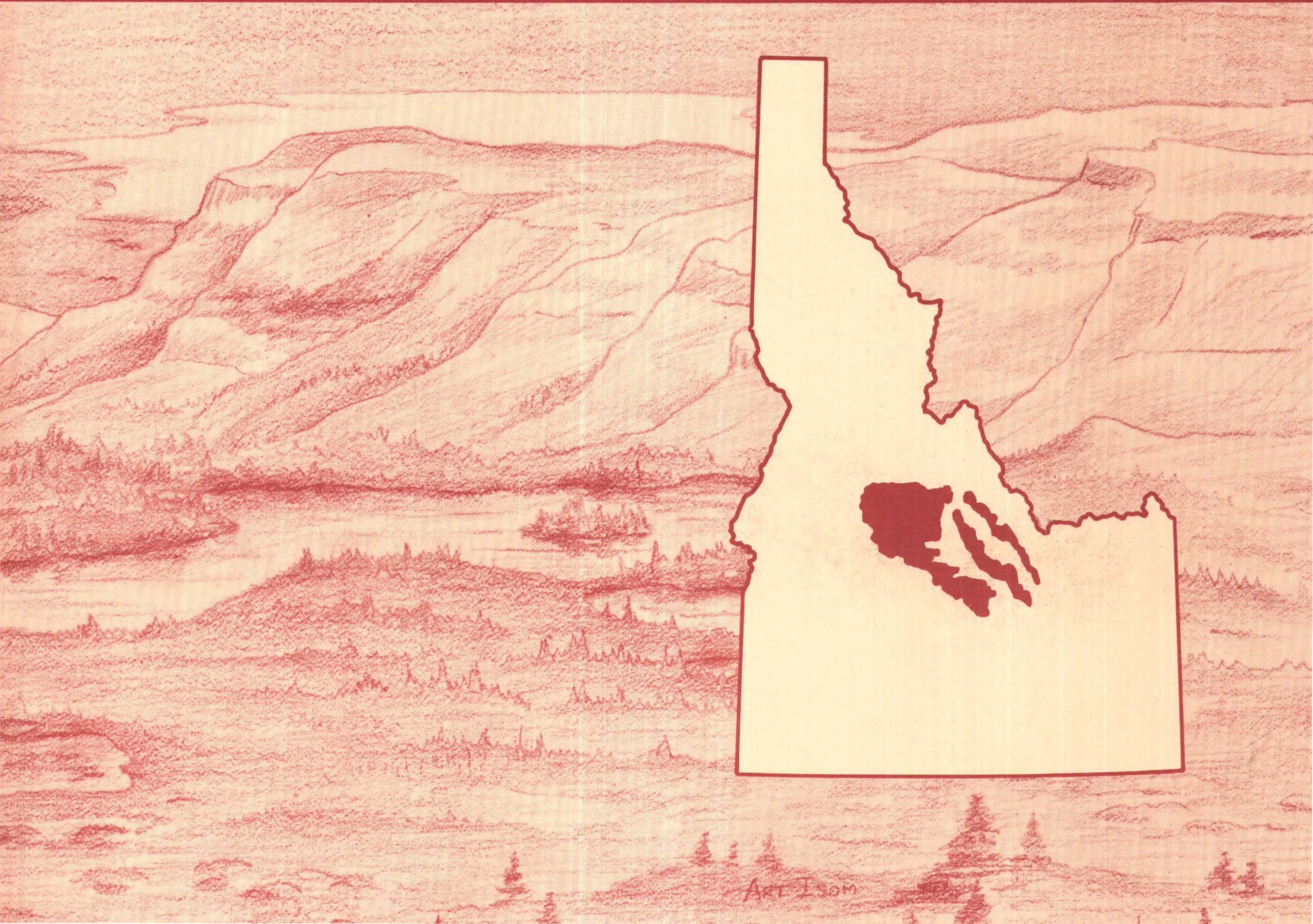
Mineral Resource Potential and Geology of the Challis National Forest, Idaho

U.S. GEOLOGICAL SURVEY BULLETIN 1873



Mineral Resource Potential and Geology of the Challis National Forest, Idaho

By RONALD G. WORL, ANNA BURACK WILSON,
COLE L. SMITH, and M. DEAN KLEINKOPF
U.S. Geological Survey

with a section on Salable Minerals
By ROBERT C. SYKES
U.S. Forest Service

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Summary

This assessment of the mineral resource potential of the Challis National Forest, Idaho, was made to assist the U.S. Forest Service in fulfilling requirements of Title 36, Chapter 2, part 219.22, Code of Federal Regulations, and to supply resource information and interpretations so that the mineral resources of this Forest can be considered with other resources in land use planning. Geologic, geochemical, and geophysical data were compiled at 1:250,000 scale, and all available published information on mineral deposits and occurrences, as of June 1987, was used in assessing the mineral resource potential of the Forest.

The mineral resource potential of some of the wilderness study areas in the Forest has already been assessed by the U.S. Geological Survey and the U.S. Bureau of Mines; published studies cover the Frank Church–River of No Return Wilderness and additions, the Sawtooth National Recreation Area, the Boulder–Pioneer Wilderness Study Area, and the White Cloud–Boulder Roadless Area. The U.S. Geological Survey recently completed a mineral resource evaluation of the Challis 1° × 2° quadrangle.

The Challis National Forest is endowed with a wealth of mineral resources, and mining and exploration activity has played a central role in the settlement and economic development of this area. Major deposits of silver, gold, lead, zinc, copper, tungsten, and molybdenum have been exploited, and there has been some production of fluorspar, uranium, and rare-earth minerals. Active exploration programs by industry are designed to seek new deposits of base and precious metals, rare-earth elements, and other mineral resources. Commercially important mineral production in the future seems assured.

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Character and Geologic Setting

The Challis National Forest and administrated lands cover 4,338 mi^2 of mountainous terrain in an area about 140 mi long in a northwest direction and 75 mi wide. The Forest consists of four major tracts; the northeastern and central tracts are separated from each of the others, and the northwestern and southwestern tracts are connected only by a narrow strip. The northeastern tract is along the west slope of the Lemhi Range; the central tract is in the higher parts of the Pahsimeroi Mountains and the Lost River Range; the northwestern tract covers the Boulder Mountains, northern Sawtooth Range, Stanley Basin, and the extensive Salmon River Mountains; and the southwestern tract covers the White Knob Mountains, Copper Basin, and the eastern part of the Pioneer Mountains. Elevations range from about 6,000 ft above sea level near Howe on the edge of the Snake River Plain to 12,662 ft on Borah Peak, which is the highest point in the State of Idaho.

Rocks exposed in the Forest range from nearly 2 billion year old Precambrian gneisses to modern alluvial gravels. Five major rock-forming and structural events occurred in this part of Idaho: (1) Deposition of sedimentary rocks along the margin of a major land mass from about 2,000 million to 260 million years ago; (2) compressional structural activity within the sedimentary pile after 260 million and prior to 70 million years ago; (3) emplacement of the Idaho batholith plutonic rocks from about 110 million to 70 million years ago; (4) extensional tectonic activity that started about 70 million

(4) extensional tectonic activity that started about 70 million years ago and continued to Holocene (Recent) time; and (5) volcanism that produced the Challis volcanic field from about 51 million to 37 million years ago. Glaciation and erosion during the past 2 million years sculpted the landscape to its present form.

The oldest recorded geologic event was the deposition, beginning about 2 billion years ago, of a thick sequence of Precambrian marine sedimentary quartzite, argillaceous quartzite, local limestone and sandstone, and minor interbedded volcanic rocks. These rocks were deformed, metamorphosed, and intruded by plutonic rocks 1.4–1.2 billion years ago. From about 570 million to 240 million years ago (the Paleozoic Era), the area was part of a geosyncline along the west edge of a major land mass. The types of sedimentary rocks deposited at this time ranged from dominantly limestone in the east, through clastic rocks, to dominantly deep water black-shale sequences in the west. Facies changes across short distances of time-equivalent rocks characterize the Paleozoic rocks in this area. During Mesozoic time, 240–66 million years ago, thrust faulting of the Paleozoic rocks resulted in juxtaposition of rock units that were originally many miles apart. This faulting, combined with the depositional facies changes, has resulted in a very complex Paleozoic rock terrane. Most of the Paleozoic rocks exposed in the Forest are part of imbricated structural plates and were moved along thrust faults from the places where they were formed.

During mid- to Late Cretaceous time, 110–70 million years ago, granitic to tonalitic intrusive activity formed the Idaho batholith and related bodies. Emplacement of the batholith engulfed, deformed, and metamorphosed the Paleozoic sedimentary host rocks. Extensive volcanism from several centers and calderas produced the volcanic and volcaniclastic rocks of the Challis volcanic field during the period from about 51 million to 37 million years ago. Most of the area of the Forest was covered by volcanic rocks by the end of this period. Numerous intrusive bodies, which range in size from the large Sawtooth batholith (about 20 × 12 mi) to small dikes, also were emplaced during this period. Formation of regional northeast-trending high-angle faults occurred from the end of the Mesozoic, about 65 million years ago, to late Tertiary time. Block faulting along north and northwest trends, which started sometime in the mid-Tertiary and continued to the Holocene, produced the Basin and Range topography characteristic of this area. Glaciers sculpted some of the higher mountains from about 1.5 million years ago to Holocene time, and erosion by fluvial and mass-wasting processes produced the steep-sided mountain stream valleys. Debris from the mountain streams formed the large mountain-front alluvial fans present in much of the Forest.

Mineral Resources

The first major prospecting and mining in the Forest took place during the 1860's and 1870's when most of the known gold placer and lode deposits were discovered. Production of gold from deposits in and near the Forest has been nearly continuous until the present. Lead-silver-copper-zinc ores were discovered during the gold rush of the 1860's, and the rich secondary deposits of the oxidized zone were mined during the 1880's. Mining of primary ores has been nearly continuous since the turn of the century; the Clayton Silver mine recorded the largest production. Tungsten was produced sporadically from mines in and near the Forest from about 1911, with major production, mainly from the Ima mine, from 1936 into the late 1950's. Extensive exploration for molybdenum during the 1960's resulted in several discoveries and the development of the Thompson Creek mine which is still in production. Of the 2,516,191 acres within the Challis National Forest proper, about 1,800,000 acres are available for location of mining claims and mineral materials development. The remaining 787,789 acres are legislative and administrative withdrawals closed to the location of mining claims and mineral-materials development.

Resource Potential—Locatable and Leasable Minerals

The assessment of mineral resource potential in this report is summarized in table 1, which gives the total size of areas of high, moderate, or unknown resource potential for locatable lode, locatable placer, leasable, and salable commodities. Figure 1 shows areas of high, moderate, and unknown resource potential for locatable lode minerals; figure 2 shows areas of high and moderate resource potential for locatable placer minerals and high to moderate potential for leasable commodities; figure 3 shows areas of high resource potential for salable commodities.

Table 1. Summary of areas of high and moderate mineral resource potential

[Leaders (---) indicate no areas present or no value calculated]

Type of resource	Area of resource potential (in square miles)		
	High	Moderate	Total
Locatable lode	1002	1037	---
Locatable placer	298	200	---
Leasable	---	---	1930
Salable	132	---	132
Unknown	---	---	851

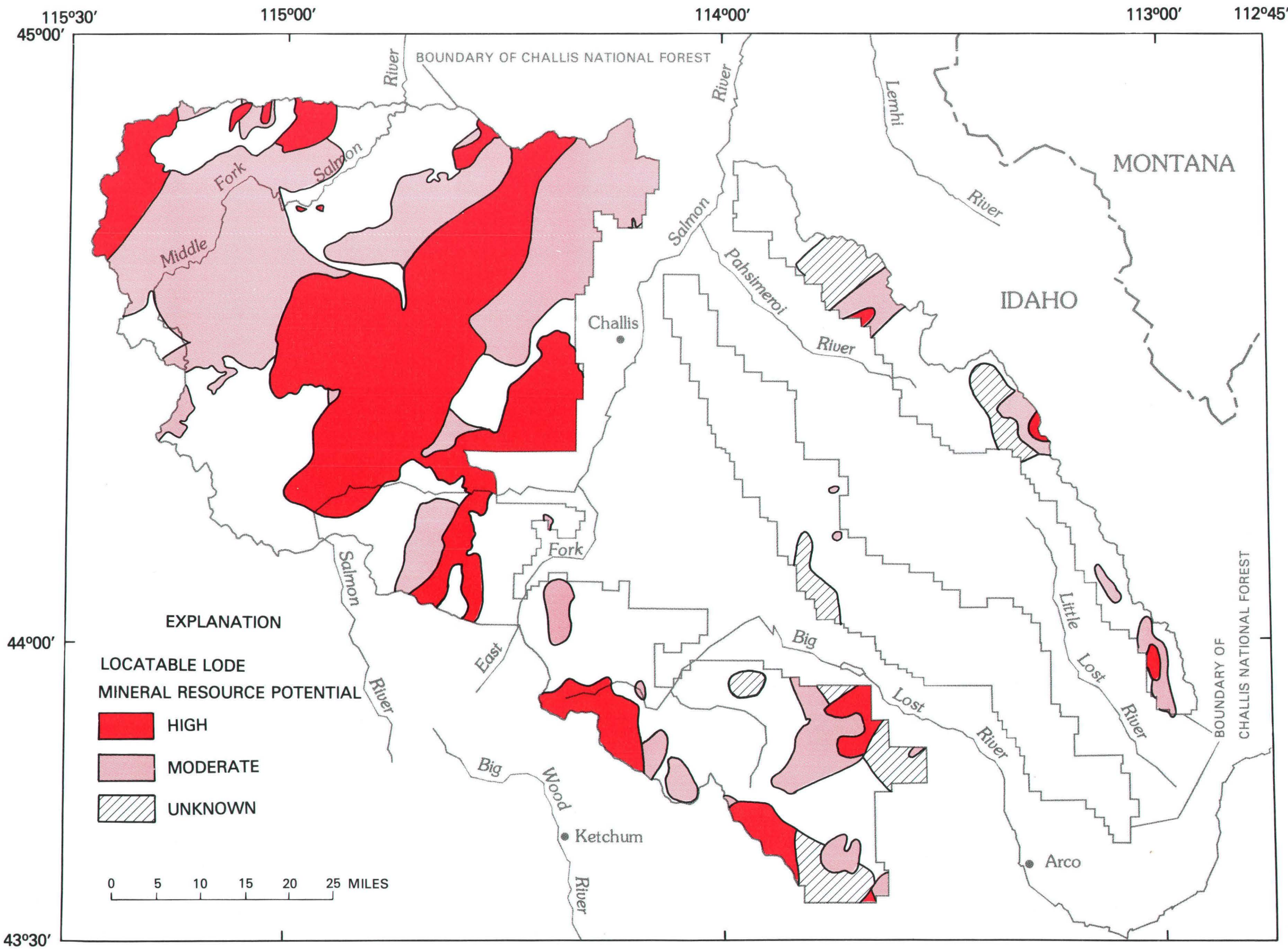


Figure 1. Map showing resource potential for locatable lode minerals, Challis National Forest, Idaho.

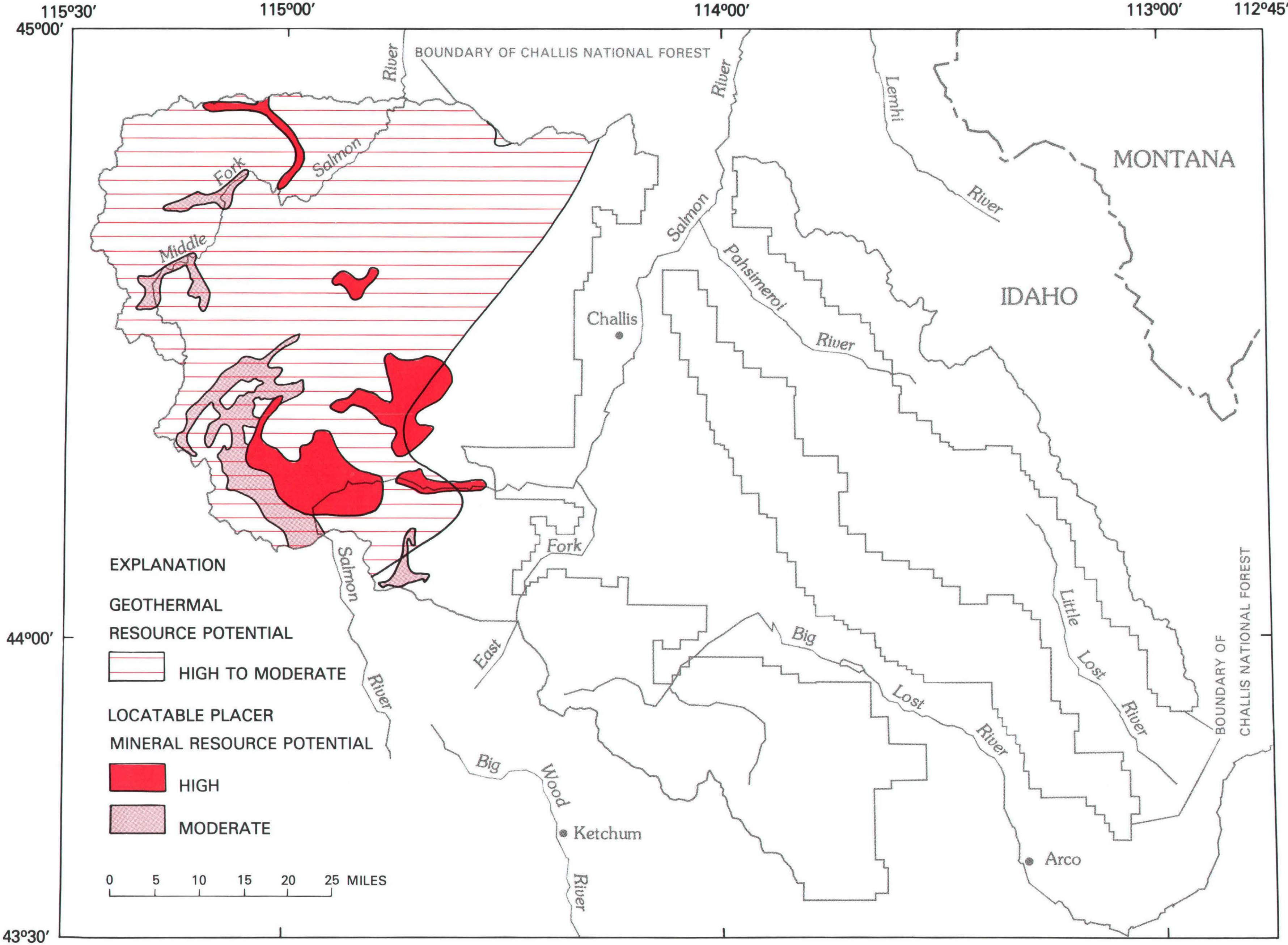


Figure 2. Map showing resource potential for locatable placer deposits and leasable (geothermal) commodities, Challis National Forest, Idaho.

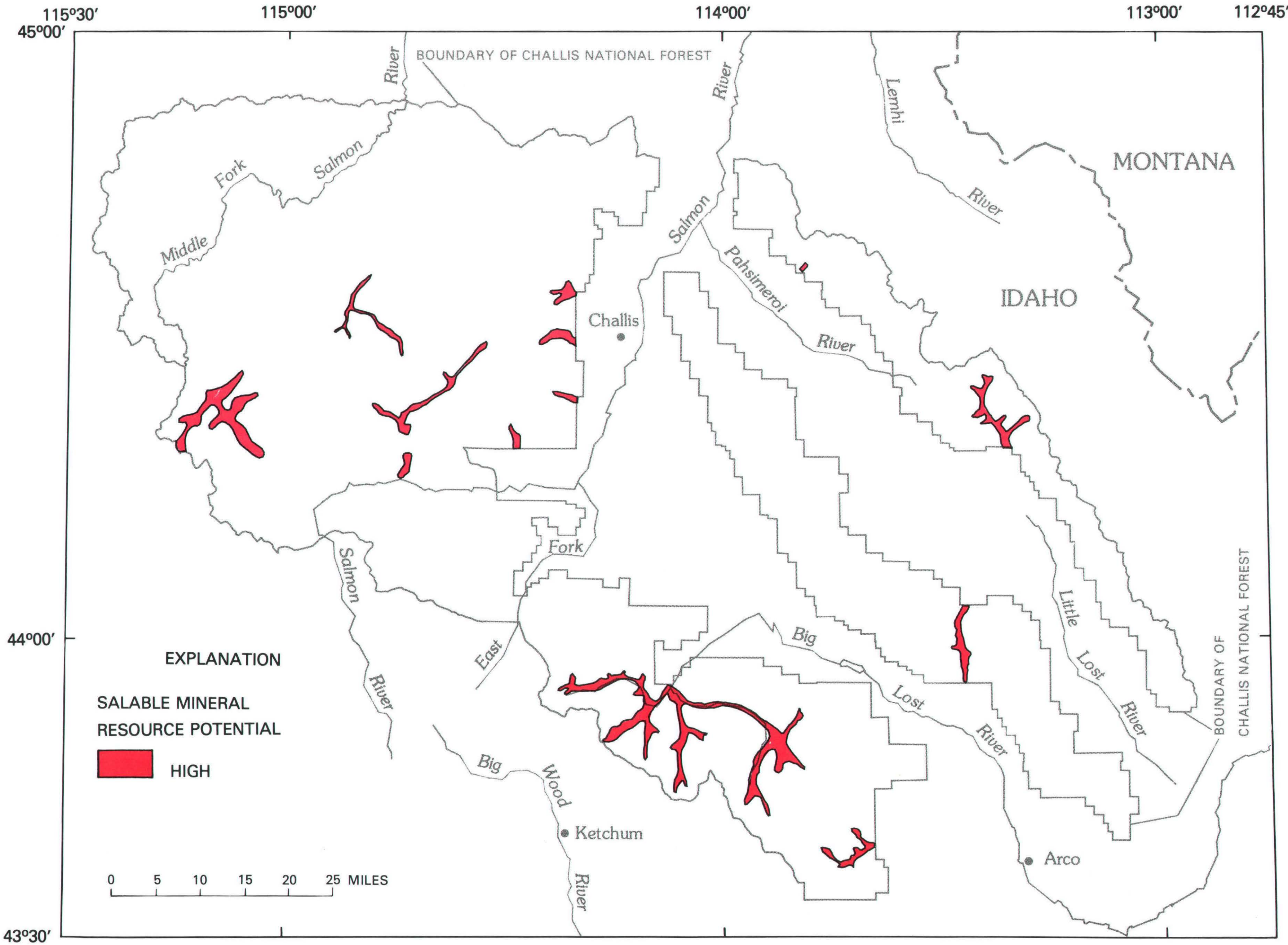


Figure 3. Map showing resource potential for salable minerals, Challis National Forest, Idaho.

Most metals and industrial minerals are included in the category of locatable commodities by the General Mining Law of 1872. The principal types of deposits considered in the assessment of mineral potential for locatable commodities in the Challis National Forest are listed below, and the metals found in each type of deposit and the principal areas of resource potential are briefly summarized. Letter symbols shown in the list below are used throughout this report to designate particular types of deposits.

A Fluorspar veins; formed from low-temperature hydrothermal solutions, commonly related to hot spring systems along regional high-angle faults. Areas of high resource potential are in the trans-Challis fault system at Meyers Cove and near Stanley.

B Polymetallic veins in black-shale terrane; related to igneous intrusions emplaced during the interval 100–40 million years ago; principally valuable for silver, lead, and zinc, but also contain some gold, tin, antimony, and copper. Most of the black-shale belt, as exposed in the Star Hope Creek and Summit Creek areas and in a broad band extending from Galena Summit northward and northeastward to Mill Creek just west of Challis, has moderate to high resource potential.

C Polymetallic veins in quartzite terrane; formed by fissure filling and replacement from hydrothermal solutions of unknown origin; contain mainly lead and silver with some zinc and gold. Areas of moderate to high resource potential are in the southern part of the Lemhi Range.

D Polymetallic veins in carbonate terrane; formed by fissure filling and replacement of limestone along fractures; generally associated with igneous intrusions; contain mainly lead and silver with some gold and zinc. Areas of high resource potential are in the central Lemhi Range, in the White Knob Mountains, and at Leadbelt Creek.

E Polymetallic veins in Tertiary extrusive terrane; complex deposits within large areas of alteration; formed from hydrothermal systems driven by the heat from intrusive bodies; principally valuable for silver, lead, and zinc, but also contain copper, gold, tin, and bismuth. Areas of moderate to high resource potential are in the Sheep Mountain-Bowery Peak, Lehman Creek, and Iron Bog Creek areas, all in the southwestern portion of the Forest.

F Precious-metal veins; formed from hydrothermal solutions along fractures of the northeast-trending trans-Challis fault system; contain mainly gold and silver with some lead, zinc, and copper. Principal areas of high resource potential include a broad zone extending from Stanley northeast through the Yankee Fork mining district and two small zones in the Meyers Cove area.

G Base-metal veins; related to igneous intrusions (Idaho batholith) emplaced about 80 million years ago; valuable mainly for zinc and lead, but also contain copper, gold, and silver. Areas of moderate to high resource potential are in parts of the Idaho batholith in the northwestern portion of the Forest.

H Vein uranium deposits; formed from hydrothermal solutions associated with igneous intrusions. Data are adequate for assessment only in that portion of the Forest within the Challis $1° \times 2°$ quadrangle. A small area of high resource potential is in the Stanley area.

I Tungsten stockwork and vein deposits; developed in shear zones and close to igneous intrusive bodies of Cretaceous and Tertiary age; valuable mainly for tungsten, but also contain antimony, gold, silver, and molybdenum. Areas of high resource potential are in the northern Lemhi Range and the northwesternmost part of the Forest.

J Stockwork molybdenum deposits; formed in the upper parts of granite bodies; valuable mainly for molybdenum, but also contain copper, silver, gold, tungsten, and antimony. Areas of high resource potential are in the northern Lemhi Range, White Cloud Peaks, and Thompson Creek area.

K High-level, rhyolite-hosted, precious-metal deposits; disseminations and stockworks of gold and silver formed in structurally favorable parts of rhyolite intrusive bodies that were emplaced at or near the surface. Data are adequate for assessment only in that part of the Forest within the Challis $1° \times 2°$ quadrangle. Area of high resource potential extends as a broad band along the northeast-trending trans-Challis fault system from Cape Horn to Meyers Cove in the north-central part of the Forest.

L Polymetallic skarn deposits; formed at the contacts between intrusive igneous rocks and chemically reactive host rocks; valuable mainly for tungsten and copper, but also contain zinc, lead, silver, gold, bismuth, iron, and molybdenum. Principal areas of high resource potential include several small areas in the northwestern part of the Forest, part of the black-shale belt extending north and northeastward from Galena Summit to Mill Creek just west of Challis, and the eastern part of the White Knob Mountains.

M Irregular replacements of base and precious metals; formed by hydrothermal solutions moving along and outward from high-angle faults and reacting with limestone and dolostone; contain silver, lead, and zinc with some copper and gold. Principal areas of high resource potential are in the Bayhorse mining district west of Challis.

N Fluorspar breccia manto deposits; formed by hydrothermal solutions reacting with limestone and dolostone in stratiform breccia zones; fluorspar is main commodity, but barite, gold, silver, lead, and zinc are also present. Area of high resource potential is on Keystone Mountain west of Challis.

O Sediment-hosted, jasperoid-associated, precious-metal deposits; formed where solutions replaced receptive host rocks with massive silica (jasperoid); contain gold and silver with trace amounts of arsenic, antimony, mercury, and thallium. Areas of moderate resource potential are mainly in Paleozoic carbonate rocks in the south-central part of the Forest.

P Precious-metal deposits in volcanic tuffs; stratabound disseminations and veinlets formed during the late stages of deposition of the host rocks; contain mainly gold and silver. Areas of high resource potential are in the Yankee Fork area and in the northwest corner of the Forest.

Q Stratabound syngenetic deposits of precious and base metals; formed from geothermal brines in restricted depositional environments during the Paleozoic Era; valuable mainly for barite, zinc, lead, silver, or gold with some vanadium and molybdenum. Areas of moderate to high resource potential are in the black-shale belt in the Summit Creek area and in a broad band extending northeast from Galena Summit to Mill Creek just west of Challis.

R Stratiform vanadium deposits; formed from geothermal brines in restricted depositional environments during the Paleozoic Era; principally valuable for vanadium. Areas of moderate to high resource potential are in the black-shale belt in the Summit Creek area and in a broad band extending northeast from Galena Summit to Mill Creek just west of Challis.

S Gold placer deposits; deposited by streams that traversed and eroded gold-bearing bedrock. Areas of moderate to high resource potential are in Yankee Fork drainage, in Stanley Basin, and along several streams that drain into the Middle Fork of the Salmon River.

T Radioactive black-sand placer deposits; deposited by streams carrying weathered material from the Idaho batholith terrane; contain varying amounts of heavy minerals with thorium oxide, rare-earth oxides, and niobate and tantalate pentoxides. Areas of moderate resource potential are in the western part of the northwestern portion of the Forest where rocks of the Idaho batholith crop out.

U Areas of unknown resource potential; indications of mineralization, but no definitive data for resource assessment. Eight areas located in the northeastern, central, and southwestern parts of the Forest, all outside the Challis 1°×2° quadrangle, in areas with sparse data.

V. Geothermal resources; manifested by natural hot waters and steam. Area of moderate to high resource potential is in the western part of the Forest.

Resource Potential—Salable Minerals

Present production of salable mineral materials on the Forest meets current U.S. Forest Service needs. Local needs, principally for sand and gravel, are met from alluvial deposits on private and Bureau of Land Management lands in the Lost River Valley and Pahsimeroi Valley and from patented placer mining claims in the Yankee Fork drainage.

Sand and gravel that is suitable for construction purposes is available in certain areas of the Forest; the major source areas are the Yankee Fork drainage and the Cape Horn area. The Lost River and Lemhi Ranges have little to no potential for the development of sand and gravel deposits. Sand and gravel are in Pleistocene and Holocene fluvial deposits.

Sources of dimension stone that is suitable for construction purposes are located in the Summit Creek, Squaw Creek, Bayhorse Creek, and Mill Creek areas of the Forest. Riprap that is adequate for construction purposes is available in most areas of the Forest except for the Lost River Range and southern Lemhi Range. Deposits of riprap are mostly colluvial deposits of Tertiary volcanic rocks of the Challis Volcanic Group and some fluvial deposits that contain rocks of the Cretaceous Idaho batholith and Tertiary Sawtooth batholith.

Areas of high potential for salable minerals are shown on figure 3. Table 2 shows the average use per year calculated over a 4-year period of the Forest's mineral-materials transactions from 1983 to 1986.

INTRODUCTION

This report presents an assessment of the mineral resource potential of the Challis National Forest, Idaho (usually referred to as the Forest in this report), based on information available as of June 1987. The Challis National Forest and administrated lands contain 4,338

Table 2. Mineral-materials transactions 1983–1986

[Leaders (---) indicate no data or no value calculated]

Commodity	Permits (per year)	Tons mined	Value (in dollars) Sold	Free	Used by U.S. Forest Service
Sand and gravel........	0.25	98.00	75.00	---	---
	.75	288.00	---	280.00	---
	---	11,630.00	---	---	2,908.00
Dimension stone........	3.50	25.00	41.00	---	---
(building stone).	---	.25	---	---	25.00
Riprap.................	.75	64.00	66.00	---	---
	.75	63.00	---	44.00	---
	---	1,974.00	---	---	995.00

Table 3. Type mine localities for mineral deposit types

[Numbers refer to reference numbers in Mitchell and others (1981b, 1986), Hustedde and others (1981), and Strowd and others (1981)]

A.	Fluorspar veins:	
	A	Meyers Cove deposits; Nos. 139-164, Challis 1° x 2° quadrangle.
B.	Polymetallic veins in black-shale terrane:	
	B	Livingston mine; No. 1170, Challis 1° x 2° quadrangle.
C.	Polymetallic veins in quartzite terrane:	
	C	Wilbert mine; No. 150, Idaho Falls 1° x 2° quadrangle.
D.	Polymetallic veins in carbonate terrane:	
	D	Windy Peak area; Nos. 215-224, Dubois 1° x 2° quadrangle.
E.	Polymetallic veins in Tertiary extrusive terrane:	
	E	Hornsilver mine; No. 112, Idaho Falls 1° x 2° quadrangle.
F.	Precious-metal veins:	
	F	Lucky Boy mine; No. 403, Challis 1° x 2° quadrangle.
G.	Base-metal veins:	
	G	Sea Foam mine; No. 205, Challis 1° x 2° quadrangle.
H.	Vein uranium deposits:	
	H	Lightning mines; Nos. 945 and 946, Challis 1° x 2° quadrangle.
I.	Tungsten stockwork and vein deposits:	
	I	Ima mine; No. 328, Dubois 1° x 2° quadrangle.
J.	Stockwork molybdenum deposits:	
	Ja	Thompson Creek; No. 1123, Challis 1° x 2° quadrangle.
	Jb	Walton-White Mountain; No. 536, Hailey 1° x 2° quadrangle.
K.	High-level, rhyolite-hosted, precious-metal deposits:	
	K	Golden Sunbeam mine; No. 346, Challis 1° x 2° quadrangle.
L.	Polymetallic skarn deposits:	
	La	Empire mine; No. 13, Idaho Falls 1° x 2° quadrangle.
	Lb	Springfield mine; No. 778, Challis 1° x 2° quadrangle.
M.	Irregular replacements of base and precious metals:	
	M	Clayton Silver mine; No. 1103, Challis 1° x 2° quadrangle.
N.	Fluorspar breccia manto deposits:	
	N	Keystone Mountain deposits; Nos. 1063-1076, Challis 1° x 2° quadrangle.
O.	Sediment-hosted, jasperoid-associated, precious-metal deposits:	
	None.	
P.	Precious-metal deposits in volcanic tuffs:	
	Pa	Sunnyside mine; No. 66, Challis 1° x 2° quadrangle.
	Pb	Dewey mine; No. 47, Challis 1° x 2° quadrangle.
Q.	Stratabound syngenetic deposits of precious and base metals:	
	Qa	Hoodoo mine; No. 1160, Challis 1° x 2° quadrangle.
	Qb	Phi Kappa mine; No. 563, Hailey 1° x 2° quadrangle.
R.	Statiform vanadium deposits:	
	None, see Fisher and May (1983).	
S.	Gold placer deposits:	
	None.	
T.	Radioactive black-sand placer deposits:	
	None.	

mi^2 (2,776,668 acres) of mountainous terrain, much of which has difficult access (fig. 4). Central Idaho is sparsely populated, and Stanley, Challis, and Mackay are the closest towns to the Forest. Material in this report is provided to assist the U.S. Forest Service in fulfilling the requirements of the Code of Federal Regulations (CFR 219.22) to supply information and interpretations so that the mineral resources of this area can be considered along with other kinds of resources in land use planning.

Mineral resource information is given in terms of mineral deposit types and their geologic settings. Deposit types are based on geologic characteristics of known and inferred deposits within or close to the Forest. Most deposit types are represented by type mine localities (fig. 5, table 3). A letter designation (A, B, and so on) for various deposit types is used in the text, tables, figures, and plates. Areas of resource potential for each deposit type are summarized in table 4. The geologic setting is discussed in terms of geologic terranes and major structural features. Geologic terrane for this report is defined as a particular rock type or assemblage and the area in which it crops out. Definitions of terms used in the assessment of mineral resource potential are provided in Appendix 1.

The first step in assessing the mineral resource potential was compilation of data at a scale of 1:250,000. The geologic map (pl. 1) was compiled by Anna Wilson, U.S. Geological Survey (USGS), and Victoria Mitchell, Idaho Geological Survey, using the best available geologic mapping at any scale. This map is a simplified geologic map in which the units have been combined in such a way as to best illustrate the various geologic terranes. The purpose is to emphasize the geologic features that are important to the mineral resource assessment.

The USGS recently completed a detailed CUSMAP (Conterminous United States Mineral Assessment Program) study of the mineral resources of the Challis 1° × 2° quadrangle which includes much of the northwestern part of the Challis National Forest. Preliminary results of that study were published in McIntyre (1985) and Fisher and Johnson (1987). These results provided the data base for the resource analysis of that part of the Forest within the Challis 1° × 2° quadrangle. The geology, mineral resource data, and mineral deposit models from the CUSMAP study were recast into the format of this study with few changes. The rest of the Forest by comparison, except for local exceptions, does not have as complete a data base in quantity or quality. In fact, some areas are almost totally lacking in data needed for a resource assessment. This has resulted in the assignment of lower levels of certainty to areas of potential in that part of the Forest outside the Challis 1° × 2° quadrangle.

Published data from nine geochemical surveys were used as an aid in the assessment of mineral resource potential of the Challis National Forest (tables 5, 6). No single geochemical survey covered the entire area of the Forest (fig. 5). Geochemical signatures for individual mineral deposit types were determined from published results of the geochemical surveys that covered the area of a type mine locality for that deposit type (tables 3, 7; fig. 5; pl. 3). In areas where a type mine locality was within the boundaries of more than one geochemical survey, only data from the survey most useful for resource assessment were used to determine the geochemical signature of the type deposit.

Several USGS resource assessment programs included parts of the Challis National Forest (table 5), and all of the Challis National Forest was covered by samples collected and analyzed by various laboratories under the National Uranium Resource Evaluation (NURE) program. NURE data were used to determine geochemical signatures where USGS data were unavailable. Where available, published threshold values were used to determine the geochemical signatures reported here. If threshold values were not published, they were determined from raw data at two standard deviations from the population mean, assuming that the element distribution was lognormal. Sampling density of the surveys, within the Forest boundaries, ranged from about 2.6 samples per 1 mi^2 in the Boulder-Pioneer Wilderness Study Area (Simons, 1981) to less than 0.03 samples per 1 mi^2 in the Dubois NURE project (LaDelfe, 1980).

The geophysical data available for use in the mineral resource assessment studies of the Challis National Forest are regional aeromagnetic and gravity data. Additional information about the mineral resources and the geologic terranes of the Forest might be obtained from a more indepth analysis of the gravity and magnetic data.

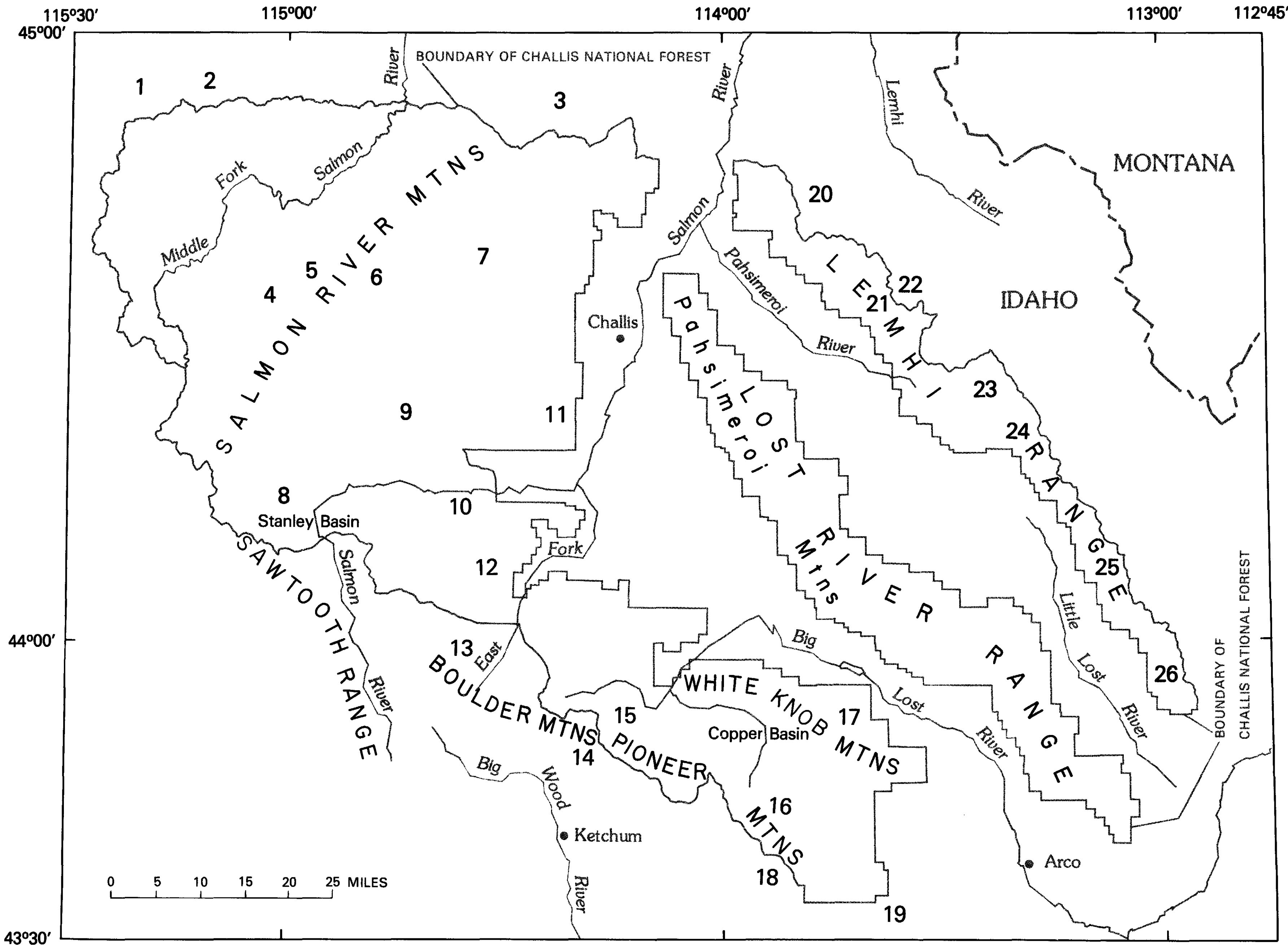
Aeromagnetic data are presented on plate 2. These data were compiled from a variety of magnetic surveys that were flown for mineral resource evaluation during the past 17 years (see index map, pl. 2). The surveys were flown at line spacings that ranged from 0.5 to 5 mi, either at a constant barometric elevation or a constant altitude above terrain. These variable datums have been normalized, and the resultant magnetic map is a composite of these surveys with the digital data reduced by computer techniques to a uniform datum of 1,000 ft above terrain. In addition to the aeromagnetic data (pl. 2), a regional gravity map (A.E. McCafferty and Viki Bankey, written commun., 1987) was compiled for the mineral resource assessment.

Information on mines, prospects, and resources came mainly from the Idaho Geological Survey Mines and Prospects Map Series for the Challis, Dubois, Hailey, and Idaho Falls 1° × 2° quadrangles. These publications contain resource information from all available sources, including the USGS Mineral Resource Data System (MRDS) and the U.S. Bureau of Mines Mineral Inventory Lands System (MILS).

All available information was assembled and analyzed according to procedures outlined by Shawe (1981) and Taylor and Steven (1983). Mineral resource potential information is portrayed on plates 3 and 4 and on figures 1–3 and 13–33.

Known mineral deposits and their geologic settings were examined by R.G. Worl and A.B. Wilson during the summer of 1986. Field work was not undertaken to fill gaps in knowledge or to reconcile differences in interpretations. The resource analysis is based upon the geologic interpretations by the authors at the time of writing. Significant new data in the future may lead to new interpretations that could affect the mineral resource assessment. Many geologists with the USGS, U.S. Bureau of Mines, U.S. Forest Service, U.S. Bureau of Land Management, and Idaho Geological Survey were consulted, and their help is gratefully acknowledged.

This study is based primarily on information from published literature, including theses and dissertations, and unpublished material from studies in progress.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BOUNDARY OF CHALLIS NATIONAL FOREST
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SALMON RIVER MTNS
LEMHI RANGE
LOST RIVER RANGE
Pahsimeroi Mtns
SAWTOOTH RANGE
BOULDER MTNS
PIONEER MTNS
WHITE KNOB MTNS
Middle Fork Salmon River
Salmon River
Pahsimeroi River
Lemhi River
East Fork
Salmon River
Big Lost River
Little Lost River
Big Wood River
Challis
Stanley Basin
Copper Basin
Ketchum
Arco
BOUNDARY OF CHALLIS NATIONAL FOREST
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MINING DISTRICTS:

1 Yellow Pine	7 Parker Mountain	12 Boulder Creek	17 Alder Creek	22 Junction
2 Thunder Mountain	8 Stanley	13 East Fork	18 Little Wood River	23 Texas
3 Gravel Range	9 Yankee Fork	14 Warm Springs	19 Lava Creek	24 Spring Mountain
4 Sea Foam	10 Robinson Bar	15 Alto	20 McDevitt	25 Hamilton
5 Sheep Mountain	11 Bayhorse	16 Copper Basin	21 Blue Wing	26 Dome
6 Loon Creek				

Figure 4 (above and facing page). Index map showing location of the Challis National Forest and principal mining districts within or partially within the Forest.

Specific references have been kept to a minimum to avoid excessive interference with continuity of the text. References are given where needed to indicate the source of information or to give proper credit for studies, ideas, or concepts. The reference list indicates the available literature that provided background information; not all of the references are cited in the text.

The assessment of mineral resource potential, which is at a scale of 1:250,000, is meant to show areas where mineral deposits of a certain type may occur. Although these assessments are not site specific, information provided in the report should be useful in site-specific examinations. Characteristics of each mineral deposit type are given and information is provided to indicate what mineral deposit types could be expected in each of the geologic terranes present in the Forest. Knowledge of the type of geologic terrane and the presence or absence of the assessment criteria for each mineral deposit type will be useful for site-specific evaluations.

GEOLOGY

The Challis National Forest includes the western part of the Lemhi Range, the Lost River Range, the White Knob Mountains, Copper Basin, the eastern part of the Pioneer Mountains, the Pahsimeroi Mountains, the White Cloud Peaks, Stanley Basin, the northern part of the Sawtooth Range, and parts of the extensive Salmon River Mountains (fig. 4). The major drainages include the Salmon, Big Lost, and Little Lost Rivers. Rocks that host the mineral deposits range in age from Precambrian to Holocene.

The basic framework for discussion of mineral resources in this report is the geologic terrane as defined by rock assemblages (pl. 1). Superimposed on the geologic terranes are regional structures that influenced the location of some of the mineral deposits (fig. 6). An understanding of the nature and distribution of geologic terranes and structures is necessary for an assessment of mineral resources. The important terranes in the Forest are Precambrian (Proterozoic) rocks, Paleozoic carbonates, Paleozoic quartzites, Paleozoic flysch assemblage, Paleozoic black shales, Cretaceous batholithic and plutonic rocks, Tertiary extrusive volcanic rocks, Tertiary intrusive rocks, and post-Challis cover rocks. The important structural features include the northeast-trending trans-Challis fault system and parallel high-angle fault systems to the south (fig. 6), north- to northwest-trending high-angle fault systems, extensive thrust fault plates in Paleozoic rocks, and caldera and collapse features associated with the Challis Volcanic Group. Only parts of the individual terranes contain or have potential for mineral deposits. The occurrence of

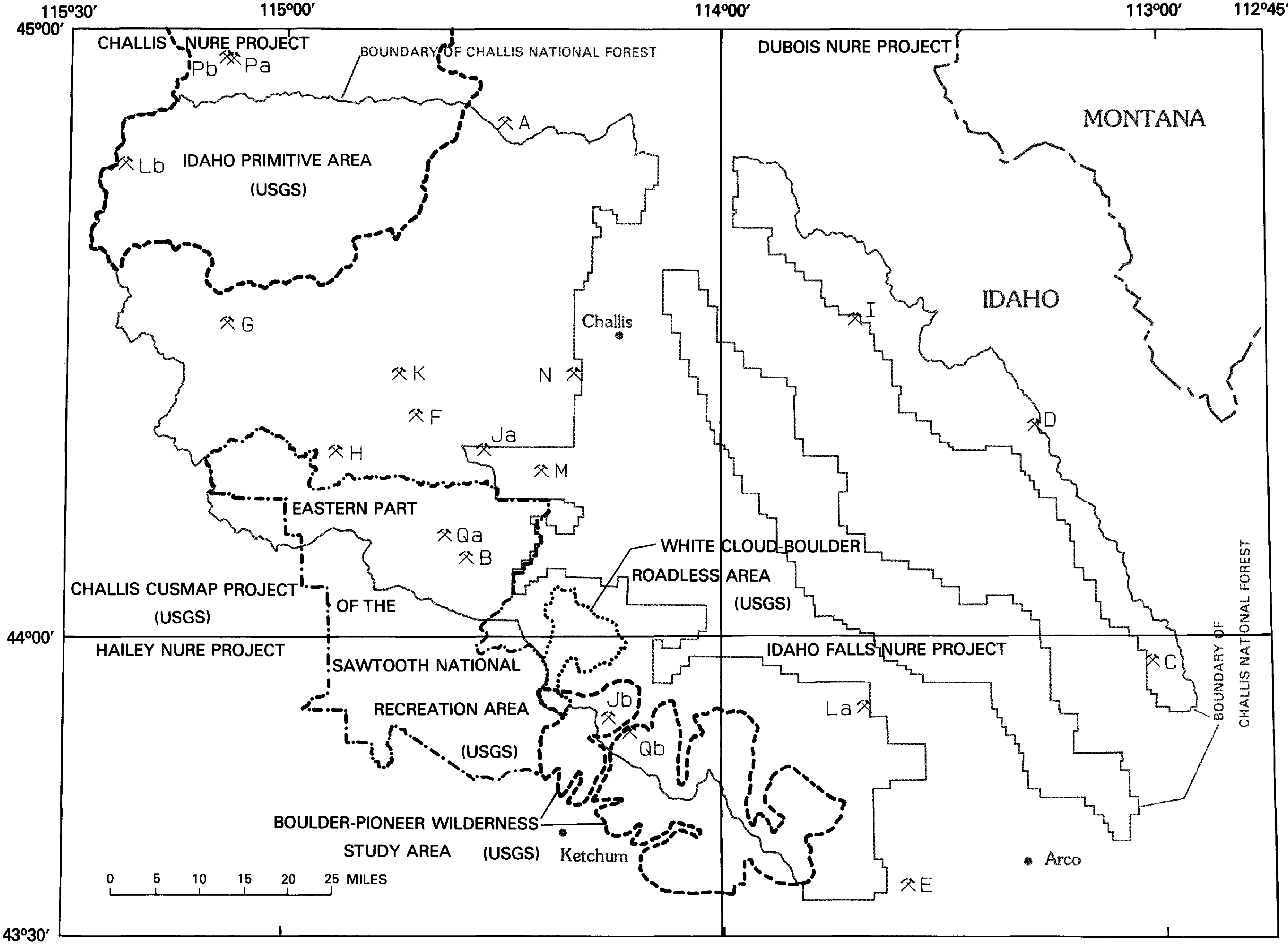


Figure 5. Map showing location of type mine localities for mineral deposit types [identified by crossed-hammers symbol and letter (identified in table 3)] and boundaries of geochemical surveys that cover parts of the Challis National Forest.

Table 4. Description of areas of mineral resource potential for locatable and leasable resources in the Challis National Forest, Idaho

[Commodities listed in order of relative importance; level of potential/level of certainty explained in Appendix 1. Leaders (---), not applicable]

Map area	Resource potential	Potential/ certainty	Commodities (by-products)	Size, type of deposit
A1	High	H/D	Fluorspar (Au)	Medium, fluorspar veins.
A2	High	H/D	Fluorspar	Medium, fluorspar veins.
A3	Moderate	M/D	Fluorspar (Au,Sb)	Small, fluorspar veins.
A4	Moderate	M/D	Fluorspar (Au)	Small, fluorspar veins.
A5	Moderate	M/D	Fluorspar	Small, fluorspar veins.
B1	High	H/D	Ag,Pb,Zn (Au,Sn,Sb,Cu)	Medium, polymetallic veins.
B2	Moderate	M/D	--do----	Do.
B3	High	H/B	Ag,Pb,Zn (Au,Cu)	Do.
B4	Moderate	M/B	--do----	Do.
C1	High	H/B	Ag,Pb	Small, fissure veins.
C2	Moderate	M/B	Ag,Pb (Au)	Do.
D1	High	H/C	Ag,Pb (Cu,Zn,Au)	Medium, replacement veins.
D2	High	H/C	Pb,Zn,Ag (Cu,Au)	Do.
D3	Moderate	M/B	Ag,Pb (Cu,Zn,Au)	Small, replacement veins.
D4	Moderate	M/B	Pb,Zn,Ag (Cu,Au)	Do.
D5	High	H/B	Ag,Pb,Zn (Au,Cu)	Medium, replacement veins.
E1	Moderate	M/B	Ag,Pb,Zn (Au,Bi,Sn)	Small, polymetallic veins.
E2	Moderate	M/B	Ag,Pb (Zn,Au)	Do.
E3	Moderate	M/C	Ag,Au (Zn,Pb,Sn,Mo)	Do.
F1	High	H/D	Au,Ag (Pb,Cu,Zn)	Small, lenticular pods.
F2	Moderate	M/D	--do----	Do.
G1	High	H/D	Zn,Pb,Cu (Ag,Au)	Medium, pods and veins.
G2	Moderate	M/D	--do----	Do.
H1	High	H/D	U (Au,Ag)	Small, stringers in faults.
H2	Moderate	M/D	--do----	Do.
I1	High	H/C	W (Sb,Au,Ag)	Medium, veins and replacements.
I2	High	H/C	W (Mo,Pb,Zn)	Medium, veins and stockworks.
I3	Moderate	M/B	--do----	Small, veins and stockworks.
I4	Moderate	M/C	W,Mo (Pb,Zn)	Small, veins and replacements.
J1	High	H/D	Mo,W (Ag,Cu)	Large, stockworks.
J2	High	H/D	--do----	Do.
J3	High	H/B	Mo,W (Pb,Zn)	Medium, stockworks.
J4	Moderate	M/D	Mo(?)	Do.
J5	Moderate	M/C	Mo(?)	Medium, veins and stockworks.
K1	High	H/C	Au,Ag	Large, stockworks and disseminations.
K2	Moderate	M/C	--do----	Do.

Table 4. Description of areas of mineral resource potential for locatable and leasabe resources in the Challis National Forest, Idaho—Continued

[Commodities listed in order of relative importance; level of potential/level of certainty explained in Appendix 1. Leaders (---), not applicable]

Map area	Resource potential	Potential/ certainty	Commodities (by-products)	Size, type of deposit
L1	High	H/C	Cu (Pb,Zn,Ag,Au)	Large, contact skarn.
L2	Moderate	M/C	--do----	Do.
L3	Moderate	M/C	W (Mo)	Small, skarn lenses.
L4	Moderate	M/B	Cu (Pb,Zn,W)	Medium, contact skarn.
L5	Moderate	M/D	W,Zn,Cu,Pb,Ag	Do.
L6	High	H/D	--do----	Do.
L7	Moderate	M/D	W	Small, skarn lenses.
L8	High	H/D	W	Medium, contact skarn.
L9	Moderate	M/B	Pb,Zn,Ag,Fe	Medium, contact skarn.
M1	High	H/D	Ag,Pb,Zn	Large, irregular replacements.
M2	Moderate	M/B	Ag,Pb,Zn (Cu,Au)	Medium, irregular replacements.
M3	Moderate	M/B	Ag,Pb,Zn (Au)	Do.
N1	High	H/D	Fluorspar (Ag,Au,Pb,Zn)	Large, mantos and replacements.
N2	Moderate	M/D	--do----	Do.
O1	Moderate	M/B	Au,Ag	Medium, disseminations.
P1	High	H/C	Au,Ag	Medium, blankets.
P2	Moderate	M/C	--do----	Do.
P3	Moderate	M/C	--do----	Medium, disseminations.
Q1	High	H/D	Zn,Pb,Ag,Au	Medium, syngenetic stratiform.
Q2	Moderate	M/D	--do----	Do.
Q3	Moderate	M/B	--do----	Do.
R1	High	H/D	V (Zn,Pb,Ag,Ba)	Medium, syngenetic stratiform.
R2	Moderate	M/C	--do----	Do.
R3	Moderate	M/B	--do----	Do.
S1	High	H/D	Au	Medium to large, placers.
S2	Moderate	M/D	--do----	Do.
T1	Moderate	M/D	Th,REE,Nb,Ta,U,Au	Medium, placers.
T2	Moderate	M/B	--do----	Do.
U1	Unknown	--	Base- and precious-metal veins, replacements, and disseminations.	
U2	Unknown	--	Base- and precious-metal veins, skarns, and replacements.	
U3	Unknown	--	Veins, skarns, replacements, and jasperoid-associated deposits.	
U4	Unknown	--	Veins, skarns, replacements, disseminations, and jasperoid-associated deposits.	
U5	Unknown	--	Base- and precious-metal vein and stockwork deposits.	
U6	Unknown	--	Vein and stockwork deposits associated with ring fractures.	
U7	Unknown	--	Base- and precious-metal stockworks and disseminations.	
U8	Unknown	--	Base- and precious-metal veins and replacements.	
V	High	H/C	Hot- and warm-water springs.	
	Moderate	M/C	Steam.	

Table 5. Geochemical studies that cover parts of the Challis National Forest, Idaho

Study	Percent[1]	Collect[2]	Analyze[3]	Reference
Challis CUSMAP project (CHUS).	59	USGS	USGS	Fisher and Johnson (1987); Adrian and others (1985); Callahan and others (1981a, b); McDanal and others, (1984); Hopkins and others (1985).
Challis NURE project (CHNU).	59	SLR	SLR	Thayer and Cook (1980).
Eastern part of the Sawtooth Recreation Area (SNR).	7	USGS	USGS	Tschanz and others (1974); Tschanz and Frischnecht (1986); Kiilsgaard and Van Noy (1984).
Idaho Primitive Area (IP).	15	USGS	USGS	Cater and others (1973).
Dubois NURE project (DUNU).	20	LANL	LANL	LaDelfe (1980).
Idaho Falls NURE project (IFNU).	15	SRL	ORGDP	Grimes (1982c, d).
Boulder-Pioneer Wilderness Study Area (BPW).	4	USGS	USGS	Simons (1981).
Hailey NURE project (HANU).	5	SRL	ORGDP	Grimes (1982a, b).
White Cloud-Boulder Roadless Area (WCBRA).	<.5	USGS	USGS	Fisher, May, and others (1983).

[1]Percent of the Challis National Forest covered by the study.

[2]Organization that collected geochemical samples: USGS, U.S. Geological Survey; LANL, Los Alamos National Laboratory; SRL, Savannah River Laboratory; ORGDP, Oak Ridge Gaseous Diffusion Plant.

[3]Organization that analyzed geochemical samples.

the mineral deposits in a terrane may also depend upon other factors such as the presence of a specific sedimentary bed, high-angle regional faults, thrust faults, or juxtaposition of two terranes, such as igneous rocks that intrude carbonate rocks.

Geologic Framework

The oldest rocks in the Challis National Forest were deposited in deep basins along the margin of a major landmass starting about 1,700 million years ago during the Early Proterozoic Era. The deposits were primarily sedimentary in origin but included some volcanic material. The earliest sequence of rocks was deformed, metamorphosed, and intruded by plutonic rocks 1,400–1,200 million years ago. Deposition in the basins continued to about 900 million years ago at which time the area was uplifted to form a highland along the northwest-trending Lemhi arch (fig. 6). The seas invaded the region again about 550 million years ago, and the region remained submerged through most of the Paleozoic to about 260 million years ago. During the early Paleozoic, sediments were deposited in a miogeosynclinal basin west of the Lemhi arch and on the shallowly submerged cratonic shelf to the east. Intermittent uplift, from Late Devonian through Early Mississippian time, of the Antler highlands to the west of the area shed clastic material to the Copper Basin depositional trough to the east. In Late Mississippian time, the Copper Basin highlands began to rise, and shelf carbonates were deposited to the east while deeper water sediments were

Table 6. Sources of analytical data, Challis National Forest, Idaho

Laboratory[1]	Elements analyzed	Analytical method[2]	Reference
Savannah River... Laboratory.	U, Th, Hf, Ce, Fe, Mn, Na, Sc, Ti, V, Al, Dy, Eu, La, Sm, Yb, Lu, Br, Cl, F.	NAA	Cook and Fay (1982).
	Ag, Co, Cu, Ni, Zn, Mo, Cr, Y, Be, Sr, Mg, Pb, Sn, Ba.	AA	
	Nb, W, P	Color	
	K, Li	Flame	
Los Alamos....... Scientific Laboratory.	U	DNC	LaDelfe (1980).
	Ag, As, Bi, Cd, Cu, Nb, Ni, Pb, Se, Sn, W, Zr.	XRF	
	Bi, Li	ESpec	
	Al, Au, Ba, Ce, Cl, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, Ti, V, Yb, Zn.	NAA	Nunes and Weaver (1977).
U.S. Geological.. Survey.	Fe, Mg, Ca, Ti, Mn, Ag, As, Au, B, Ba, Be, Bi, Cd, Co, Cr, Cu, La, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, V, W, Y, Zn, Zr, Th.	ESpec	O'Leary and Meyer (1986).

[1]Only those laboratories providing data used in the resource assessment are listed.

[2]Several analytical methods were used: NAA, neutron activation analysis; AA, atomic absorption; Color, colorimetric analysis; Flame, flame emission; XRF, X-ray fluorescence; DNC, delayed neutron counting; ESpec, emission spectrography.

deposited to the west. The entire region was emergent by Late Permian time. Changing depositional patterns throughout the Paleozoic resulted in the complex interfingering and facies changes that characterize the Paleozoic units in this area.

During Mesozoic time, extensive thrust faulting of the Paleozoic rocks resulted in foreshortened sections and juxtaposition of time-equivalent rocks that had been deposited in different depositional environments. Most of the Paleozoic formations exposed in the Forest are allochthonous and occur in imbricated structural plates that are stacked younger over older. Many of the individual formations, especially in the flysch and black-shale terranes, are tectono-stratigraphic units in the sense that neither the base nor the top is exposed because of faulting. Different formation names have been applied to units that are essentially coeval but are in different structural plates.

The complex of plutons known as the Idaho batholith and satellite bodies of similar composition were emplaced from about 110 million to 70 million years ago, that is, in mid- to Late Cretaceous time. Late-stage pegmatites and quartz veins accompanied most of the intrusive events. The batholithic intrusions engulfed and metamorphosed large blocks of sedimentary rocks. Extensive areas of sedimentary rocks surrounding the plutons also were contact metamorphosed.

High-angle faulting, mainly along northeast trends, began at the end of Mesozoic time and helped localize extensive Eocene volcanism. Volcanism that produced the Challis Volcanic Group began about 51 million years

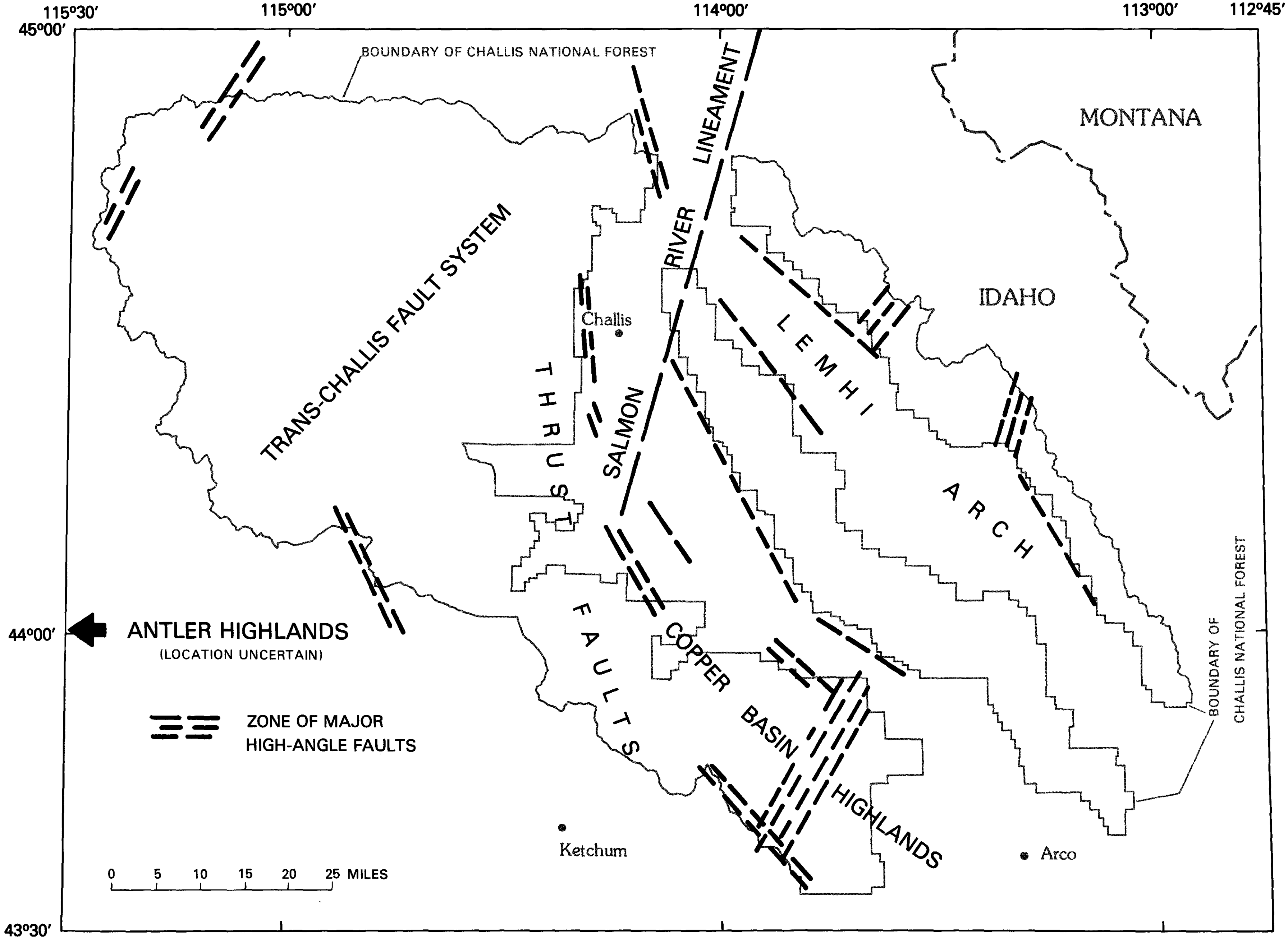


Figure 6. Map showing major structural elements within or close to the Challis National Forest.

Table 7. Geochemical signatures of mineral deposit types at type mine localities

[Leaders (--) indicate no data]

	Deposit type	Type mine locality (shown on pl. 3)	Geochem survey[1]	Sample media[2]	Signature[3]
A.	Fluorspar veins	Meyers Cove (A)	CHUS	cons	Sn, Ag, Au, Pb.
				ss	Ag, Be, Mo.
B.	Polymetallic veins in black-shale terrane.	Livingston mine (B)	SNR	r	Hg, Sn, W, Bi, As, Sb, Cu, Cd, Zn, Pb, Au, Ag.
				ss	Mo, Sn, As, Sb, Cd, Zn, Pb, Au, Ag.
C.	Polymetallic veins in quartzite terrane.	Wilbert mine (C)	IFNU	ss	Pb.
D.	Polymetallic veins in carbonate terrane.	Windy Peak area (D)	DUNU	no samples	Unknown.
E.	Polymetallic veins in Tertiary extrusive terrane.	Hornsilver mine (E)	IFNU	ss	Ag, Cu.
F.	Precious-metal veins	Lucky Boy mine (F)	CHUS	cons	Ag, Au, Sn, Ba, Bi, Cu, Mo, Pb.
				ss	Ag.
G.	Base-metal veins	Sea Foam mine (G)	CHUS	cons	Ag, Bi, Cu, Pb, Sn, Au, B, Mo, W, Th.
				ss	Pb, Ag, B, Cu.
H.	Vein uranium deposits.	Lightning mines (H)	CHUS	cons	Th, Mo, Pb, Sn.
				ss	None.
I.	Tungsten stockwork and vein deposits.	Ima mine (I)	DUNU	ss	Cu, Pb, Sb, W.
J.	Stockwork molybdenum deposits.	Thompson Creek (Ja)	CHUS	cons	Bi, Cu, Mo, Pb, W, B, Sn, Th.
				ss	Mo, W, Ag, Bi, Cu.
		Walton-White Mountain (Jb).	BPW	ss	Cu, Pb, Mo, Ag, Zn.
K.	High-level, rhyolite-hosted, precious-metal deposits.	Golden Sunbeam mine (K).	CHUS	cons	Ag, Cu, Pb, Au, As, Ba, Sn, W.
				ss	Ag, Be, Mo, Cu, Pb, Zn.

Table 7. Geochemical signatures of mineral deposit types at type mine localities—Continued

[Leaders (- -) indicate no data]

	Deposit type	Type mine locality (shown on pl. 3)	Geochem survey[1]	Sample media[2]	Signature[3]
L.	Polymetallic skarn deposits.	Empire mine (La)	IFNU	ss	Cu.
		Springfield mine (Lb).	IP	ss	Zn, Mn, Cu, Mo, Be, As.
M.	Irregular replacements of base and precious metals.	Clayton Silver mine (M).	CHUS	cons	Ag, B, Cu, Pb, Zn, Ba, Bi, Mo, Cd, Sn, W.
				ss	Ag, B, Pb, Zn, As, Cu.
N.	Fluorspar breccia manto deposits.	Keystone Mountain deposits (N).	CHUS	cons	Ag, B, Be, Pb, Bi, Cd, Cu, Mo, Sb, Zn.
				ss	B, Ag, Pb.
O.	Sediment-hosted, jasperoid-associated, precious-metal deposits.	None.	--	--	--
P.	Precious-metal deposits in volcanic tuffs.	Sunnyside mine (Pa)	IP	ss	Mo, Cu, As.
				r	As, Mo, Ag.
		Dewey mine (Pb)	IP	ss	As.
				r	As, Mo, Ag.
Q.	Stratabound syngenetic deposits of precious and base metals.	Hoodoo mine (Qa)	SNR	ss	Sb, Cd, Zn, Pb, Ag, Mo, Au.
				r	Hg, Zn, Pb Sn, Bi, Sb, Cu, Ag.
		Phi Kappa mine (Qb)	BPW	ss	Pb, Mo, Zn, B.
R.	Stratiform vanadium deposits.	None.	--	--	--
S.	Gold placer deposits	None.	--	--	--
T.	Radioactive black-sand placer deposits.	None.	--	--	--

[1]CHUS, USGS Challis 1° x 2° quadrangle CUSMAP project; SNR, Eastern part of the Sawtooth National Recreation Area, Idaho; IFNU, Idaho Falls 1° x 2° quadrangle NURE project; DUNU, Dubois 1° x 2° quadrangle NURE project; BPW, Boulder-Pioneer Wilderness Study Area, Idaho; IP, Idaho Primitive Area, Idaho.

[2]Sample media: cons, panned heavy-mineral fraction of stream-sediment sample; ss, stream-sediment sample; r, rock sample.

[3]Elements with anomalous concentrations in one or more samples from sites near the type mine locality.

ago with effusive eruptions of intermediate-composition lavas. At about 49 million years ago volcanism changed to explosive eruptions of rhyodacite ash-flow tuff with attendant development of cauldron complexes. Volcanism ceased about 37 million years ago (Fisher and Johnson, 1987). Numerous intrusive bodies, including the Casto pluton and the Sawtooth batholith, were formed concurrently with the Challis volcanism. Block faulting mainly along north to northwest trends throughout the Tertiary and Quaternary is reflected by present topography. The present landscape of the Forest was created by glaciers that sculpted some of the higher mountains and by high-gradient streams that transported and, in the valleys, deposited the detritus. The degree of maturity of the landscape varies from young along some of the mountain fronts where large alluvial fans are forming to a more mature appearing landscape over some of the Idaho batholith terrane.

Several metallogenic episodes during the geologic history of the Forest produced the metal deposits that are available today. Metals were deposited syngenetically with volcanic and sedimentary rocks during Early Proterozoic time. Later in Proterozoic time some of the metals were remobilized by tectonism and plutonism into vein deposits. During most of Paleozoic time deposition of metal-enriched sediments in deep, restricted marine basins formed in parts of the flysch and black-shale terranes. Some of the metals in these units were locally remobilized during at least two later episodes, the emplacement of the Idaho batholith and the emplacement of Tertiary plutons. There may have been other periods of remobilization that are now indistinguishable from those related to the main periods of plutonism. More metals, including a suite of elements characteristic of felsic igneous rocks and pegmatites, were introduced at the same time as the emplacement of the Idaho batholith during the Late Cretaceous. The metals were concentrated as disseminations, in pegmatitites, in contact skarn deposits, or in vein and replacement deposits through related hydrothermal systems. The Tertiary also was a time of introduction and remobilization of metals. Metals introduced during Tertiary time include those characteristically found in terranes of extensional tectonics. Most of the metals introduced or remobilized at this time were concentrated in hydrothermal systems. These systems developed commonly during the late stages of volcanic and intrusive activity and were centered on deep-seated high-angle faults and other fractures such as those in caldera structures. Hydrothermal systems were very widespread during the Tertiary and affected all rock types, even at considerable distances from known volcanic centers. The processes of erosion and transportation during the past million years have extracted the heavier metals and minerals from country rock and lode mineral deposits and concentrated them in placer deposits.

The description that follows is based upon geologic terranes. The formations that compose a particular terrane will be discussed briefly along with the geologic settings of any mineral resources that may occur in that terrane.

Precambrian Rocks and Structures

Precambrian rocks in the Challis National Forest include the Early Proterozoic gneiss complex of Wildhorse Creek and a thick sequence of Middle Proterozoic metaquartzites and argillaceous metaquartzites. Several map units are represented in the metaquartzite sequence including, from oldest to youngest, the Middle Proterozoic Yellowjacket Formation, the Hoodoo Quartzite, formations of the Lemhi Group (Inyo Creek, West Fork, Big Creek, Apple Creek, Gunsight), and the Swauger and Lawson Creek Formations. The gneiss complex of Wildhorse Creek, with an age of about 2,000 million years (Dover, 1981, p. 25), may be the oldest rocks in the Forest. The gneiss complex is mainly quartzo-feldspathic and quartzitic gneiss and some calc-silicate zones and a distinct marble unit. The marble is locally metasomatized to tactite that contains economic to subeconomic amounts of tungsten (Cook, 1956, p. 12).

The Yellowjacket Formation is mainly dark-gray argillaceous metaquartzite and includes some intervals of calcareous strata, siltite, and volcanic and subvolcanic material. The Hoodoo Quartzite is chiefly massive, very light colored, fine- to medium-grained quartzite that may be a facies of the Yellowjacket Formation. Parts of the Yellowjacket Formation and the Hoodoo Quartzite, mainly calcareous and metavolcanic strata, are hosts for gold, silver, cobalt, and base-metal deposits just north of the Forest. These metals were probably originally deposited syngenetically with the enclosing sediments from seafloor springs or volcanic activity. Later metamorphic, tectonic, and plutonic activity remobilized the metals into the present deposits. The other Precambrian units are mainly fine-grained micaceous quartzites, argillaceous metaquartzites, and siltstones with locally abundant feldspar and hematite and calcareous cement. The Big Creek, Apple Creek, and Gunsight Formations host the tungsten and base-metal stockwork veins associated with the Tertiary intrusive in the Blue Wing district (Ima mine) (fig. 4). These deposits are fracture-fillings deposited from hydrothermal solutions. The metals were probably introduced with the intrusive body rather than remobilized from the country rock. Generally the Proterozoic quartzites, other than the Yellowjacket Formation and Hoodoo Quartzite, do not host significant deposits. Quartz veins where present in the quartzites are generally thin and contain only trace amounts of base and precious metals, in sharp contrast to the large and metal-rich quartz veins that occur in nearby Paleozoic carbonate terrane. Numerous prospects explore hematitic quartz veins and secondary copper occurrences, but no production has been recorded. The secondary copper occurrences are in or associated with the locally pyritic Apple Creek Formation and may represent metal leached from the green siltite and fine-grained quartzite of that formation (E.T. Ruppel, Montana Bureau of Mines and Geology, written commun., 1987).

Paleozoic Rocks and Structures

Paleozoic sedimentary rocks in the Forest, which range in age from Late Cambrian to Early Permian, were deposited in a major geosyncline along the western edge of a craton. Numerous lithologic types are represented that attest to deposition in several marine-shelf and geosynclinal environments. There are four major Paleozoic geologic terranes in the Forest, each represented by a dominant rock assemblage—quartzite, carbonate, flysch, or black shale. The quartzite terrane is mainly in the Lemhi and Lost River Ranges, the carbonate terrane is in the Lemhi and Lost River Ranges and the White Knob and eastern Salmon River Mountains, the flysch terrane is in the eastern Pioneer Mountains, and the black-shale terrane is in the Boulder-Pioneer Mountains.

Evidence of tectonic activity in the Paleozoic is in the depositional record; individual structures developed at that time were probably reactivated or obscured by major tectonic activity in the Mesozoic (Dover, 1980, p. 371). The important structures for ore control in the Paleozoic rocks are post-Paleozoic in age. Major Paleozoic structural elements indicated by the depositional record include the Lemhi arch, Antler highlands, and Copper Basin highlands (fig. 6). Although the northwest-trending Lemhi arch was emergent only until the Middle Devonian, it continued to influence depositional patterns through the late Paleozoic even after submergence (Ruppel, 1986, p. 119). The Copper Basin Formation is composed of detritus shed from a highland west of the region during the Mississippian. The highland probably developed during the Antler orogeny (Dover, 1980, p. 371). The Copper Basin highlands arose in Middle Pennsylvanian time and influenced depositional patterns for the remainder of Paleozoic time by separating deep-water deposition to the west from deposition on a carbonate bank to the east (Skipp and Hall, 1980, p. 387).

Quartzite Terrane

The quartzite terrane includes a few formations, principally Cambrian and Ordovician in age, that are dominantly composed of quartzite. The Late Proterozoic(?) and Lower Cambrian Wilbert Formation and the Lower Ordovician Summerhouse Formation are exposed in the southern part of the Lemhi Range and in small areas of the Lost River Range. These units thin and pinch out to the north. They were apparently deposited in near-shore environments on the edge of the emergent Lemhi arch. The Wilbert and Summerhouse Formations are dominantly pink, maroon, and white quartzites that contain interbedded sandstone, shale, conglomerate, and sandy dolostone. Portions of the quartzite have been altered to carbonate. Differential weathering of the carbonate alteration areas has resulted in a mottled rock with an abundance of irregular cavities. Carbonate alteration is associated with the economically significant polymetallic vein deposits in fractured quartzite in the southern Lemhi Range. Metals in the vein deposits were introduced by hydrothermal solutions from an unknown source. The massive, cliff-forming Middle Ordovician Kinnikinic Quartzite, which was the first unit to be deposited across the Lemhi arch following its submergence, is extensively exposed in the Forest. In most places, the Kinnikinic unconformably overlies Proterozoic rocks. Numerous prospects for base and precious metals are in Kinnikinic rocks, but no significant deposits have been found and there is no recorded production.

Carbonate Terrane

The carbonate terrane includes many formations, and limestone and dolostone are the dominant rock types in the eastern half of the Forest. The carbonate units differ from the east to the west sides of a major north-northeast-trending structural element called the Salmon River lineament (Hobbs, 1985, p. 67) (fig. 6). Rocks on the east side of the lineament are part of the predominantly carbonate facies Paleozoic strata that are extensively exposed in southeastern Idaho and southwestern Montana. These rocks are Ordovician to Permian in age and are composed of sediments deposited on the continental shelf. The carbonate units include the Saturday Mountain Formation (Middle and Upper Ordovician and locally Lower Silurian), Fish Haven Dolostone (Upper Ordovician and Lower Silurian), Laketown Dolostone (Middle and Upper Silurian), Roberts Mountains Formation (Upper Silurian and Lower Devonian), Beartooth Butte Formation (Lower Devonian), Jefferson Formation (Middle and Upper Devonian), Grand View Dolostone (Upper Devonian), Three Forks Formation (Upper Devonian), Middle Canyon Formation (Lower and Upper Mississippian), Scott Peak Formation (Upper Mississippian), South Creek Formation (Upper Mississippian), Surrett Canyon Formation (Upper Mississippian), White Knob Limestone (Upper Mississippian), Arco Hills Formation (Upper Mississippian), Bluebird Mountain Formation (Upper Mississippian and locally Lower Pennsylvanian), and Snaky Canyon Formation (Upper Mississippian to Lower Permian). The lower part of this sequence (Ordovician through Devonian) is mainly dolostone and limestone, silty limestone, quartzite, sandstone, and siltstone. The middle part of the sequence (Mississippian) is mainly massive limestone that is locally fossiliferous, bioclastic, or cherty. The upper part of the sequence (Pennsylvanian to Early Permian) is interbedded limestone, dolostone, sandstone, siltstone, and mudstone. Significant mineral deposits occur in carbonate rocks of this sequence at several locations. The White Knob Limestone is host rock for skarn and polymetallic vein deposits in the Alder Creek district (fig. 4) where all deposits are close to the Mackay stock. In the Spring Mountain district (fig. 4) in the central part of the Lemhi Range, replacement and polymetallic vein deposits occur in limestone and dolostone of the Saturday Mountain Formation. The mines on Leadbelt Creek, Lava Creek district (fig. 4), are in limestone of the carbonate bank sequence where deposits are polymetallic veins and replacements. The few deposits in the Lost River Range are in carbonate terrane. Most are small, except for those in the Lone Cedar Creek area, which are shown as an area of unknown potential on plate 3.

Carbonate units exposed west of the Salmon River lineament include the Upper Cambrian or Lower Ordovician Bayhorse Dolomite, Middle Ordovician Ella Dolomite, and Middle and Upper Ordovician Saturday Mountain Formation. The Saturday Mountain Formation, which is the only unit exposed on both sides of the Salmon River lineament, is of significantly different facies and thickness on the western side of the lineament than on the eastern side. This western sequence of rocks is mainly sandy and silty dolostone and limestone, and shale, quartzite, and some argillite. A major distinction between the western and eastern carbonate sequences is the presence of an underlying thick sequence of black shales and other carbonaceous beds beneath the western sequence. These black shales and other carbonaceous beds have been proposed as the source of some of the metals for the extensive mineral deposits in the carbonate rocks (Hobbs, 1985). The Bayhorse Dolomite hosts lead, zinc, silver, and fluorspar vein and replacement deposits in the Bayhorse district (fig. 4) and at Keystone Mountain just to the east. Within the Bayhorse district extensive lead, silver, and zinc replacement deposits along Kinnikinic Creek, including those of the Clayton Silver mine, are in the Ella Dolomite. Lead-silver replacement bodies and vein and replacements in shear zones along Squaw and Sullivan Creeks, to the south of the Bayhorse district, are in the Saturday Mountain Formation. The western sequence of carbonate rocks is in a structurally complex area that contains numerous intrusive bodies; both the complex structure and the intrusions influenced the remobilization of metals from the sedimentary rocks into vein and replacement deposits.

Mineral deposits in the carbonate terrane are dominantly silver, lead, and zinc, and some copper, iron, and fluorspar. There is no apparent lithologic preference in terms of which carbonate unit is most likely to host ore deposits. The important factors for formation of the vein and replacement deposits seem to be carbonate rock in contact with or in close proximity to felsic igneous intrusive rocks in areas of deep-seated high-angle faults. Carbonate rocks in other terranes are also prime host rocks. In all three of the other Paleozoic geologic terranes represented, many of the deposits are in thin interbeds of carbonate rock.

Black-Shale Terrane

This terrane is in a belt of highly mineralized, black, siliceous-facies, clastic sedimentary rocks of Late Cambrian to Permian age that are exposed in the west-central part of the Forest from the Summit Creek area, Alto district, northward through the Bayhorse district just west of Challis (fig. 4). Map units include, from youngest to oldest, the Lower Permian Grand Prize Formation, Lower Permian to Middle Pennsylvanian Wood River Formation, Devonian Milligen Formation, Middle Silurian Trail Creek Formation, Middle Silurian to Lower Ordovician Phi Kappa Formation, Ordovician(?) Ramshorn Slate, Paleozoic(?) Salmon River assemblage, and several unnamed units of probable Silurian to Devonian age. The units are allochthonous and occur in imbricated structural plates separated by thrust faults. Rocks of the black-shale terrane are predominantly black, fine-grained argillite, siltite, limy sandstone, siltstone, shale, fine-grained quartzite, and micritic limestone. Deposition was in relatively deep basins and restricted basins west of the cratonic shelf where the rocks of the carbonate terrane were deposited. Syngenetic metal deposits may form locally in these depositional environments, and carbonaceous lithologies deposited in them are commonly metal enriched. Rocks of the black-shale terrane contain stratiform deposits of barite, zinc, and vanadium, and vein, skarn, and replacement deposits of silver, lead, zinc, antimony, arsenic, barite, gold, molybdenum, tin, tungsten, and vanadium. The source for many of the metals in the vein, skarn, and replacement deposits was probably the more carbonacous units of the rock sequence. The metals were remobilized out of the sedimentary rocks by heat and hydrothermal convection cells related to igneous intrusive activity (Hall, 1985).

Flysch Terrane

A flysch terrane is represented by the Copper Basin and McGowan Creek Formations of Mississippian age (Skipp and Hall, 1980, p. 391). The lower parts of both formations were deposited in deep and narrow marine foreland basins. Clastic material and turbidites were derived from eroding highlands to the west, the Antler highlands (fig. 6), and carbonate turbidites were derived from the developing carbonate bank to the east. Rocks in the lower parts of the Copper Basin and McGowan Creek Formations are poorly fossiliferous, fine-grained, thinly bedded argillite, mudstone, siltstone, and limestone turbidites. The upper part of the Copper Basin Formation is mainly siliceous pebble conglomerate, quartzite, and sandstone deposited in marginal-marine to shallow-marine environments. The upper part of the McGowan Creek Formation is calcareous siltstone interbedded with silty micritic limestone deposited in a deep-marine starved basin. The Copper Basin and McGowan Creek Formations are treated as black-shale terrane for resource analysis. Deposits in the lower parts of the formations include polymetallic veins and replacements in the Lava Creek, Copper Basin, and Alto districts and possible syngenetic stratiform deposits in the Alto district (fig. 4). Polymetallic vein deposits in the Lone Cedar Creek area of the Lost River Range may be within or composed of metals remobilized from the McGowan Creek Formation. Geochemical studies (Erdman and others, 1988) suggest that parts of the McGowan Creek Formation in the Timbered Dome area, Lava Creek district, are metal enriched.

Mesozoic Rocks and Structures

Mesozoic time was one of major igneous plutonic activity and major low-angle thrust faulting. Sedimentary or volcanic rocks were not deposited in this area during the Mesozoic. The Idaho batholith, a very extensive mass of relatively homogeneous igneous rock that underlies much of the western part of the Forest, was emplaced during the Late Cretaceous to earliest Tertiary. In detail this mass is composed of several plutonic phases that range in composition from granite to tonalite and have gradational borders. Ages of the various phases range from 97 million to 64 million years (Kiilsgaard and Lewis, 1985, p. 37). The various phases are peraluminous and show a calc-alkaline alkali-enrichment trend. Magmas that formed rocks of the batholith were probably generated by partial melting along a major subduction zone at a continental margin. Rocks in the eastern part of the batholith probably formed as a result of partial melting of metamorphic rocks in the lower crust, whereas those in the western part formed as a result of partial melting in or above a subducting slab of oceanic lithosphere (Lewis and others, 1987). Along its eastern border, which is the area covered by the Forest, the batholith intruded Paleozoic sedimentary rocks. Sedimentary rocks in the contact area and the numerous inclusions in the batholith were metamorphosed to hornfels and calc-hornfels. Satellite plutonic bodies of compositions similar to those of the batholith intruded the sedimentary rocks tens of miles east of the main batholith.

Cretaceous plutonic rocks are associated with several different types of mineral deposits, many of which are genetically related to the plutonic rocks. Deposit types include disseminations in the host rock, polymetallic skarns, pegmatites, stockworks, and hydrothermal veins. At the present time the most economically important deposits are the stockwork molybdenum deposits, such as those at Thompson Creek (Ja, pl. 3) and Little Boulder Creek, Boulder Creek district (fig. 4). Numerous polymetallic tactite (skarn) deposits along the eastern border of the batholith and in inclusions in the batholith contain mainly tungsten with some zinc and lead, such as at the Springfield (Lb, pl. 3) and Tungsten Jim mines, Bayhorse district (fig. 4). Pegmatites of the batholith have been prospected for a variety of minerals, but there has been no recorded production within the Forest. Base- and precious-metal veins in the batholith, such as those at the Lost Packer, Loon Creek district (fig. 4), Sea Foam (G, pl. 3), and numerous other mines and prospects, may relate to the formation of the batholith. Many other vein deposits, primarily precious-metal types, and alteration zones are related to emplacement of Tertiary stocks and hypabyssal bodies. Weathering and erosion of the batholithic rocks concentrated heavy minerals, such as columbite-tantalite, ilmenite, monazite, euxinite-polycrase, allanite, zircon, and numerous others, into radioactive black-sand deposits. The most extensive of these deposits are located west of the Forest.

Sometime after deposition of Early Permian sediments and prior to deposition of the conglomerate at the base of the Challis Volcanic Group, large masses of rocks were thrust eastward and northeastward. Faulting began no later than 100 million years ago and terminated 70–75 million years ago (Ruppel and Lopez, 1984, p. 33). The resultant complex of thrust faults juxtaposed marine rocks of deep-water, transitional, and miogeosynclinal facies. Several thrust plates in the region are composed of imbricated thrust complexes; within the Forest these plates include, from west to east, the Milligan–Wood River–Grand Prize thrust complex; Devonian, Silurian, and Ordovician rocks undivided; Copper Basin plate; White Knob plate; Grouse plate; Lost River–Arco Hills plate; and Hawley Creek plate (Skipp, 1987, p. 220). All rocks from Archean (Precambrian) through Lower Permian were involved in the thrust faulting (fig. 6). Most, if not all, of the thrust sheets are cut by rocks of the Cretaceous Idaho batholith and related intrusive bodies. Following thrusting, but prior to volcanism, the thrust plates were broadly folded. Tectonic models for this thrust belt have included overthrusting, gravitational sliding or spreading, and underthrusting or continental subduction.

Much of the area of the thrust faults has not been mapped in detail, and as these studies are completed in the future the distribution and mechanisms of formation will become better known. Whatever the exact mechanism, the present configuration of thrust plates had a pronounced effect on the localization of the Tertiary mineral deposits. Hall (1985, p. 127) noted that the vein-type lead-silver-zinc deposits in the black-shale terrane lie directly under regional thrust faults, especially where the faults are domed. In the Lemhi Range, Ruppel (1978, p. 18) has shown that the emplacement of Tertiary intrusive rocks and related mineral deposits was to a large extent controlled by structural features associated with a regional thrust system.

Tertiary Rocks and Structures

The Tertiary was a time of large-scale volcanism and extensional tectonics, in contrast to the Mesozoic, which was a time of batholith formation and large-scale compressional tectonics. The change was not abrupt as there is some overlap in ages of all the above activities. Many of the important rock terranes—volcanic rocks, plutonic and hypabyssal rocks, epiclastic sediments, and tuffaceous rocks—formed in Tertiary time, as did the major high-angle faults of northeast, northwest, and locally north trend. High-angle faults also formed in the Mesozoic, but these are tear faults related to the thrusting and, where found, are confined to the Paleozoic rocks of a particular thrust plate. The trans-Challis fault system (fig. 6), which is a series of northeast-trending high-angle faults and related structures (Fisher and Johnson, 1987) that extend discontinously across Idaho and Montana, is the most important Tertiary structure. Subparallel fault systems occur to the south; the most prominent is the series of dikes and faults that extend southwestward from just north of Mackay (fig. 6). Northwest- to north-trending deep-seated high-angle faults also developed during the Tertiary; the most prominent are the range-bounding faults along the Lemhi and Lost River Ranges. Movement along the northwest- to north-trending structures during Tertiary to Holocene times created the Basin and Range topography of the southeastern part of the Forest. In general, the northeast-trending systems are thought to be older than the northwest-trending systems.

In that portion of the Forest within the Challis quadrangle many features associated with Challis volcanism, intrusive activity, and related mineralization are localized along the trans-Challis fault system (Fisher and Johnson, 1987). Southeast of the trans-Challis fault system, the major northwest-trending faults may have been just as important in localizing plutonism and mineralization; one example is the northwest-trending system that extends from the Lava Creek district northwest through the Pioneer Mountains. The Challis volcanic rock terrane includes volcanic rocks and volcaniclastic sediments deposited within and outside of large calderas, on the sides of stratovolcanoes, and in the vicinity of numerous smaller vents. This terrane also includes a great variety of hypabyssal bodies. Within the Challis quadrangle the volcanics are a suite of calc-alkaline, peraluminous rocks deposited between 51 million and 45 million years ago (Fisher and Johnson, 1987). These compositional and age constraints may or may not fit the Challis Volcanic Group in the rest of the area covered by the study (pl. 1).

Plutonic and related hypabyssal rocks of Eocene age, which are part of a diorite-granite bimodal group, constitute the Tertiary plutonic rock terrane. Dacite and rhyodacite dike swarms are associated with diorite plutons, and rhyolite dikes are associated with granite plutons (Fisher and Johnson, 1987). Rocks in the plutonic terrane have equivalents in rocks of the volcanic terrane. The diorite and granite complexes occur near each other. Granite bodies (for example, the Casto batholith, Sawtooth batholith, Pioneer Mountain stock, and Mackay stock) are generally larger than the diorite bodies and also form most of the spectacular peaks in this region. The diorite complexes were emplaced 50–45 million years ago, and the epizonal granites were emplaced 45–42 million years ago (Bennett and Knowles, 1985, p. 82). Eocene granites are distinguished by a coarse granitoid texture and a characteristic pink color that is caused by an abundance of perthitic potassium feldspar. They also contain miarolitic cavities and have uranium, thorium, and potassium-40 contents two to three times higher than granitic rocks of the Idaho batholith (Fisher and Johnson, 1987). Eocene plutonic rocks in this area are of the type that forms in zones of intercontinental rifting or extensional tectonics (Bennett and Knowles, 1985, p. 82).

Large areas of the Eocene volcanic and plutonic rock terranes are hydrothermally altered, including the areas around all known mineral deposits. Altered rocks should be treated separately for the purposes of mineral resource appraisal, but in most areas mapping is not adequate to do so. During the late stages of volcanic and plutonic activity, meteoric water was set into convective motion by heat generated from shallow intrusive bodies. Convective cells developed best in permeable volcanic rocks but were present in all rock types. Several cells have been documented in the Challis quadrangle by Criss and others (1984), and many more cells that were active, as indicated by altered zones, have not been studied. The degree of alteration varies considerably from the presence of zeolites along fractures in otherwise unaltered rocks, through rocks that show an increase in calcite, chlorite, and epidote, to rocks that have been completely replaced by variable amounts of sericite, clay minerals, secondary silica, arsenopyrite, and pyrite. Altered rocks associated with mineral deposits are commonly highly silicified, bleached, and stained with iron oxides.

Mineral deposits that formed during the Tertiary are all genetically related. They contain the same group of elements with variable degrees of concentration; some of the elements were remobilized from previous concentrations, mainly in the black-shale sequences, and some were introduced from other sources. All the deposits have a tie to the major geologic events of the period—deep-seated extensional faulting along northeast and north to northwest trends, volcanism, emplacement of plutonic and hypabyssal bodies, and generation of hydrothermal cells. Many of the mineral deposit types discussed in this report were formed in the Tertiary. The fluorspar veins, fluorspar breccia manto deposits, polymetallic veins in Tertiary extrusive terrane, precious-metal veins, high-level rhyolite-hosted precious-metal deposits, precious-metal deposits in volcanic tuffs, and sediment-hosted jasperoid-associated precious-metal deposits all formed at this time. Many, if not all, of the polymetallic veins in quartzite terrane, polymetallic veins in carbonate terrane, and irregular replacements of base and precious metals also formed in the Tertiary. Some of the polymetallic veins in black-shale terrane, tungsten stockwork and vein deposits, stockwork molybdenum deposits, and polymetallic skarn deposits formed in the Tertiary; the rest formed in the Cretaceous during emplacement of the Idaho batholith. During volcanism and plutonism the metals were concentrated in several environments. Some metals were deposited in stockworks in the late stages of crystallization of the igneous rocks; other metals were moved into the hydrothermal systems along with volatiles and were deposited in veins and replacement bodies. The exact character of the deposits that were formed depended upon the host rock and configuration, distance from intrusive bodies, and nature of the fracture systems.

Quaternary Rocks and Structures

Pleistocene and Holocene alpine glacial till and glaciofluvial sand and gravel record glaciation that affected the central parts of the high ranges. The increased weathering and fluvial transport associated with the glaciation choked all but the larger streams with debris, much of which remains today. Rock glaciers and talus slopes, which are still forming today, are characteristic of the higher mountain slopes. The erosional base level of many areas in the Forest changed several times during Pleistocene and Holocene time as evidenced by the numerous terraces along many of the valleys, especially in the southeastern part of the Forest, and by the multiple pediment surfaces in some of the larger valleys. The large alluvial fans and Holocene fault scarps along some of the range fronts and recent seismic activity attest to the continuing tectonic activity and uplift in this area.

In the western part of the Forest are remnants of a high-level erosional surface called the "Idaho peneplain" which exposed Idaho batholith rocks. Soil horizons were developed on this decomposed surface prior to glaciation. The soil and eluvium on this surface were enriched in heavy minerals. Increased fluvial activity during glaciation concentrated heavy minerals into alluvial deposits nearby. Also during glaciation streams eroded areas of lode-gold deposits and concentrated the detrital gold into placer deposits, locally at some distance from the source. Subsequent erosion following the lowering of erosional base levels has resulted in reworking of some of the older placer deposits in terrace gravels into Holocene alluvial deposits farther downstream.

Aspects of Quaternary erosion other than placer deposits also have to be considered in mineral evaluations. Pediment surfaces and many of the terraces along the streams are cut in bedrock. Commonly there is a relatively thin veneer of gravel on these surfaces that may mask mineral deposits or geologic features diagnostic of mineral deposits at depth.

GEOCHEMISTRY

Geochemical Surveys

Two government organizations have conducted regional geochemical surveys of the areas within the boundaries of the Challis National Forest, the Department of Energy (DOE) and the USGS (fig. 5).

The NURE program was a program of the DOE to acquire and compile geologic and other information with which to assess uranium resources at a scale of 1:250,000 and to determine areas favorable for the occurrence of uranium in the United States. The hydrogeochemical and stream-sediment reconnaissance (HSSR) program of NURE provided for the collection of water and sediment samples located on the $1°\times 2°$ National Topographic Map Series quadrangle grid across the conterminous United States and Alaska and for the analysis of these samples for uranium as well as for a number of additional elements (Information Systems Program, 1985). Both the sample collection and analysis were contracted to commercial laboratories.

The USGS programs in the Challis National Forest were designed either for resource assessment of areas being considered for wilderness status or for resource assessment of the Challis 1°×2° quadrangle. The USGS was responsible for both the collection and analysis of samples. USGS sampling and analytical techniques have evolved over a period of years, and analytical results of earlier studies are not directly comparable with those of later studies.

Table 5 lists geochemical surveys that cover parts of the Challis National Forest, the area of the National Forest covered by the survey, the group that collected the samples, and the group that analyzed the samples. Table 6 indicates laboratories and their analytical methods for the geochemical data used in the mineral resource assessment of the Challis National Forest. In most surveys, not all samples were analyzed by all the listed methods.

NURE Programs

(1) Hailey NURE program; samples were collected by Savannah River Laboratory and were analyzed by Oak Ridge Gaseous Diffusion Plant. Analyses for soils, dry-wash sediments, and waters were reported (Cook and Fay, 1982). Although sediments from streams with flowing water might have been collected, analytical results are not available. The minus-100-mesh fraction of soils and dry-wash sediments was analyzed by an ion-coupled plasma (ICP) analytical technique. The minus-100-mesh fraction of sediments is a useful sample medium in areas that produce good hydromorphic anomalies. Even in arid regions where hydromorphic anomalies are not well developed, this size fraction is adequate, provided the analytical technique is precise and has relatively low limits of determination. ICP is a precise analytical method, but the limit of determination for some elements such as Ag is high (2 ppm) and several elements of interest in resource evaluation, including As, Sb, Bi, Cd, and W, were not analyzed. Sample density of the survey was adequate but not uniform. Most samples were collected near roads, and thus those areas with few or no roads have few or no sample sites.

(2) Idaho Falls NURE program; like the Hailey NURE program, samples were collected by Savannah River Laboratory and were analyzed by Oak Ridge Gaseous Diffusion Plant. This sampling and analytical program shares the same strengths and weaknesses as the Hailey NURE program. For general resource assessment, the sample density was adequate within the boundaries of the Challis National Forest.

(3) Dubois NURE program; water and stream-sediment samples in this program were collected and analyzed by Los Alamos Scientific Laboratory. The minus-100-mesh fraction of stream sediments was analyzed for an extensive suite of elements that includes As, Sb, Bi, Cd, and W. Precision of the analyses was typically better than 25 percent if the element concentration was an order of magnitude above its detection limit. Although some elements, such as Ag (limit of detection 5 ppm), had limits of detection that are too high to be useful for a thorough resource evaluation, many elements had limits of detection that were within an order of magnitude of their average crustal abundance. Unfortunately, few samples were collected within the boundaries of the Challis National Forest, and this area has the lowest sample density of any of the study areas (0.01 samples per 1 mi^2).

U.S. Geological Survey Programs

(1) Challis CUSMAP project; samples in this project were collected and analyzed by the USGS. This study was chosen instead of the Challis NURE program to determine geochemical signatures of type mine localities, because the USGS study was designed for resource assessment of a broad range of commodities, not just uranium. The USGS Challis CUSMAP geochemical group is a composite of five separate studies, many with different sampling and analytical techniques. Samples collected specifically for the Challis CUSMAP project were collected only in areas not previously sampled by projects in the Sawtooth Primitive Area, Idaho Primitive Area, Sawtooth National Recreation Area, or Ten Mile West Roadless Area. Three of these studies (eastern part of the Sawtooth National Recreation Area, Idaho Primitive Area, and Challi CUSMAP) included portions of the Challis National Forest. These three studies will be discussed separately.

Idaho Primitive Area.—Rocks collected from mineralized and unmineralized areas and sediments collected from both flowing and intermittent streams (mesh size not specified) were analyzed by semiquantitative emission spectrography. During the time period of this study, analytical techniques were modified and limits of detection for some elements changed for samples analyzed at the beginning of the study and those analyzed toward the completion of the study. The element suite analyzed for this study is more restricted than other studies in the Challis CUSMAP project. The semiquantitative emission spectrographic analytical method is not precise (plus or minus one reporting interval at the 83 percent confidence level and plus or minus two intervals at the 95 percent confidence level), but it does allow quick processing of samples. The sample density is high and the samples are evenly distributed compared to the Challis NURE study in this same area.

Eastern part of the Sawtooth National Recreation Area.—Rocks, soils, and stream sediments (minus-80-mesh size fraction) were collected and analyzed by semiquantitative emission spectrography, by atomic absorption, and by colorimetric analytical techniques. The sampling density is high—4,654 samples were collected in the eastern part of the Sawtooth National Recreation Area. The elements analyzed include those commonly used in resource evaluation. The limit of detection or the precision of the analysis, or both, were improved by analyzing Au, Ag, Sb, Cu, Pb, and Zn by either atomic absorption or color spectrophotometry. The lack of precision in the semiquantitative emission spectrographic analytical technique is at least partially overcome by the high sample density in this area.

Challis CUSMAP project.—Rocks, soils, stream sediments (minus-200-mesh size fraction) from both dry and flowing streams and the heavy-mineral fraction of the stream sediments were analyzed by semiquantitative emission spectrography (Adrian and others, 1985; Hopkins and others, 1985). Sample density is about one sample per 2 mi^2. This is the only study in which the heavy-mineral fraction of stream sediments was collected and analyzed. Compared to the less dense silicates and oxides, heavy minerals tend to have higher concentrations of some elements of interest in resource evaluation. Many of these elements reside in the mineral matrix rather than in surface coatings, and the heavy-mineral fraction tends to have a good contrast between anomalous and background samples regardless of climate.

(2) Boulder-Pioneer Wilderness Study Area; samples in this study were collected and analyzed by the USGS. This study covers a southwestern part of the Challis National Forest and overlaps portions of both the Hailey and Idaho Falls NURE program studies. Rock, soils, and stream sediments were collected and analyzed by atomic absorption, neutron-activation, and semiquantitative emission spectrography. Sample density in this study was high, about 2.6 samples per 1 mi^2. For the reasons previously given, this study was used to determine the geochemical signatures of the type mine localities within the boundaries of this study rather than using either the Hailey or Idaho Falls NURE studies.

Geochemical Signatures

The geochemical signatures for each deposit type, as listed in table 7, were defined by examining the analytical results of samples collected near the type mine localities (fig. 5, table 3) and determining which elements had unusually high concentrations in those samples. Because of different limits of detection/determination, elements analyzed, sample media, sampling density, and analytical precision among the various geochemical surveys, the geochemical signatures given in table 7 should be used for resource assessment only within the boundaries of the survey that contains the type mine locality. Many of the mineral deposit types described in this report have theoretical geochemical signatures that are based on similar mineral deposits that occur outside of the Challis National Forest. These "ideal" geochemical signatures are modified from geochemical signatures associated with deposit models in Cox and Singer (1986). Because of different sampling and analytical methods, these "ideal" geochemical signatures usually will not match the observed geochemical signatures reported in table 7. A discussion of the geochemical signatures for each type is included in the deposit type descriptions in the "Resource potential—locatable minerals" section of this report.

GEOPHYSICS

The aeromagnetic map as superimposed on the geologic map (pl. 2) illustrates the correlation of magnetic patterns with various types of mineral deposits and provides information applicable to prospecting for buried geologic structures and igneous intrusions that might have associated mineral deposits. The gravity maps are reconnaissance in nature, but provide valuable insights for prospecting, such as information about regional structures and distribution of low-density igneous intrusions typical of the felsic granitic rocks of this region (Mabey and Webring, 1985).

Several of the mineral deposit types discussed in this report commonly are spatially related to granitic intrusions and fault or shear zones. Within the Forest prominent positive magnetic anomalies are often associated with the exposed Tertiary granitic intrusions. In some cases the correlations are not exact, which indicates that the intrusion is not uniformly magnetic. Configuration of some individual anomalies may indicate the presence of concealed Tertiary intrusions or more extensive subsurface development of the exposed plutons. The widespread Cretaceous biotite-granodiorite rocks of the Idaho batholith are less magnetic and generally show low magnetic gradients and exhibit no distinctive expressions that could be used to pinpoint their contacts. Diorites of Cretaceous age are sparse, but where present they exhibit high-amplitude positive anomalies. Thus, in areas where distinctive positive anomalies occur over Cretaceous granitic terrane, buried dioritic or Tertiary intrusions may be present.

Fault zones and shear zones may exhibit linear magnetic trends, typically as patterns of contours parallel to the zones. A series of northeasterly linear magnetic trends correlates with the trans-Challis fault system as defined by Fisher (1985). The sources of these trends are interpreted as faults that cut or offset the rhyolite, which results in the juxtaposition of rocks with different magnetic properties. Some of the faults inferred from the magnetic data have not been recognized in exposures and apparently do not cut the ground surface.

The regional gravity map (A.E. McCafferty and Viki Bankey, written commun., 1987) exhibits patterns that can be attributed largely to the low-density granitic intrusions of Cretaceous to Tertiary age. Mabey and Webring (1985) made physical property measurements of rocks in the study of the Challis $1° \times 2°$ quadrangle and reported the following average specific gravity values: Precambrian crystalline rocks, 2.7 g/cm^2; sedimentary rocks, 2.6 g/cm^2; Cretaceous Idaho batholith, 2.58 g/cm^2; major intrusions of Tertiary granite, 2.56 g/cm^2; Tertiary diorite intrusions, 2.7 g/cm^2; and Tertiary Challis Volcanic Group, about 2.5 g/cm^2.

MINERAL RESOURCES—LOCATABLE MINERALS

Locatable minerals include all minerals subject to exploration, development, and production under the Federal General Mining Law of 1872. Most metals and industrial minerals are included in this group and are considered in this section.

Mining and Exploration History

The area covered by the Challis National Forest has experienced a long history of mining and mineral exploration. See Ross (1963a) and Wells (1983) for excellent discussions of the history of mining in this area. Several commodities have been sought and exploited and many others have been sought, but because of geologic conditions, logistics, or economics, have not been fully exploited. The cycle of mineral exploration and appraisal never ends, and deposits and occurrences known for many years become resources due to increased knowledge, technological advances, or changes in supply and demand. Exploration and development have come in spurts with emphasis at various times on ores of gold, silver-lead-zinc, copper-lead-zinc, tungsten, molybdenum, uranium, fluorspar, radioactive minerals, and rare-earth minerals. Some of these commodities sustained a sizable industry that lasted many years; others were short lived in interest and production. Commodities such as iron, barite, cobalt, mercury, sulfur, antimony, manganese, and arsenic are recorded as present but have had essentially no production. Lands of the Forest have also been evaluated for many other commodities of which there is no record.

This part of Idaho was first explored in the 1860's by groups of gold seekers. By 1869 all the known placers and most of the lode deposits had been discovered (Weissenborn, 1964, p. 14). Gold has been mined intermittently from lode deposits since the 1860's. Production of gold from placer deposits was mainly prior to 1900 with a revival of placer operations during the 1930's and the operation of the Yankee Fork dredge in the 1940's and 1950's. The latest exploration activity in the Forest has been for gold in large low-grade lode deposits.

During the "gold rush" in the 1860's rich silver-lead ores were noted in several areas. Mining of these ores began in the early 1880's at many locations within the Forest. Smelters were constructed at Bayhorse (fig. 4), Nicholia to the east of the Forest, and Wood River (Ketchum) to the west of the Forest. The erection of smelters in these districts spurred exploration activity, and small operations from most of the known mineralized areas in the area shipped ore to one of these smelters during the 1880's. Stamp mills were constructed at many of the sites. There was a sharp decline in production around 1890 when the rich secondary deposits being mined were exhausted, and the smelters were closed, the last at Clayton in the Bayhorse district (fig. 4) in 1902. Mining of the silver, lead, zinc, and copper in and near the Forest, however, has continued almost uninterrupted since the turn of the century: For example, the Wilbert mine in the Dome district from 1906 to 1918 and 1924 to 1931; the Empire mine in the Alder Creek district intermittently from 1901 into the 1960's; mines at Leadbelt Creek in the Lava Creek district in 1908, 1910, 1913, and the mid 1920's; the Last Chance mine in the Lava Creek district in 1943; mines in the Bayhorse district nearly continously with a major period from 1920 to 1923; the Lost Packer mine in the Loon Creek district from 1904 to 1916; the Livingston mine in the Boulder Creek district from 1920 to 1930; the Clayton Silver mine in the Bayhorse district in nearly continuous operation from the mid 1920's to 1986; and numerous small operations.

Mines within or near the Forest have been major past producers of tungsten. Tungsten minerals were known in this part of Idaho from the time of the active gold and silver mining in the late 1800's mainly because tungsten minerals came as unwanted by-products in the extraction of the precious metals. There was sporadic production of tungsten from the Ima mine in the Blue Wing district from 1911 to 1935 and continuous production from 1936 to the late 1950's. The Ima mine was a major domestic producer and is second in total tungsten production in Idaho only to the Yellow Pine mine which is located just northwest of the Forest. The major period of tungsten production was 1942–1944. Another period of major tungsten activity in this part of Idaho was 1950–1956; several new discoveries were made, and the deposits at Wild Horse Creek in the Alto district and at Thompson Creek in the Bayhorse district were worked at this time. This period of activity was in response to Federal Government stockpile purchases, which ceased in 1956.

Molybdenite, the major molybdenum mineral, has been known in numerous occurrences in the Forest since early in this century. Little interest was shown in the commercial extraction of molybdenite until extensive exploration during the 1960's discovered or delineated several major stockwork molybdenite deposits within or close to the Forest. The Thompson Creek deposit was brought into production in 1983. Molybdenum exploration is currently at a standstill because of worldwide oversupply and low prices.

Extensive exploration projects sought uranium in this area in the 1950's and again in the 1970's. The Stanley area produced uranium ore from vein and bedded deposits in 1959 and 1960. Uranium was also one of the commodities recovered from placer mining of radioactive black sands in the late 1950's. Most of this placer mining was west of the Forest in Bear Valley, although there was extensive exploration throughout the region. The other commodities produced from the black-sand deposits include niobium-tantalum oxides, thorium, rare-earth minerals, and titanium oxides. The placer mining was in response to Federal Government stockpiling orders.

Almost all the known fluorspar deposits in Idaho are in or close to the Forest. The first commercial production of fluorspar was in 1951–1953 from the Meyers Cove deposits in the Gravel district, which were discovered in 1941 and worked intermittently from 1954 to 1972. A small amount of fluorspar was mined from the Keystone Mountain area in the Bayhorse district during 1947–1953 and from the Stanley district in the late 1940's. Extensive exploration in the 1960's and 1970's delineated large stratabound fluorspar deposits in the Bayhorse district, but there has been no production from these deposits.

A variety of commodities have been mined in the Forest in the past. Much of the mining activity came in spurts, usually in response to a national demand. Major wars fueled some of the demand, but some came in response to modern technological needs that require "space-age" elements, such as the rare-earth elements. This trend will probably continue in the future; as a new need arises, the known occurrences will be reexamined and new sources will be sought.

Metals

The Challis National Forest has many types of mineral deposits that contain base, precious, and ferrous metals in several geologic terranes (figs. 7–12). The deposits formed during many metallogenic events including Precambrian sedimentation and later plutonism, Paleozoic sedimentation, Cretaceous igneous-hydrothermal activity centered on the formation of the Idaho batholith, Tertiary igneous-hydrothermal activity related to formation of the Challis volcanic field, and Pleistocene to Holocene weathering and erosion.

Precambrian submarine exhalative metal concentrations of cobalt, bismuth, arsenic, nickel, copper, silver, gold, and iron formed during deposition of the Yellowjacket Formation. These metals were remobilized by intrusive activity about 1,800 million years ago into deposits such as those at the Blackbird mine located just north of the Forest and at small and low-grade occurrences within the Forest.

Stratabound concentrations of metals that formed during deposition of the Paleozoic black-shale sequences include silver, barium, copper, molybdenum, vanadium, lead, zinc, nickel, and others. Some of these metals, namely vanadium, molybdenum, nickel, and zinc, have relatively high solubilities in sea water (Desborough and Poole, 1983, p. 99) and may have been concentrated directly from sea water by bacteriogenic activity. Other possible concentrating mechanisms include deposition from heated basin brines or from submarine exhalative solutions. The metal concentrations took the form of massive sulfide lenses, stringers and disseminations of sulfide minerals, and probably entrapment of metals in nonsulfide minerals. Known stratabound syngenetic deposits of precious and base metals (Q) (fig. 7) include the stratiform zinc deposits at the Hoodoo mine (Qa, fig. 5) and the Livingston mine (Boulder Creek district, fig. 4). Numerous other deposits are thought to be stratiform in part. In parts of the Salmon River assemblage vanadium occurs in concentrations greater than 1 percent in stratabound vanadium deposits (R) (fig. 7) that may be commercial in the future. In addition to the stratabound deposits that may be present, the carbonaceous sedimentary rocks (black shales) held an enormous reservoir of metals that could have been mobilized and concentrated by igneous-hydrothermal systems active in the Cretaceous and Tertiary (examples are deposits of type B, fig. 7).

Igneous-hydrothermal systems related to the emplacement of the Cretaceous Idaho batholith and the Tertiary Challis volcanic field developed most of the deposit types present in the Forest. The batholith event and the volcanic event were distinctly different as reflected in the characteristics of metallogenesis and the associated deposit types. Some deposit types were formed exclusively during emplacement of the Cretaceous batholith, whereas other types formed exclusively during the Tertiary plutonism and volcanism; a few other types formed during both events. There is a strong genetic relationship among all the deposits formed

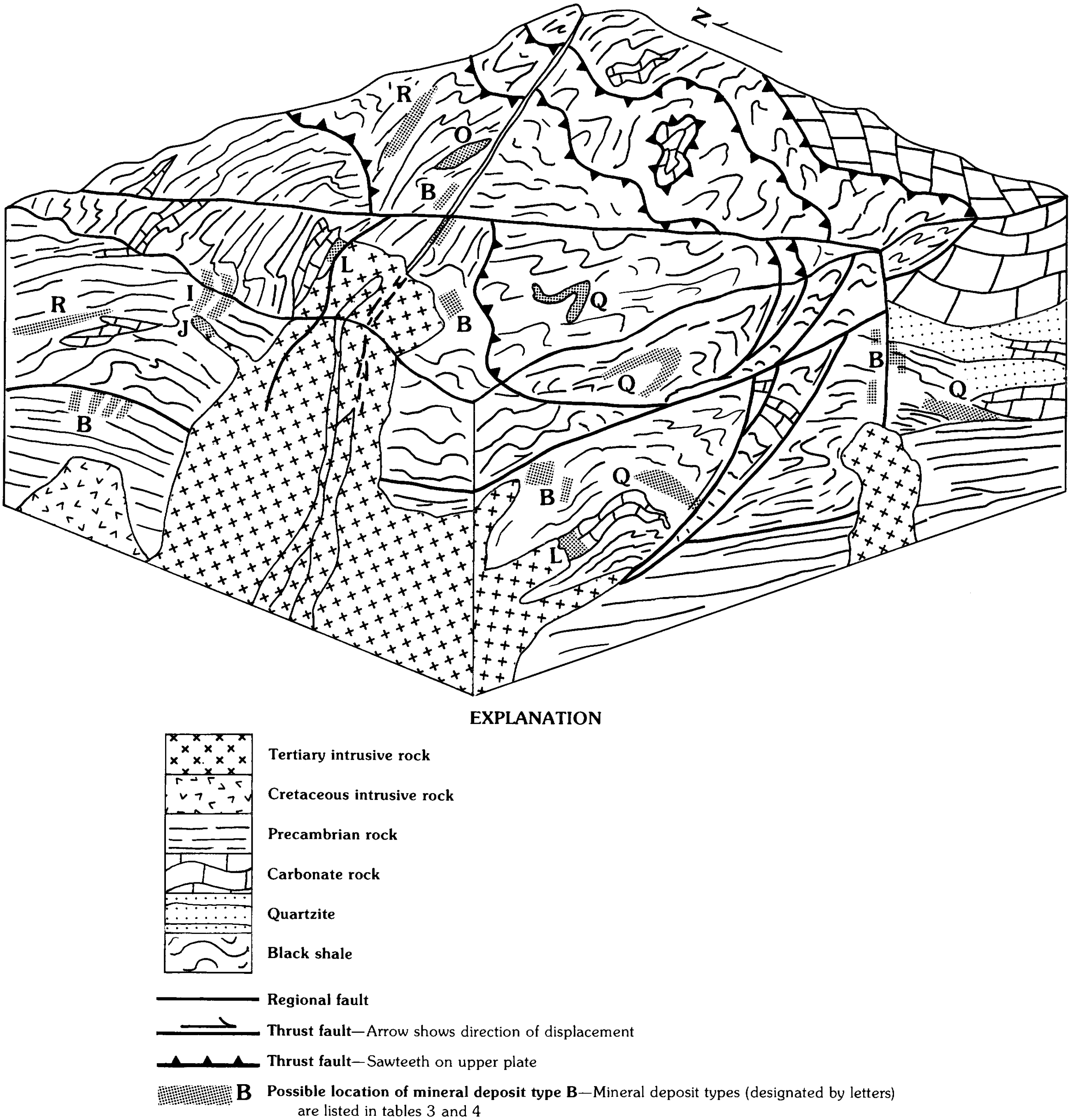


Figure 7. Schematic diagram of deposit types in black-shale terrane.

during the Tertiary igneous-hydrothermal events. The main differences among deposit types formed during the Tertiary events are in details of structural and lithologic setting. The same may be true, although less obviously so, for the deposits formed during the Cretaceous event.

Pegmatites and veins that formed from the late-stage fluids of the developing Cretaceous batholith concentrated a characteristic suite of metals including niobium, thorium, tin, tungsten, lithium, rare-earth elements, beryllium, and uranium. Some of the vein uranium deposits (H) (fig. 8), such as those at the Lightning No. 2 mine (H, fig. 5), might be related to pegmatitic rocks of the Idaho batholith. Known commercial metal deposits in pegmatites are located outside the Forest to the southwest. The metal and mineral concentrations in the late-stage crystallization products of the Idaho batholith, including pegmatites, were the source of the minerals in the radioactive black-sand placer deposits formed in Pleistocene to Holocene times.

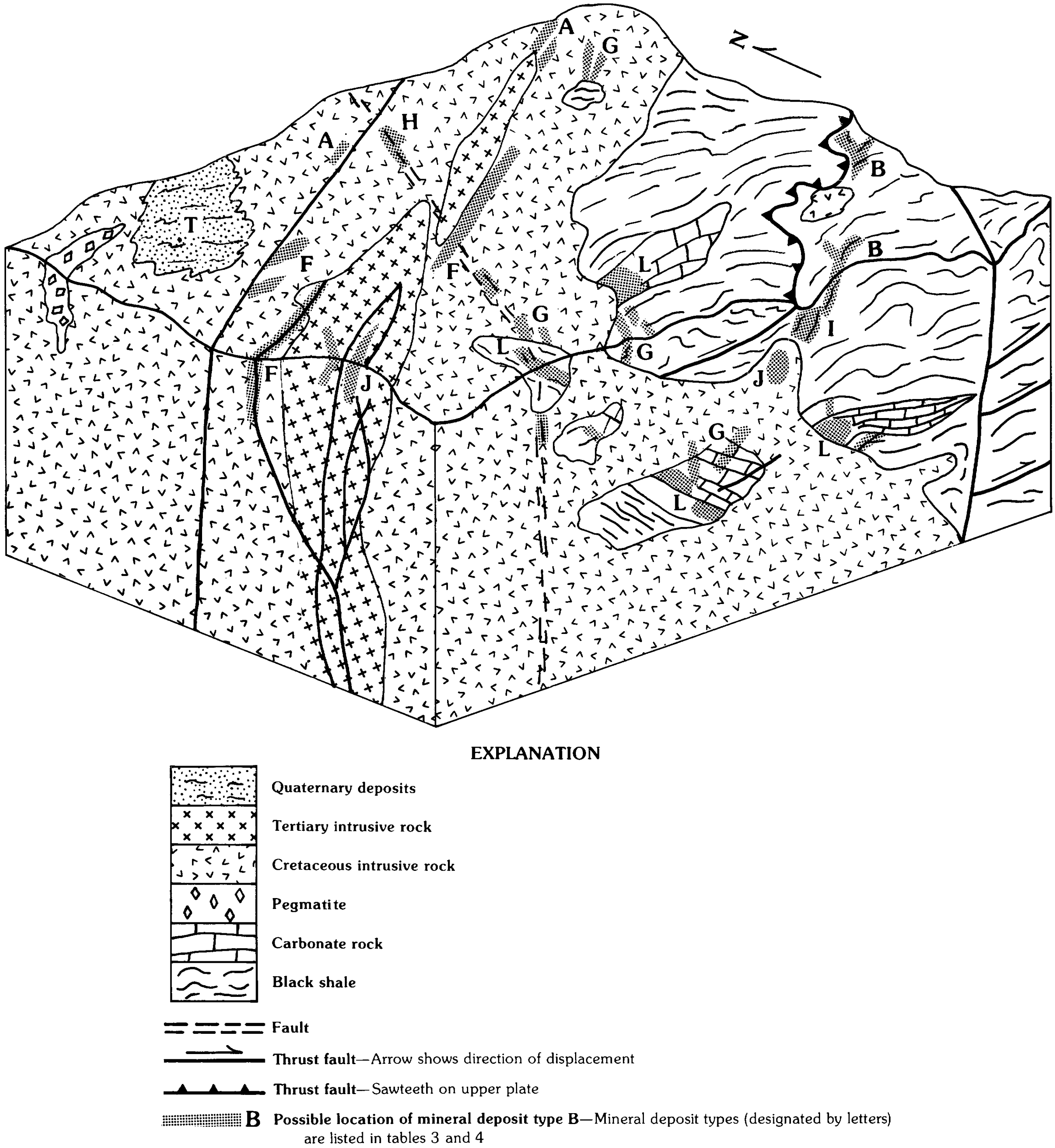
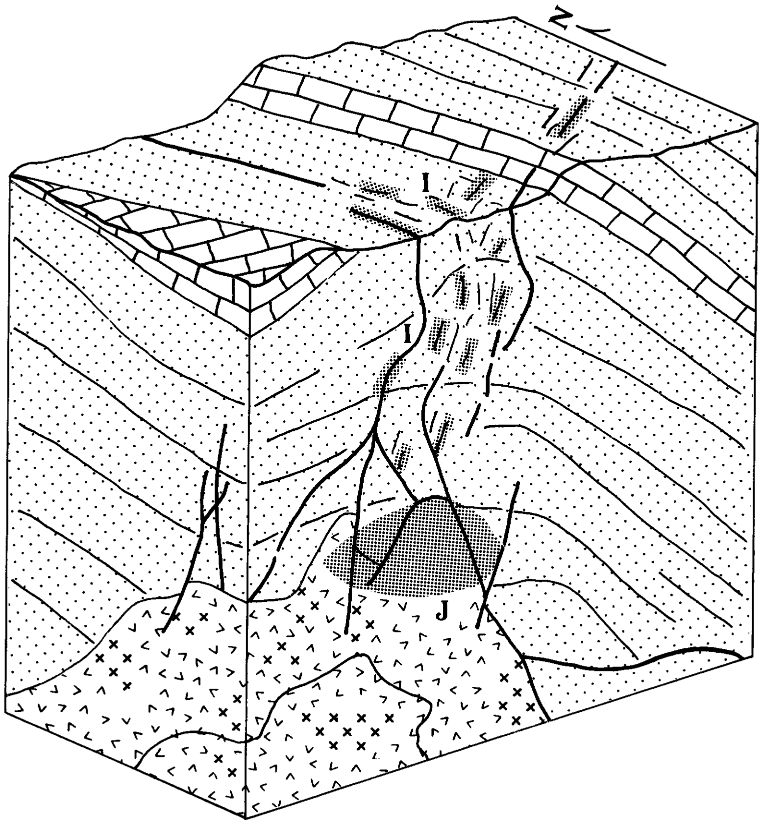


Figure 8. Schematic diagram of deposit types in Idaho batholith terrane.

Some of the Cretaceous plutons (probably satellite bodies of the Idaho batholith) contain stockwork molybdenum deposits (J) (figs. 7, 8, 9) with associated copper and silver, such as at the Thompson Creek mine (Ja, fig. 5). The stockworks are located in the upper parts of the intrusive body or in the surrounding country rocks and are generally associated with tungsten and base-metal skarn and vein deposits. Some stockwork molybdenum deposits (J) (figs. 8, 9) formed in and along Tertiary hypabyssal bodies. Examples are the Walton–White Mountain prospect (Jb, fig. 5) and the Ima mine (I, fig. 5). These deposits are a combination of disseminations in the intrusive rocks and stockworks and subparallel veins in the intrusive rocks and surrounding,



EXPLANATION

Tertiary or Cretaceous intrusive rock

Carbonate rock

Quartzite

Fault

I Possible location of mineral deposit type I—Mineral deposit types (designated by letters) are listed in tables 3 and 4

Figure 9. Schematic diagram of stockwork molybdenum and tungsten vein deposits.

intensely altered country rocks. Tungsten veins formed directly above the molybdenum stockworks at the Ima mine.

Polymetallic skarn deposits (L) (figs. 7, 8, 10, 11) formed where Cretaceous or Tertiary magmas intruded favorable country rocks, such as limestone and dolostone, and altered them to silicate minerals. Polymetallic skarn deposits associated with Cretaceous intrusive rocks are generally enriched in tungsten but also contain lead and zinc. Many such deposits, like those at the Springfield mine (Lb, fig. 5), are within carbonate inclusions in batholithic rocks (fig. 8). Other such deposits are around the satellite bodies of the Idaho batholith, especially bodies that contain the stockwork molybdenum deposits, such as at the Tungsten Jim mine (Bayhorse district, fig. 4). Polymetallic skarn deposits formed along Tertiary plutonic bodies and along smaller felsic dikes, dike swarms, and irregular-shaped bodies. Examples of skarn deposits along a plutonic body are the deposits at the Empire mine (La, fig. 5). Examples of skarn deposits along hypabyssal bodies (fig. 10) are some of the deposits in the Star Hope (Copper Basin district, fig. 4) and Windy Peak areas (Spring Mountain district, fig. 4). Polymetallic skarn deposits are mainly copper, lead, zinc, and silver occurrences but include some tungsten and iron.

Emplacement of the Idaho batholith and related bodies generated hydrothermal vein deposits. Most of the base-metal veins (G) (fig. 8) probably formed during the Cretaceous intrusive-hydrothermal activity. Deposits in the Sea Foam mine (G, fig. 5) are good examples of this type. Many of the tungsten vein deposits that occur along north-trending fractures in Idaho batholith rocks

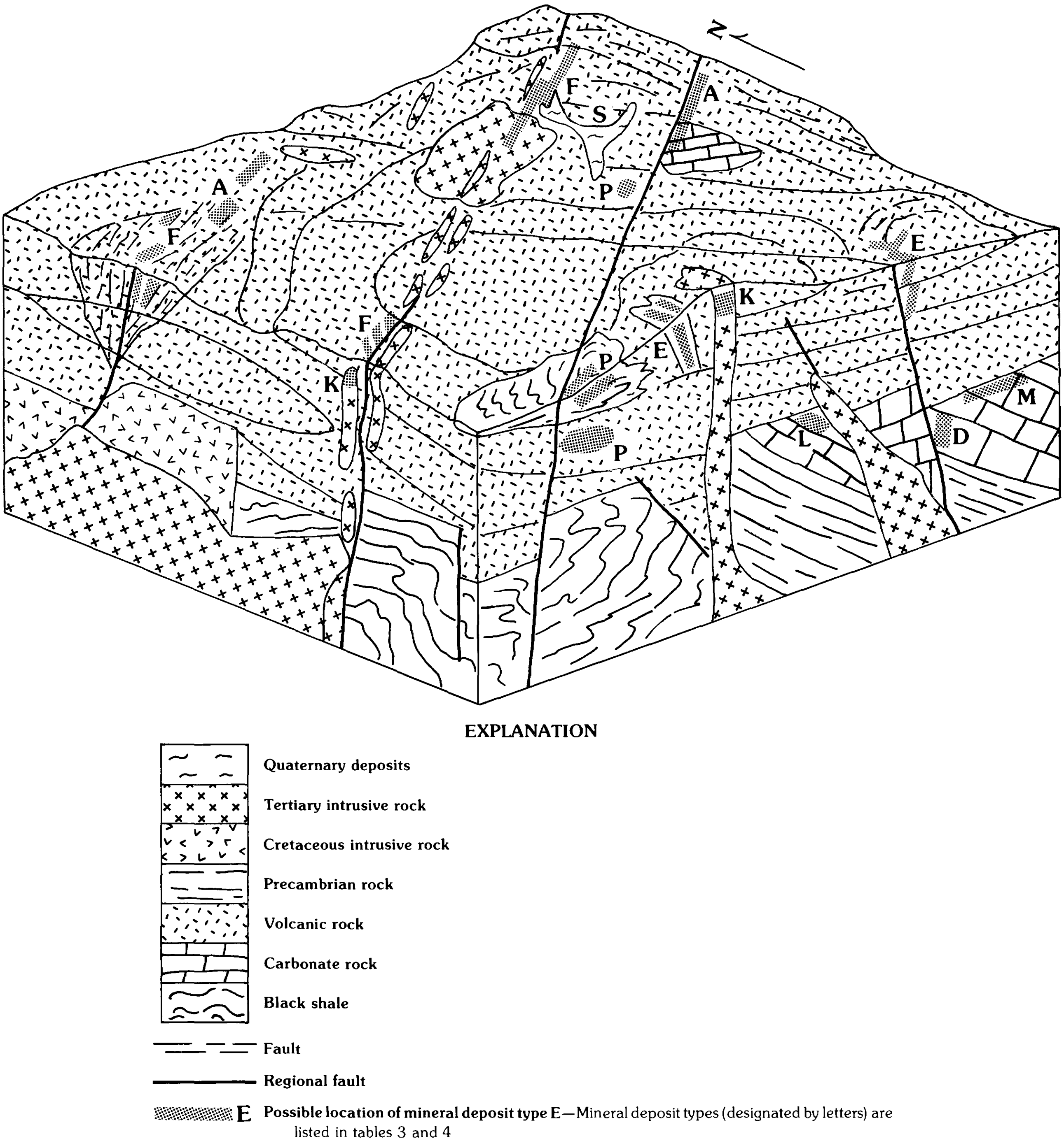


Figure 10. Schematic diagram of deposit types in volcanic terrane.

may also have been formed during this event, but some were probably formed during the Tertiary igneous-hydrothermal event. Polymetallic veins in black-shale terrane (B) (figs. 7, 8) developed within the contact metamorphic zones of both Cretaceous and Tertiary intrusive bodies. The Cretaceous and Tertiary deposits are indistinguishable, at least with the present state of knowledge, because most of the metals in these polymetallic veins were probably remobilized from the carbonaceous units.

Tertiary igneous-hydrothermal activity and attendant metallization took place in an environment of structural extension that was characterized by deep-seated high-angle fractures and rift structures. Deposits

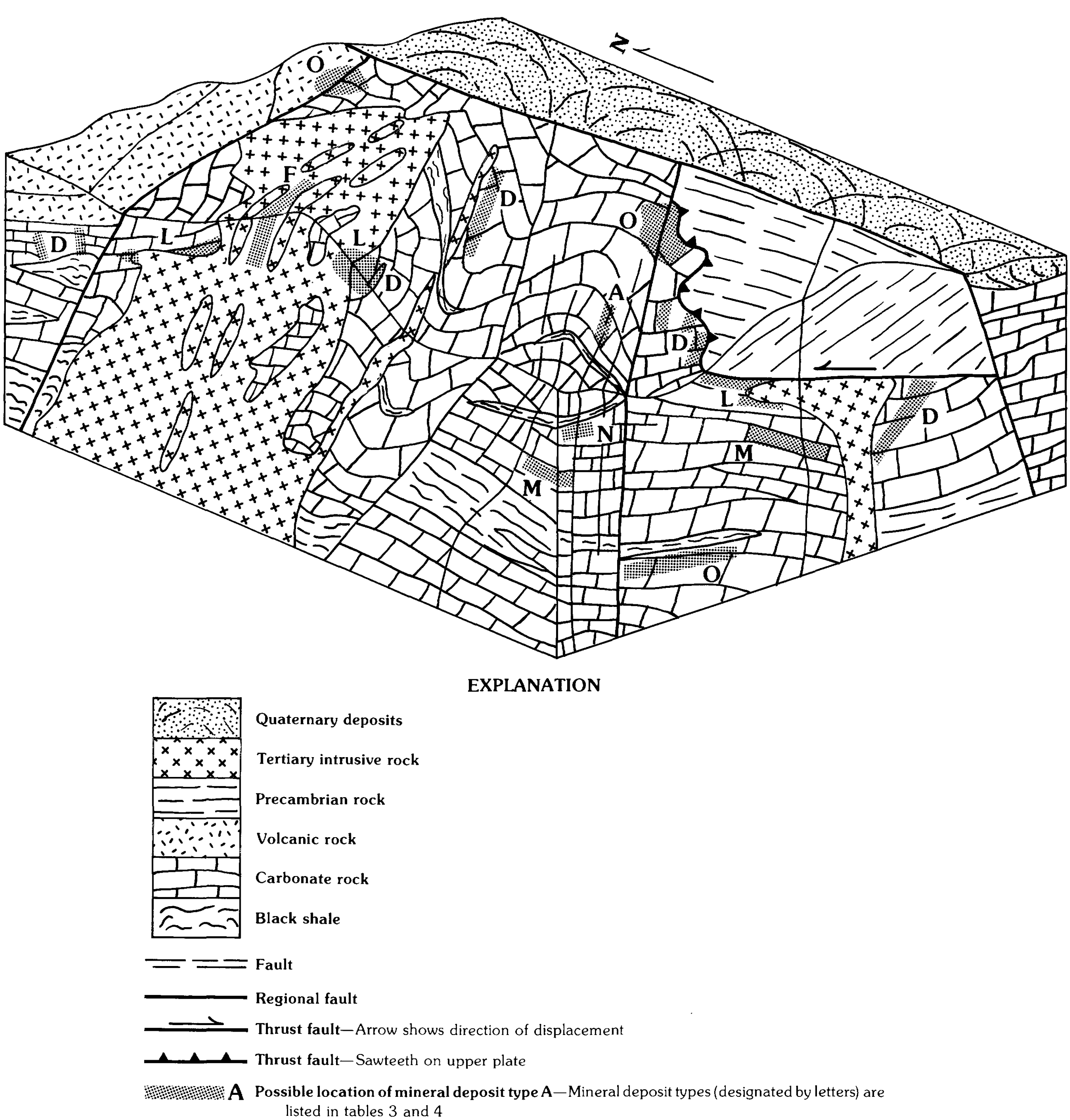


Figure 11. Schematic diagram of deposit types found in carbonate terrane.

formed in these geologic environments generally show some enrichment in fluorine, barium, potassium, silica, gold, silver, antimony, beryllium, iron, lithium, manganese, molybdenum, lead, strontium, tin, tellurium, uranium, vanadium, and zinc. The mineralogy, metal content, and physical form of an individual deposit depended upon the relative control of igneous rock composition, regional and local structures, depth below ground level, distance from intrusive rocks, composition and permeability of host rock, extent of development of hydrothermal system, and availability of metals.

The high-level, rhyolite-hosted, precious-metal deposits (K) (fig. 10) and the precious-metal deposits in volcanic tuffs (P) (fig. 10) represent late-stage and hydrothermal deposition of metals within the igneous rocks. The Tertiary stockwork molybdenum deposits (J) are similar but formed at a lower level in the crust and, in fact, may underlie some of the high-level, rhyolite-hosted,

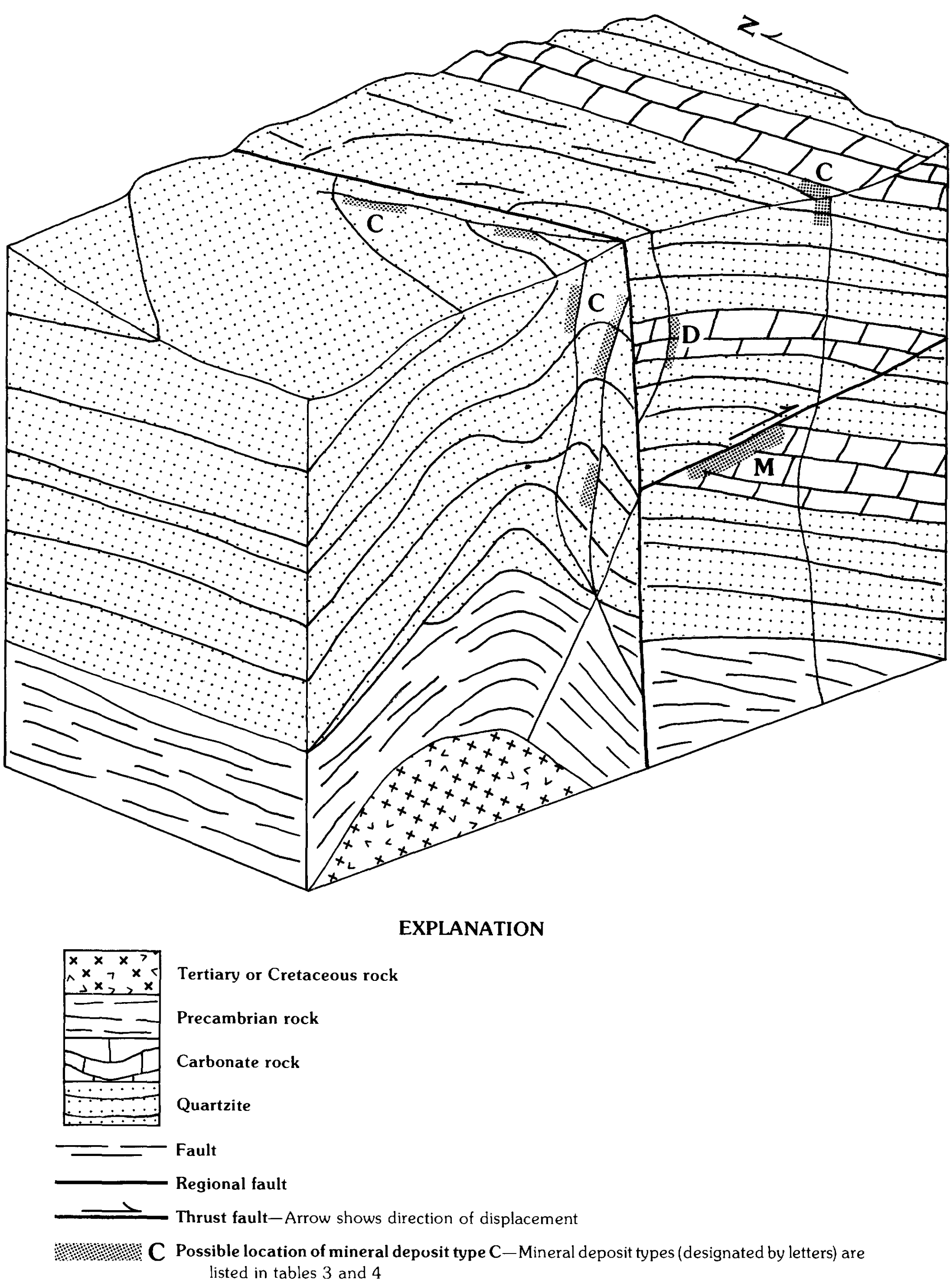


Figure 12. Schematic diagram of deposit types in quartzite terrane.

precious-metal deposits (K). An example of the high-level, rhyolite-hosted, precious-metal deposits is the Golden Sunbeam mine (K, fig. 5); an example of the precious-metal deposits in volcanic tuffs is the Sunnyside mine (Pa, fig. 5). Polymetallic vein deposits in carbonate terrane (D) (fig. 11), quartzite terrane (C) (fig. 12), black-shale terrane (B) (fig. 7), and Tertiary extrusive terrane (E) (fig. 10) are essentially the same in contained metals and mineralogy, although the types of deposit differ slightly in form. All polymetallic vein deposits formed in open fractures and breccia zones from hydrothermal solutions. Examples include the Windy Peak area (D, fig. 5) for carbonate terrane, the Wilbert mine (C, fig. 5) for quartzite terrane, the Livingston mine (B, fig. 5) for black-shale terrane, and the Hornsilver mine (E, fig. 5) for Tertiary extrusive rocks. Replacement of chemically receptive rocks accompanied all the polymetallic vein deposits. Polymetallic veins developed anywhere fractures and solution traps were available within an igneous hydrothermal system. The metals were in part remobilized from the country rock and in part introduced with the magmatic fluids. Some of the polymetallic veins are a considerable distance from major intrusive bodies (figs. 10, 12), whereas other veins are next to and within intrusive bodies (figs. 7, 8). The precious-metal veins (F) (figs. 8, 10, 11), fluorspar veins (A) (figs. 8, 10), and fluorspar breccia manto deposits (N) (fig. 11) are associated directly with rift systems and deep-seated extensional fault systems such as the trans-Challis (fig. 6). These deposits formed from low- to moderate-temperature hydrothermal systems and may be a considerable distance from any known, related intrusive activity (figs. 8, 10, 11).

Metal-bearing solutions that coursed along major high-angle fault systems in carbonate rock selectively formed irregular replacements of base and precious metals (M) (figs. 10, 11, 12) in carbonate rock. The replacement bodies are most common in breccia zones or beneath an impervious cap to the solutions. The irregular replacements of base and precious metals (M) are similar in metal content to the polymetallic veins in black-shale terrane, which suggests that the metals were mobilized from the underlying black shales. The Clayton Silver mine (M, fig 5) is an example of this type of deposit. The age and source of the solutions are unknown as there is no obvious igneous relationship.

Large areas of jasperoid associated with sediment-hosted, jasperoid-associated, precious-metal deposits (O) (fig. 11) were formed by solutions that replaced the enclosing rock with silica. Most of the known jasperoids in the Forest are in limestone and along or close to major fault systems and probably formed during mid- to late Tertiary time. The solutions may have been metal bearing, in which case there may be large low-grade gold deposits within or closely associated with some of the jasperoids. Jasperoids can be seen at Lehman Butte and Bartlett Point north of Mackay.

Certain minerals, including some heavy minerals, are resistant to chemical weathering and collect as a weathering residue in soils and eluvium. The heavy minerals are further concentrated because they tend to lag behind during fluvial erosion or to be deposited first when stream currents become inadequate to carry the sediment load. The resistance to weathering and lag effect were important factors in formation of the gold placer deposits (S) (fig. 10) and radioactive black-sand placer deposits (T) (fig. 8). The source of the gold was lode deposits, and the source of the radioactive black sands was rocks of the Idaho batholith. Weathering and fluvial action formed these deposits in Pleistocene to Holocene time.

Industrial Minerals

Fluorspar in veins (A) (figs. 8, 10) and in breccia manto deposits (N) (fig. 11) formed in and near deep-seated extensional faults of the trans-Challis fault system during the Tertiary igneous-hydrothermal event. Precious metals, base metals, and barite are associated with these deposits. Barite also formed in hydrothermal veins, stringers, and pods that may represent an outer zone of polymetallic veins in carbonate terrane. Examples occur in the Lone Cedar and Saw Mill Canyon areas of the west-central Lost River Range (shown as an area of unknown potential on plate 3). Higher concentrations of barite formed during deposition of the black-shale sequences. Syngenetic, bedded barite deposits in the black-shale sequences have been exploited south of the Forest boundary near Hailey, Idaho.

High-purity limestone and dolostone in the carbonate bank sequence and the White Knob Limestone formed in a shallow-water marine environment by precipitation of calcium carbonate from sea water and by accumulation of organisms rich in calcium carbonate. Lime rock in the Forest has not been exploited, but some of the beds may be of metallurgical or chemical grade.

Pegmatites are coarse-grained, dikelike or irregular-shaped masses of igneous rock that represent crystallization of the late-stage magmas and solutions of a developing batholith or pluton. Small pegmatites are common in association with the Idaho batholith. In addition to a distinctive suite of metals, pegmatites may also contain potentially commercial amounts of feldspar, quartz, and mica. Some of the pegmatites in the Forest have been prospected, but there is no recorded production. Many of the characteristic "pink" granites of Tertiary age in this part of Idaho contain abundant miarolitic cavities, which are small crystal-lined cavities that may contain semiprecious gemstones, such as smoky quartz, microcline, topaz, and beryl (aquamarine).

Carbonaceous sedimentary rocks, such as those in the black-shale terrane, are converted to graphitic schist upon medium-grade metamorphism. Graphitic schists are common along the eastern edge of, and as inclusions in, the Idaho batholith. An example of this type of occurrence is at the Gem State mine at the north end of Elk Mountain in the Stanley district (fig. 4).

Hydrothermal cells generated from the heat of intrusive magmas are often very large, and the solutions have a slight to pronounced effect upon the rocks through which they circulate. In addition to depositing metals in various forms and concentrations, the solutions produce economic concentrations of industrial minerals by alteration of the country rocks at some locations. Two industrial mineral commodities that form in this manner are alunite and the zeolite group of minerals; both commodities occur in the Forest, but neither has been exploited. Alunite [$KAl_3(SO_4)_2(OH)_6$] forms as a product of the highest degree of alteration from strongly acidic fluids that interact with volcanic host rocks. The alteration effects on volcanic rocks in the outer margins of hydrothermal cells and from diagenetic reactions with meteoric water are commonly subtle and not readily apparent. Zeolite minerals (hydrous aluminosilicates) are common alteration products in these environments. Alteration products also include pods and veinlets of chalcedony (including agate), jasper, and opal; all these minerals are of interest as semiprecious gem stones.

RESOURCE POTENTIAL—LOCATABLE MINERALS

The Challis National Forest was evaluated for 20 deposit types (pl. 3, table 4). Table 4 is shown in the text and reproduced in part on plates 3 and 4 as an aid in following discussions of each deposit type. In this section the characteristics of known and inferred deposit types are summarized and specific areas of high, moderate, and unknown potential are reviewed. Definitions of the terminology that is used, specifically the meaning of the several levels of resource potential, are in Appendix 1. Size classifications for each deposit type are listed in Appendix 2.

Specific areas having high, moderate, or unknown mineral resource potential are given a letter-number designation. As an example, all areas that have a resource potential for stockwork molybdenum deposits, are shown with the letter J and a number following the letter, such as J1, J2, J3, and so on. Each letter-number combination (J2, for example) indicates an area with a specific resource potential/level of certainty for a restricted set of commodities that occur in a certain size and type of deposit. Areas can have different potential/certainty levels, for example J2 (H/D), J3 (H/C), J4 (M/D), and so on. Areas can have the same potential/certainty levels, such as J1 (H/D) and J2 (H/D), but different potential commodities or deposit size. All areas of a single letter-number combination, such as J2, have the same potential/certainty levels for the same set of commodities and same deposit size.

On plates 3 and 4 and figures 13–32, areas of high potential are shown in red, and areas of moderate potential are shown in pink. Areas of unknown potential are shown by black diagonal lines (fig. 33).

Fluorspar Veins (A)

Commodities, By-products, and Trace Metals

Fluorspar and gold; antimony is a potential by-product.

Host Rocks

Deposits are in plutonic and volcanic rocks. In the Stanley district (fig. 4) deposits are in granodiorite and porphyritic granodiorite of the Idaho batholith. In the Meyers Cove area, Gravel Range district (fig. 4), deposits are in a thick section of welded ash-flow tuffs of Eocene age (Fisher, McIntyre, and Johnson, 1983). Other deposits are in Tertiary granitic and dioritic rocks.

Structural Control

Deposits are within the trans-Challis fault system and localized along northeast- and northwest-trending high-angle faults and shears.

Age

Tertiary, probably Oligocene.

Deposit Description

Deposits are discontinous fissure and breccia fillings along northeast- and northwest-trending zones. Individual veins range from a few inches to more than 12 ft wide and 10 ft to several hundred feet long. Composite veins and groups may cover much larger areas. The veins are banded, vuggy, crustiform, and drusy and are suggestive of near-surface deposition. Fluorite, chalcedony, and quartz are the dominant minerals with some calcite, barite, stibnite, and base-metal sulfides. In the Stanley area fluorite is a common component of quartz-pyrite-gold veins. Small felsic and mafic dikes occur within and adjacent to many of the deposits. The type locality for this model is the Meyers Cove area (A, fig. 13), Gravel district (fig. 4).

Geochemical Signature

The Meyers Cove type locality was sampled by the USGS Challis CUSMAP project (fig. 5). Both the heavy-mineral fraction of the stream sediments and the stream sediments contained anomalous concentrations of some metals. Stream sediments contained anomalous concentrations of Ag, Be, Mo, and the heavy minerals contained

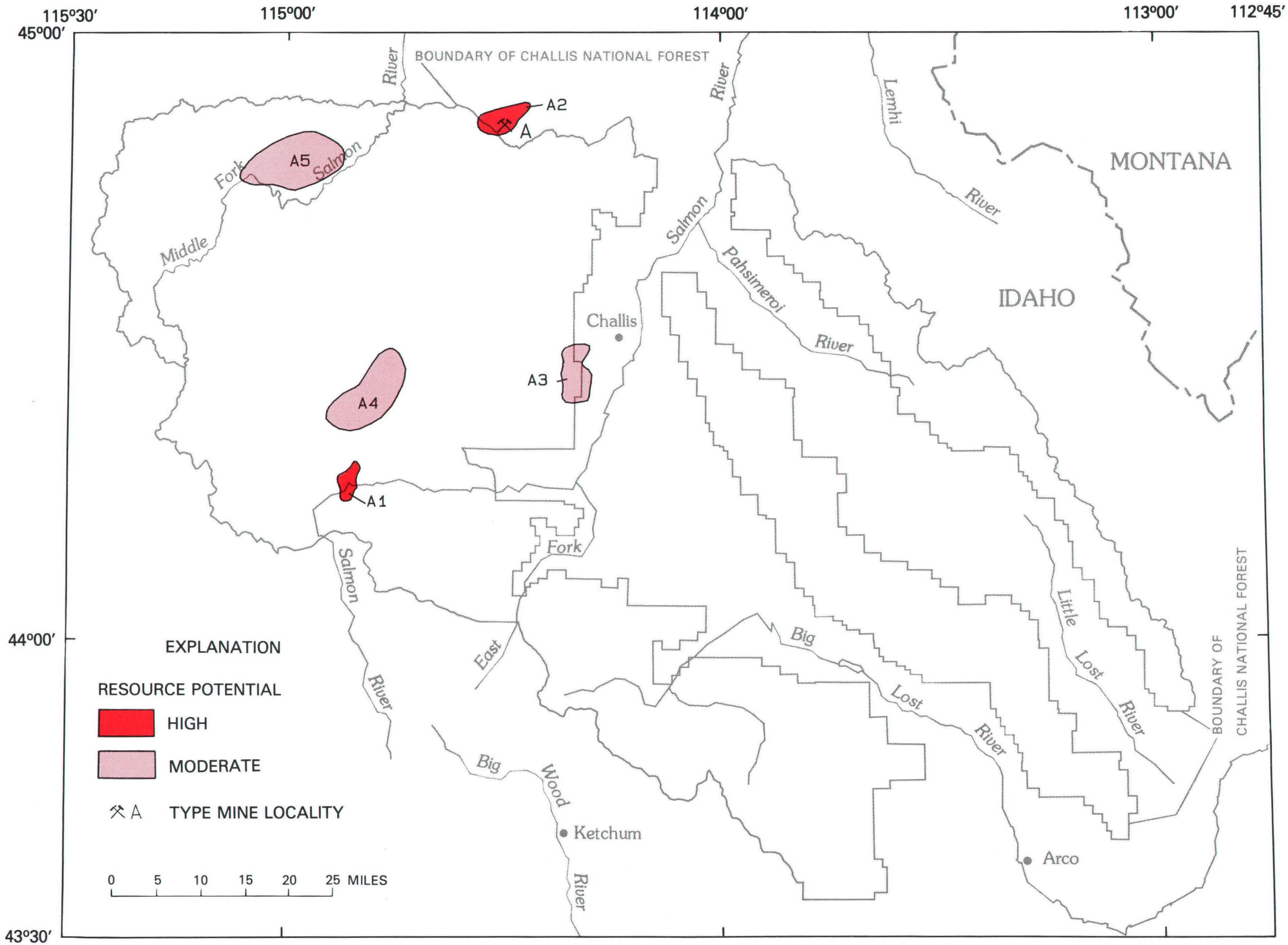


Figure 13. Mineral resource potential map for fluorspar veins (A) in the Challis National Forest and adjacent areas, Idaho. Areas (A1, A2, and so forth) of mineral resource potential are described in table 4.

anomalous concentrations of Sn, Ag, Au, and Pb (table 7). A geochemical signature commonly associated with fluorspar deposits of this type is Sb, Fe, As, Au, Ag, Hg, W, Pb, and Zn.

Geophysical Signature

The deposits have no geophysical expression, but some major faults show as linear zones of sharp magnetic gradient.

Assessment Criteria

1. Presence of high-angle faults or fractures.
2. Proximity to major tensional faults of the trans-Challis fault system.
3. Evidence of fluorspar mineralization.
4. Proximity to Tertiary hypabyssal intrusions.

Assessment

Fluorspar occurrences of this type are mostly confined to structures related to the trans-Challis fault system. They are part of a northeast-trending zone of fluorite occurrences, which extends from northwestern Nevada through Idaho into Montana. Two areas in the Forest, the Stanley fluorspar district (A1) and the Meyers Cove fluorspar district (A2), are assigned a high potential (H/D) for fluorspar vein deposits. In both areas fluorspar is in major deep-seated fracture systems of sufficient size to host exploitable deposits. Three other areas (A3, A4, A5) are assigned moderate potential (M/D). In these areas fluorite occurs mainly as a gangue mineral in other vein systems or as fluorspar veins in small isolated structures. In the Bayhorse area (A3) the fluorspar potential is mainly in manto bodies discussed elsewhere. The areas of resource potential for fluorspar veins (A) are shown on plate 3 and figure 13 and summarized in table 4.

Economic Significance

Fluorspar districts in Idaho and elsewhere in the Western United States are mostly inactive. Nearly all the fluorspar consumed in the United States comes from much larger foreign sources. Development of fluorspar properties in Idaho would require an increased demand and higher prices for fluorspar.

Polymetallic Veins in Black-Shale Terrane (B)

Commodities, By-products, and Trace Metals

Silver, lead, and zinc; gold, tin, antimony, and copper are potential by-products. Tellurium and selenium are present in some deposits.

Host Rocks

The host rocks are mainly black argillite or carbonaceous micritic limestone and also include siltstone, shale, fine-grained quartzite, and gray limestone. Veins are mostly in contact metamorphic zones close to felsic intrusive bodies where the country rocks have been altered to hornfels, tremolite-bearing limestone, calc-hornfels, and locally skarn.

Structural Control

The deposits are in high-angle faults and flat to steep-dipping sheared zones beneath major thrust faults or near regional unconformities.

Stratigraphic Control

Host rocks are the Salmon River assemblage of Late Cambrian, Late Devonian, and Late Mississippian age, the Ramshorn Slate of Ordovician(?) age, the lower part of the Copper Basin Formation of Mississipian age, and unassigned Ordovician, Silurian, and Devonian argillaceous rocks. Known deposits are all within about 3.5 mi of felsic intrusive bodies.

Age

Probably ranges from Cretaceous to Eocene.

Deposit Description

Small discontinous veins, lenses, and pods with strike length as much as 900 ft and width as much as 15 ft. Ore is mostly massive, fine- to coarse-grained sulfides but also includes disseminated sulfides in a quartz and (or) siderite or calcite gangue and in altered, sheared carbonaceous host rock. Weathering of the deposits forms noticeable to inconspicuous gossans, some of which were mined in the past for lead-silver and gold. The type locality for this model is the Livingston mine (B, pl. 3, fig. 14), Boulder Creek district (fig. 4).

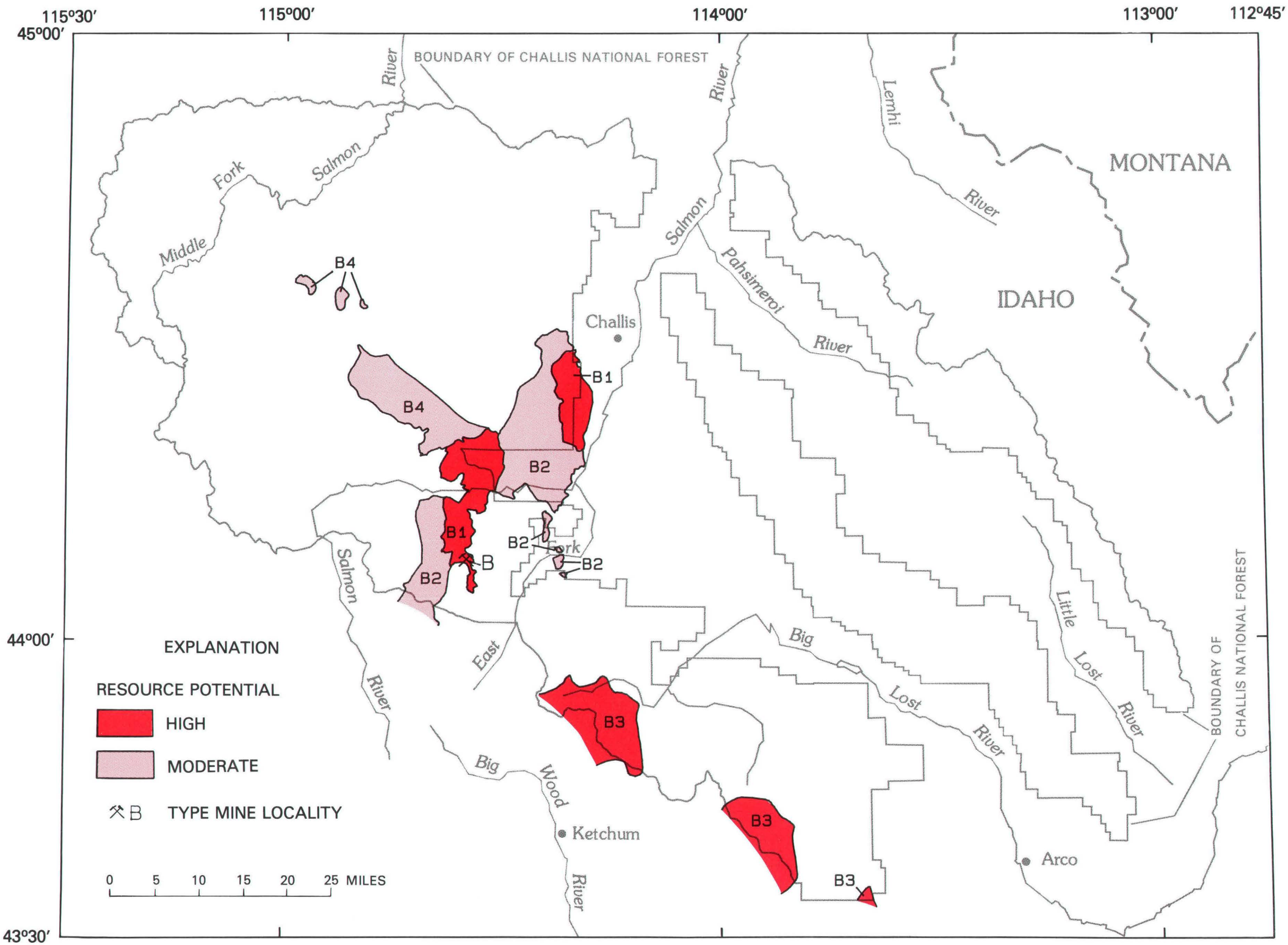


Figure 14. Mineral resource potential map for polymetallic veins in black-shale terrane (B) in the Challis National Forest and adjacent areas, Idaho. Areas (B1, B2, and so forth) of mineral resource potential are described in table 4.

Geochemical Signature

The Livingston mine type locality is within the eastern part of the Sawtooth National Recreation Area (fig. 5). Rock and stream-sediment samples are characterized by several elements in anomalous concentrations (table 7). Both rocks and stream sediments were anomalous in Sn, As, Sb, Cd, Zn, Pb, Au, and Ag. Rock samples were also anomalous in Hg, W, Bi, and Cu. Stream sediments were also anomalous in Mo. A geochemical signature commonly associated with polymetallic veins, regardless of terrane, is Zn, Cu, Pb, As, Au, Ag, Mn, Ba, Sb, and Bi.

Geophysical Signature

The deposits themselves have no direct geophysical expression, but some intrusives and major structures exhibit prominent anomalies and steep gradient zones in the magnetic and gravity anomaly data. Magnetic data suggest the presence of larger intrusive bodies in the subsurface beneath the outcrops of small plutons and hypabyssal bodies in the Bayhorse district (fig. 4) (B1, B2) and the Summit Creek area (Alto district, fig. 4) (B3). Likewise in the Star Hope (Copper Basin district, fig. 4) (B3) and Leadbelt (Lava Creek district, fig. 4) (B3) areas, magnetic data suggest buried intrusives in the vicinity.

Assessment Criteria

1. Black-shale terrane with carbonceous beds, micritic limestone, and black argillite.
2. Proximity (within 4 mi) to a granitic pluton.
3. Locally anomalous concentrations of Pb and Zn.

Assessment

A large part of the exposed black-shale terrane is favorable for polymetallic vein deposits. Two areas (B1) are assigned high potential (H/D) because of the presence of all three criteria, plus the presence of known deposits. Three areas (B3) are assigned a high level of potential but with low certainty (H/B) because of a lack of geochemical and stratigraphic knowledge. Much of the remainder of the black-shale terrane [areas B2 (M/D) and B4 (M/B)] is assigned moderate potential. Special attention is directed to area B4 by Fisher and others (1987) because of extensive areas of anomalous silver shown by stream-sediment samples. This is an area where volcanic cover is thin and discontinuous and windows of Paleozoic rocks are present. The areas of resource potential for polymetallic veins in black-shale terrane (B) are shown on plate 3 and figure 14 and summarized in table 4.

Economic Significance

Base metals and silver are supplied primarily from large-tonnage domestic and foreign mines. A major increase in demand or much higher prices for these commodities would be needed to support operation of small mines. The possible production of antimony, gold, and tin as by-products would enhance a mining operation.

Polymetallic Veins in Quartzite Terrane (C)

Commodities, By-products, and Trace Metals

Silver and lead; gold and zinc are potential by-products.

Host Rocks

Host rocks are quartzite, dolomitic quartzite, and sandy dolostone. The rock sections also include some shaly limestone and black shale. The mineralized zones are mostly in dolomitic members and in carbonate-altered quartzite (Umpleby, 1912). In the southern Lemhi Range the host units are in the Wilbert and Summerhouse Formations. Alteration consists of formation of jasperoid in the dolostone and carbonate replacement of the quartzites, with a halo of manganese and iron oxides. It is not known if the silicification and carbonate alteration involved introduction of silica and carbonate with the mineralizing solutions or local redistribution by hydrothermal solutions.

Structural Control

Structures important to ore deposition are north- to northwest-trending high-angle faults. Alteration patterns and mineralized zones are centered on these structures. Local fracture zones associated with north-trending folds and thrust faults were favorable for ore deposition.

Stratigraphic Control

The major mineralized zones are along bedding of dolomitic members of the quartzites, along carbonatized quartzites, or along highly fractured zones in quartzite.

Age

No older than Tertiary as mineralization cuts dike rocks thought to be Tertiary (Ross, 1933, p. 5).

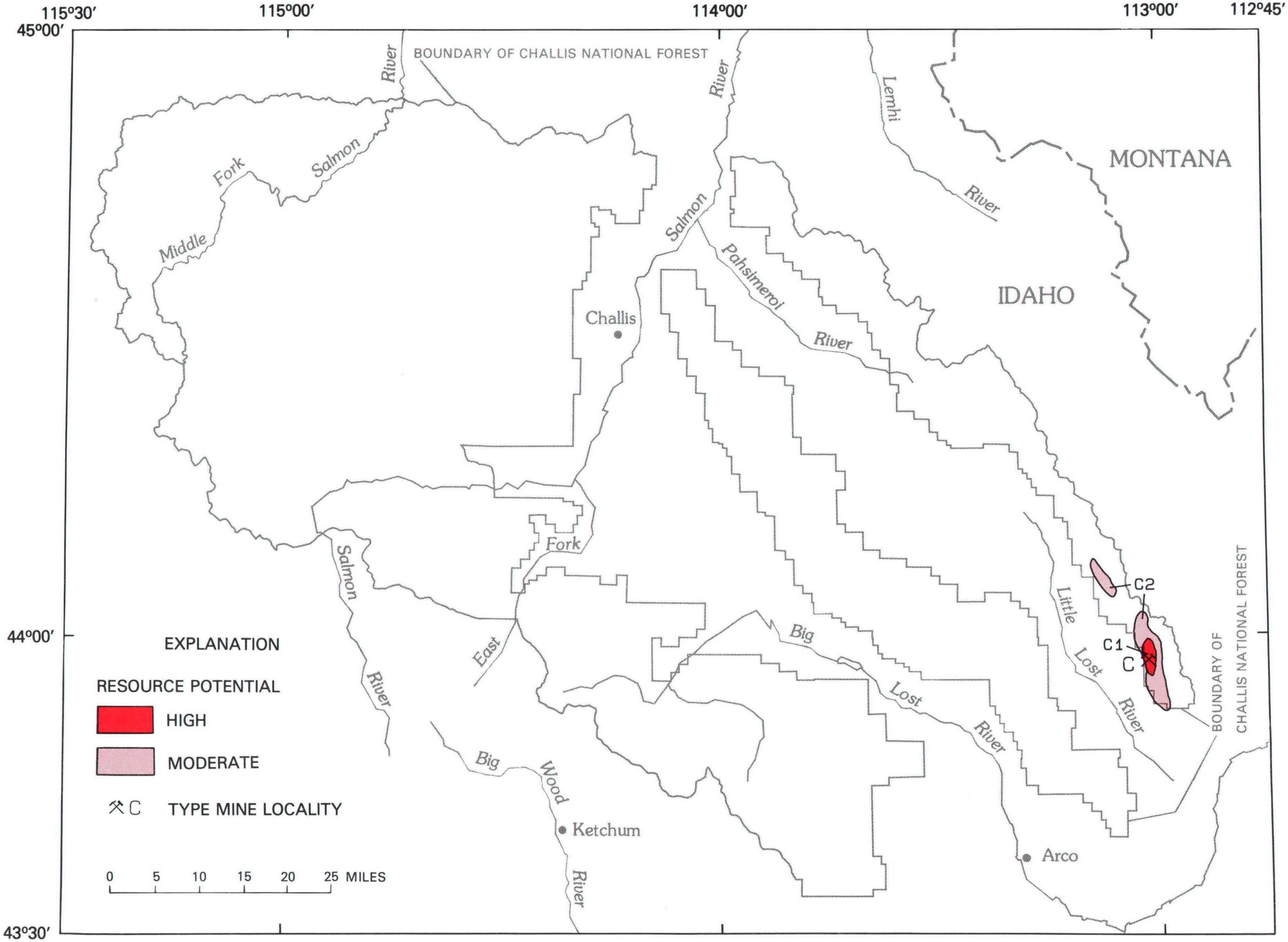


Figure 15. Mineral resource potential map for polymetallic veins in quartzite terrane (C) in the Challis National Forest and adjacent areas, Idaho. Areas (C1, C2) of mineral resource potential are described in table 4.

Deposit Description

Three types of ores are recognized in the Wilbert mine (C, pl. 3, fig. 15), Dome district (fig. 4), that are typical of this deposit type (Umpleby, 1917). The higher grade ore (20–35 percent lead) is composed of thin lenses and stringers of galena partially altered to anglesite. The second type, which is lower grade (12–20 percent lead), consists of disseminated grains of galena and has a salt-and-pepper appearance. The third type consists of galena as a fissure filling and breccia cement. The primary ore mineral is galena with minor amounts of sphalerite. Gangue is sparse and consists mainly of carbonate minerals, jasperoid, and wall-rock fragments, with minor vein quartz, barite, and smithsonite. Pyrite is disseminated through altered wall rocks. The oxidized portions contain anglesite, cerussite, lead oxides, and locally malachite, azurite, and wulfenite, in addition to iron and manganese oxides. These ores are characterized by their fine-grained nature, by the individual grains of galena which are generally less than 2 mm in diameter, and by the lack of gangue minerals. They have no close spatial association with igneous bodies.

Geochemical Character

The Wilbert mine type locality is within the Idaho Falls NURE study boundary (fig. 5). Stream sediments nearest the mine were anomalous in Pb (table 7). Few samples were collected near the type locality, and the anomalous element suite is based on only one sample. A geochemical signature commonly associated with polymetallic veins regardless of terrane is Zn, Cu, Pb, As, Au, Ag, Mn, Ba, Sb, and Bi.

Geophysical Character

Some of the regional high-angle faults may be detectable by magnetic or gravity methods.

Assessment Criteria

1. Evidence of base- or precious-metal mineralization.
2. Presence of deep-seated high-angle faults.
3. Presence of quartzite terrane with dolomitic units.
4. Carbonate alteration of quartzites along and extending away from faults.

Assessment

Portions of the southwestern part of the Lemhi Range (C2) have a moderate potential for this type of deposit. A small area (C1) in the vicinity of the Wilbert mine is assigned a high potential. The areas of resource potential (C1, C2) are cut by several high-angle fault systems, carbonate-altered quartzites occur along some of the fault systems, the quartzite sequence contains dolomitic units, and there has been production from several mines. Because there is no supporting geochemistry or detailed field mapping, a low certainty level is given to the high (H/B) and moderate potential (M/B) assignments. The expected orebodies are similar in size and grade to those exploited in the Wilbert mine. Consideration must also be given to potential gold deposits in this area, perhaps in zones of intense silicification. The areas of resource potential for polymetallic veins in quartzite terrane (C) are shown on plate 3 and figure 15 and summarized in table 4.

Economic Significance

Lead and silver are supplied primarily from large-tonnage domestic and foreign mines. A major change in demand or increase in price for these commodities would be needed to support operation of small mines. Production of gold as a by-product would certainly enhance the possibility of development.

Polymetallic Veins in Carbonate Terrane (D)

Commodities, By-products, and Trace Metals

Lead and silver; trace to by-product amounts of zinc, gold, and copper.

Host Rocks

Known host rocks are white to blue, massive to thick-bedded limestone of the Saturday Mountain Formation, the White Knob Limestone, and the carbonate bank sequence. The host rocks are generally not altered, and contact metamorphism is limited to a narrow zone of calcite and some calc-silicate minerals along some of the veins.

Structural Control

The deposits are within or closely related to high-angle faults. In the central part of the Lemhi Range, Spring Mountain district (fig. 4), the faults trend just east of north and dip steeply west. Locally felsic dikes occupy faults of the same general trend. In Leadbelt Creek area of the Lava Creek district (fig. 4) the faults and dikes trend northwest.

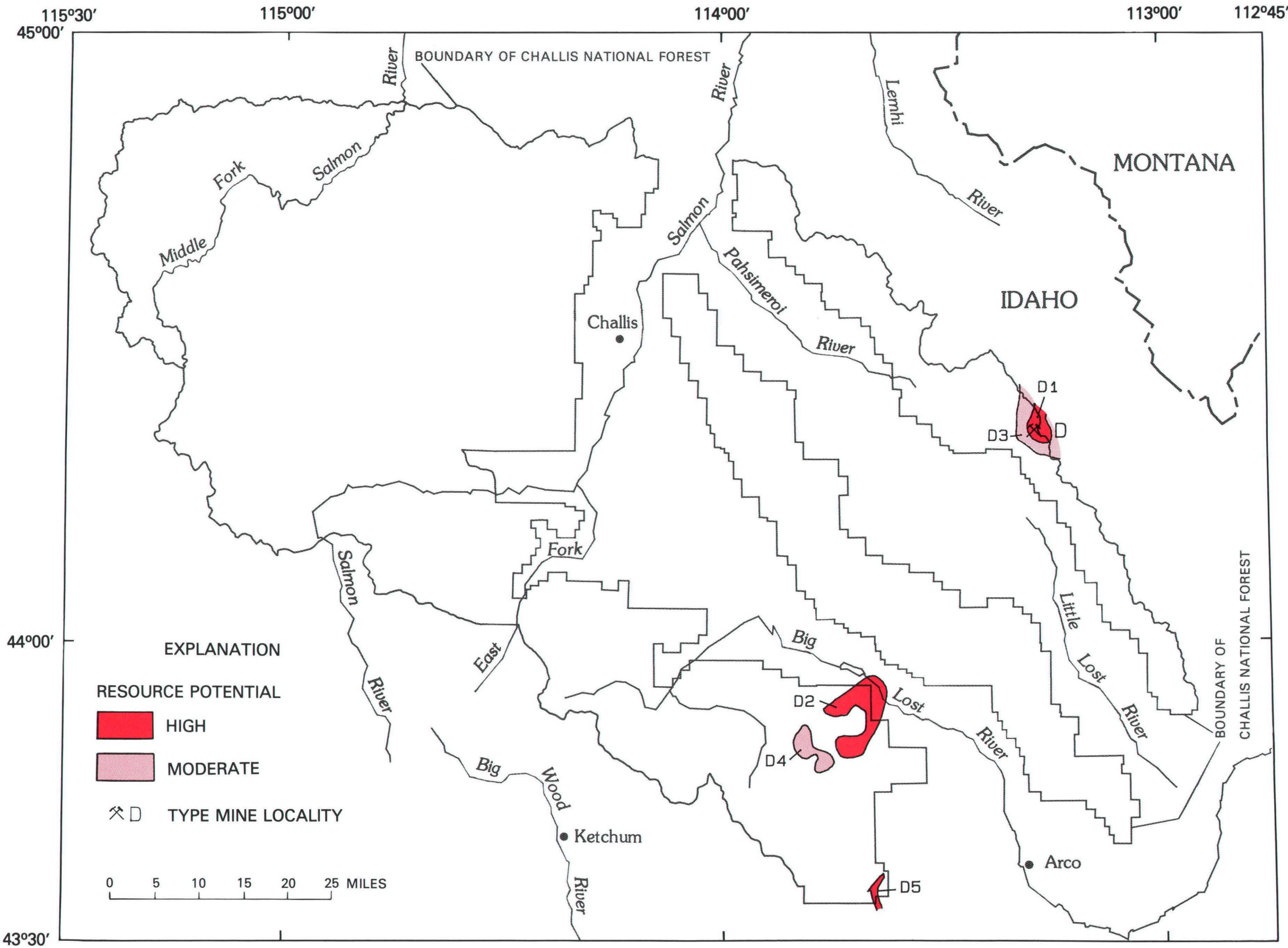


Figure 16. Mineral resource potential map for polymetallic veins in carbonate terrane (D) in the Challis National Forest and adjacent areas, Idaho. Areas (D1, D2, and so forth) of mineral resource potential are described in table 4.

Age

Cretaceous to Eocene.

Deposit Description

The deposits are mainly replacements along fractures and bedding planes of limestone. The ore minerals, argentiferous galena, pyrite, chalcopyrite, and sphalerite occur as disseminations, clots, and lenses; gangue is not abundant and is largely quartz and some calcite. Many of the deposits were worked only in the oxide zones where iron and manganese oxides, cerussite, and cerargyrite are common. The individual orebodies are generally tabular and range greatly in size, with none larger than a few thousand tons. The type locality for this model is in the Windy Peak area (D, fig. 16), Spring Mountain district (fig. 4).

Geochemical Signature

The Windy Peak area type locality is within the Dubois NURE study boundary. No samples were collected near the type locality, and thus no geochemical signature can be identified with the type locality. A geochemical signature commonly associated with polymetallic veins, regardless of terrane, is Zn, Cu, Pb, As, Au, Ag, Mn, Ba, Sb, and Bi.

Geophysical Signature

Deposits of this type may be detectable by detailed electrical methods. In the Windy Peak area the strongly oriented, linear magnetic gradient zones suggest northeast-trending structural zones that may have influenced the distribution of mineralization.

Assessment Criteria

1. Presence of carbonate terrane.
2. Presence of high-angle faults or fractures.
3. Indication of base- or precious-metal mineralization.
4. Hypabyssal igneous bodies; also along high-angle faults.

Assessment

The area (D1) around the mines in the vicinity of Windy Peak, Spring Mountain district (fig. 4), in the central part of the Lemhi Range, is assigned a high potential (H/C). This is the western part of a major mining district. A larger area (D3) surrounding D1 is assigned a moderate potential, but with a low level of certainty (M/B) because of a lack of information. The eastern part (D2) of the Alder Creek district (fig. 4) in the White Knob Mountains is assigned a high potential (H/C). Much of the lead and zinc production from this district was from veins in limestone. A small area of limestone (D4) in the western part of the Alder Creek district (fig. 4) is assigned a moderate potential with a low level of certainty (M/B). The vicinity of the Leadbelt mine (D5) in the Lava Creek district (fig. 4) is assigned a high potential with low certainty (H/B) for polymetallic veins in limestone. This area is along a major thrust fault, and mineralization occurs in the overlying limestone and in the underlying rocks of the black-shale terrane.

Hidden orebodies of this type are difficult to detect, and there are probably others similar in size and grade to those already mined in all of these districts. The areas of resource potential for polymetallic veins in carbonate rock terrane (D) are shown on plate 3 and figure 16 and summarized in table 4.

Economic Significance

Lead and silver are supplied primarily from large-tonnage domestic and foreign mines. A major change in demand or increase in price for these commodities would be needed to support operation of small mines. Production of gold as a by-product would certainly enhance the possibility of development.

Polymetallic Veins in Tertiary Extrusive Terrane (E)

Commodities, By-products, and Trace Metals

Silver, lead and zinc; trace to by-product amounts of copper, gold, tin or bismuth.

Host Rocks

Host rocks are highly altered volcanic rocks including flow rock, pyroclastics, and hypabyssal intrusive rocks. Rocks in the vicinity of the orebodies are silicified (chalcedony), sericitized, pyritized, and locally altered to alunite. The rocks in general are bleached light gray and have abundant cubes of weathered pyrite. Sericitization extends farthest (tens of feet) from the lodes; on the outer edges sericitization is shown by partial replacement of feldspars by sericite. Near the lodes the original texture of the wall rocks is completely obliterated.

Structural Control

The deposits are associated with major northwest-trending high-angle faults, especially near the intersection with northeast-trending high-angle faults. The

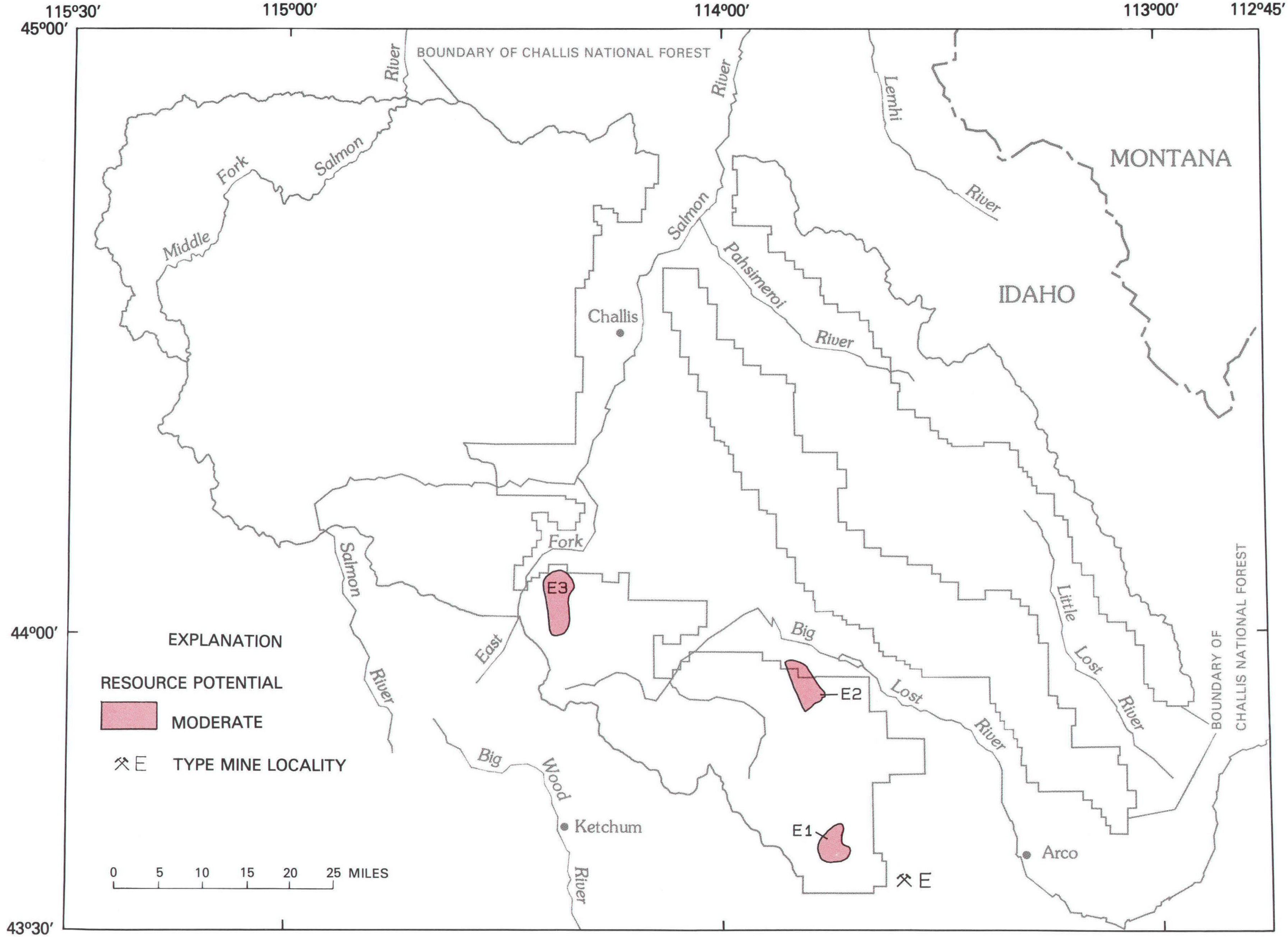


Figure 17. Mineral resource potential map for polymetallic veins in Tertiary extrusive terrane (E) in the Challis National Forest and adjacent areas, Idaho. Areas (E1, E2, E3) of mineral resource potential are described in table 4.

deposits are mostly in minor fissures and fracture zones that trend north and west; a few deposits are in minor fractures parallel to the major trends of northwest or northeast. Intersections of fissure and fracture zones contain the larger and higher grade orebodies.

Age

Tertiary.

Deposit Description

These deposits are characterized by an unusual mineral assemblage resulting from several stages of mineralization. At the Hornsilver mine (E, fig. 17), Lava Creek district, just south of the Forest, the ore minerals are grouped into early and late assemblages (Anderson, 1947b, p. 459). The early assemblage includes chalcedony, sericite, galena, sphalerite, pyrite, marcasite, and wurtzite. These minerals occur as fillings and replacements along fissures and complexly fractured rock. The ore minerals form small shoots and scattered masses along the fissures or breccia zones and are disseminated in the altered wall rock. The ore zones are very irregular and range from stringers to fillings and replacements in breccia zones that are several feet wide. The fissures and breccia fillings generally do not have distinct boundaries with the altered country rock. The late assemblage includes quartz, barite, pyrite, stannite, tetrahedrite, famatinite (Cu_3SbS_4), enargite, klaprothite [shown to be a mixture of emplectite ($CuBiS_2$) and wittichenite (Cu_3BiS_3)], chalcopyrite, and aikinite ($PbCuBiS_3$). The late-assemblage minerals are superimposed on the early-assemblage minerals in previously unfilled openings and along fractures. Because the various stages of mineralization were not entirely overlapping, there are individual lodes rich in certain metals such as zinc, copper, iron, lead-zinc, tin-bismuth, silver, gold, and tungsten. The deposits in volcanic rocks are zoned with a base-metal-rich core surrounded by a precious-metal-rich rim.

Geochemical Signature

The Hornsilver mine type locality is within the Idaho Falls NURE study boundary (fig. 5). Stream-sediment samples were anomalous in Ag and Cu (table 7). Few samples were collected near the type locality. A geochemical signature commonly associated with polymetallic veins regardless of terrane is Zn, Cu, Pb, As, Au, Ag, Mn, Ba, Sb, and Bi.

Geophysical Signature

Detailed magnetic and electrical methods may be useful in delineating major structures and extensions beneath and in altered volcanic rocks. In the Sheep Mountain-Bowery Peak area in the White Cloud–Boulder Roadless Area (fig. 5) the magnetic data suggest that the outcrops of dikes and hypabyssal bodies may be underlain by a large intrusive body at depth. Magnetic data in the vicinity of Iron Bog Creek, north of the Lava Creek district (fig. 4), are complex and show linear trends and high gradients associated with rocks of the Challis Volcanic Group. It is uncertain whether the positive anomaly is related to an intrusive at depth beneath the volcanic rocks.

Assessment Criteria

1. Regional high-angle faults.
2. Rocks of the Challis Volcanic Group.
3. Zones of alteration including sericitization and silicification.
4. Evidence of precious- or base-metal mineralization.
5. Presence of felsic hypabyssal bodies.

Assessment

The type locality for this deposit model is in the Champagne Creek area (E, fig. 17), Lava Creek district (fig. 4), just south of the southwestern part of the Forest. In the Lava Creek district polymetallic vein deposits occur in rocks of the Challis Volcanic Group and in underlying Paleozoic sedimentary rocks. Deposits in the sedimentary rocks were described as polymetallic veins in black-shale and carbonate terranes, and they are similar to those located in Leadbelt and Iron Bog Creeks just north of the Lava Creek district (fig. 4). An area (E3) around Sheep Mountain–Bowery Peak as described by Fisher, May, and others (1983) is assigned a moderate potential (M/C) for this type of deposit. Two areas of moderate potential but low certainty (M/B) are shown for this deposit type. The first area (E1), which is along the eastern side of Iron Bog Creek, contains numerous hypabyssal bodies and altered volcanic rocks. A prospect along the east side of Iron Bog Creek is not accessible, but the dump contains about equal amounts of sedimentary and altered volcanic rocks. The second area (E2) is along Lehman Creek, northwest of the Mackay Reservoir, where there is extensive silicification along a northwest-trending fault zone. Both areas are given low certainty because the alteration types and patterns in the volcanic rocks and the geochemistry are unknown. The areas of resource potential for polymetallic veins in Tertiary extrusive terrane (E) are shown on plate 3 and figure 17 and summarized in table 4.

Economic Significance

Lead and silver are supplied primarily from large-tonnage domestic and foreign mines. A major change in demand or increase in price for these commodities would be needed to support operation of small mines. Production of gold as a by-product would certainly enhance the possibility of development.

Precious-Metal Veins (F)

Commodities, By-products, and Trace Metals

Gold and silver; lead, copper, and zinc are potential by-products.

Host Rocks

Veins are mainly in Cretaceous and Tertiary igneous rocks that have been moderately to intensely hydrothermally altered. Propylitized and sericitized rocks are widespread. Close to the veins the rocks have been silicified and argillized.

Structural Control

Most of the veins are in the trans-Challis fault system and along northeast- or northwest-trending high-angle fractures. Ore is in fissures and breccia fillings. Ore is richest close to the premineral land surface, and values diminish with depth (Fisher and others, 1987).

Lithologic Control

The orebodies are commonly within, along side, or near dikes and stocks of Eocene age.

Age

Tertiary, probably Eocene.

Deposit Description

Deposits are small lenticular pods or lenses more than 100 ft across and 3 ft or more thick. Quartz, the dominant gangue mineral, ranges from cryptocrystalline to coarsely crystalline and is sometimes comb structured. Most of the precious metals are in electrum. Native gold, native silver, auriferous pyrite, and several silver-bearing sulfide minerals are also present. Other gangue minerals are fine-grained base-metal sulfides, calcite, adularia, siderite, barite, pyrite, pyrrhotite, and arsenopyrite. The deposits are massive fissure fillings, breccias, and aggregates of veinlets. Ore minerals occur in clusters, thin layers, lenses, and disseminations in vein material and altered wall rock. The type mine locality for this model is at the Lucky Boy mine (F, fig. 18), Yankee Fork district (fig. 4).

Geochemical Signature

The Lucky Boy mine type locality is within the geochemical survey for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and stream sediments have anomalous concentrations of Ag. The heavy minerals also contain anomalous concentrations of Au, Sn, Ba, Bi, Cu, Mo, and Pb (table 7). A geochemical signature commonly associated with precious-metal veins regardless of terrane is Au, As, Sb, Hg, Ag, Pb, Zn, Cu, W, Bi, Te, and Tl.

Geophysical Signature

The deposits themselves have no geophysical expression, but the ore-controlling faults might be detected by detailed magnetic surveys. Regional magnetic data shows the northeast-trending structures of the trans-Challis fault system. The Lucky Boy mine (F, fig. 18) occurs at the intersection of strong east-west and northeast linear magnetic trends. Delineation of other similar intersections may be a useful exploration tool.

Assessment Criteria

1. Evidence of precious-metal mineralization.
2. Presence of planar high-angle faults or fractures.
3. Presence of Tertiary felsic hypabyssal intrusive rocks, including dikes, stocks, and plugs.
4. Presence of open-space filling materials in faults, and fractures.
5. Proximity to trans-Challis fault system.

Assessment

Deposits of this type seem to be confined mainly to the trans-Challis fault system, but there may be some potential for deposits of this type along parallel fault systems. The potential is for precious metals within the vein systems and for broad zones of dissemination in altered rock. One large area (F1) of high potential (H/D) extends from Stanley northeast through the Yankee Fork district (fig. 4). Two small areas (F1) of high potential (H/D) are shown in the Meyer's Cove area, Gravel Range district (fig. 4). Four small areas (F2) of moderate

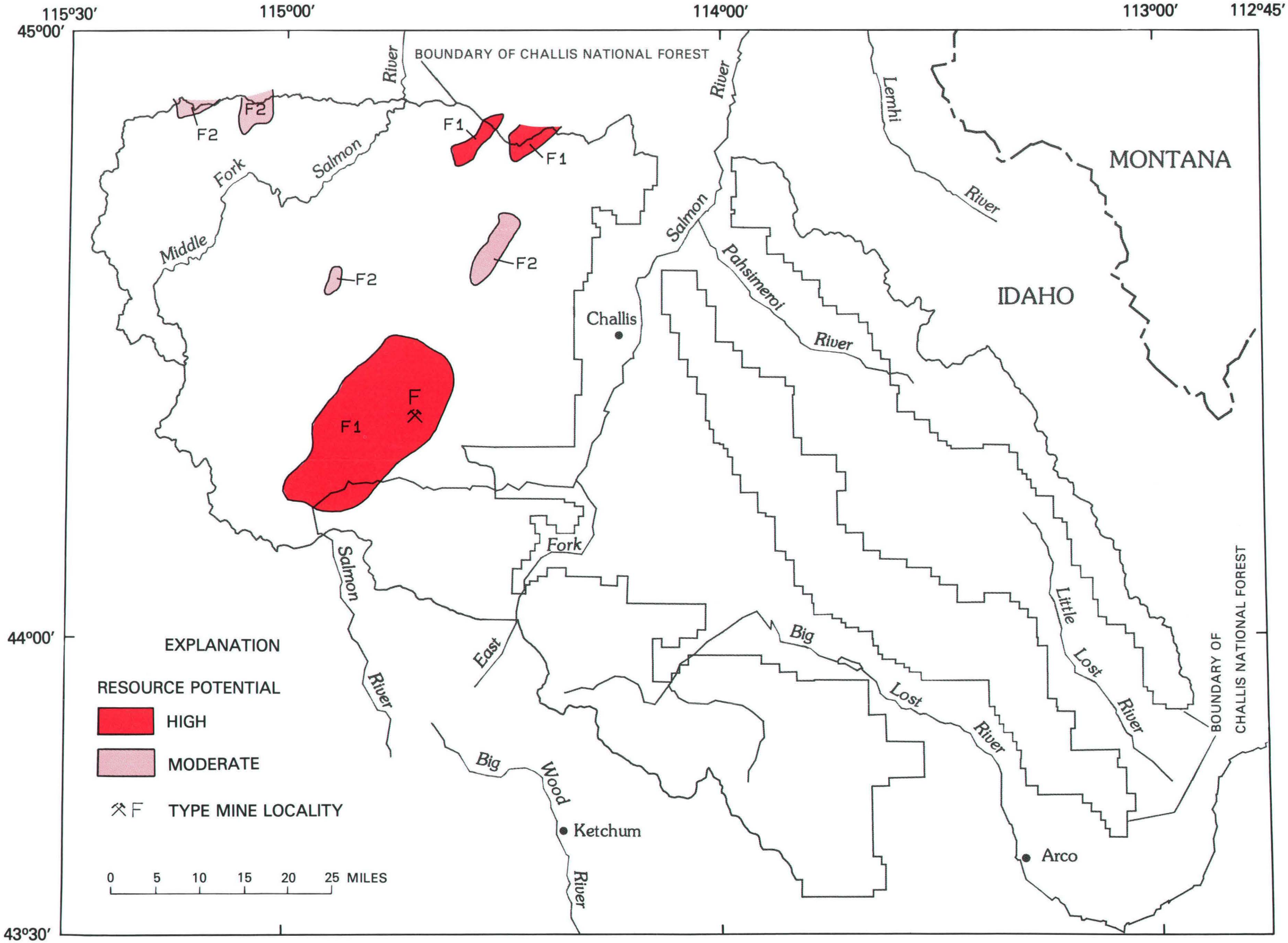


Figure 18. Mineral resource potential map for precious-metal veins (F) in the Challis National Forest and adjacent areas, Idaho. Areas (F1, F2) of mineral resource potential are described in table 4.

potential (M/D) are shown within the trans-Challis fault system. The areas of resource potential for precious-metal veins are shown on plate 3 and figure 18 and summarized in table 4.

Economic Significance

The important gold production in the Western United States, and much of the World, is from large-tonnage, low-grade deposits and not from smaller, higher grade deposits of this type. This trend will probably continue into the future. However, as long as the price remains high, smaller operations on deposits of this type could be viable.

Base-Metal Veins (G)

Commodities, By-products, and Trace Metals

Zinc, lead, copper, silver, and gold.

Host Rocks

The veins are in granitic rocks of the Idaho batholith and in metasedimentary roof pendants. One deposit is in a phyllitic member of the Yellowjacket Formation. Hydrothermally altered rock displays argillic and sericitic alteration of the feldspars with some silicification near the veins.

Structural Control

The deposits are along high-angle shear zones and fractures, but not those of a regional trend.

Age

Cretaceous, probably the same age as and related to the Idaho batholith.

Deposit Description

The deposits are mainly small pods and lenses 1 ft or so thick and tens of feet long. A few are as much as 300 ft long and 5 ft wide and extend 700 ft downdip. Ore minerals are chiefly galena, sphalerite, and chalcopyrite in a gangue of quartz, siderite, calcite, pyrite, pyrrhotite, and arsenopyrite. The ore is in layers, pods, stringers, and disseminations in the vein material. Precious metals are locally abundant. Vein contacts with the wall rocks are sharp everywhere. The Sea Foam mine (G, fig. 19), Sea Foam district, is the type locality of this model.

Geochemical Signature

The Sea Foam type mine locality is within the boundaries of the geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and stream sediments have anomalous concentrations of Ag, Pb, B, and Cu. The heavy-mineral fraction also contains anomalous amounts of Bi, Sn, Au, Mo, W, and Th. A geochemical signature commonly associated with base-metal veins is Zn, Cu, Pb, As, Au, Ag, Mn, Ba, Sb, and Bi.

Geophysical Signature

High-angle shear zones and fractures, where mineralized, can be mapped with detailed magnetic and electrical surveys.

Assessment Criteria

1. Evidence of base and precious metals.
2. Presence of high-angle planar fractures or faults.
3. Quartz is the principal gangue mineral.
4. Proximity to granitic rocks of the Idaho batholith.

Assessment

Deposits of this type are largely confined to the Idaho batholith or close proximity to it. Known deposits are small and with few exceptions have not been significant producers. Two areas (G1) of high potential (H/D) and two areas (G2) of moderate potential (M/D) are defined. The areas of resource potential for base-metal veins (G) are shown on plate 3 and figure 19 and summarized in table 4.

Economic Significance

Base metals are supplied primarily from foreign sources. A major change in the supply and demand of these commodities would be needed to support operation of small base-metal mines.

Vein Uranium Deposits (H)

Commodities, By-products, and Trace Metals

Uranium; trace amounts of gold, silver, antimony, lead, zinc, and molybdenum.

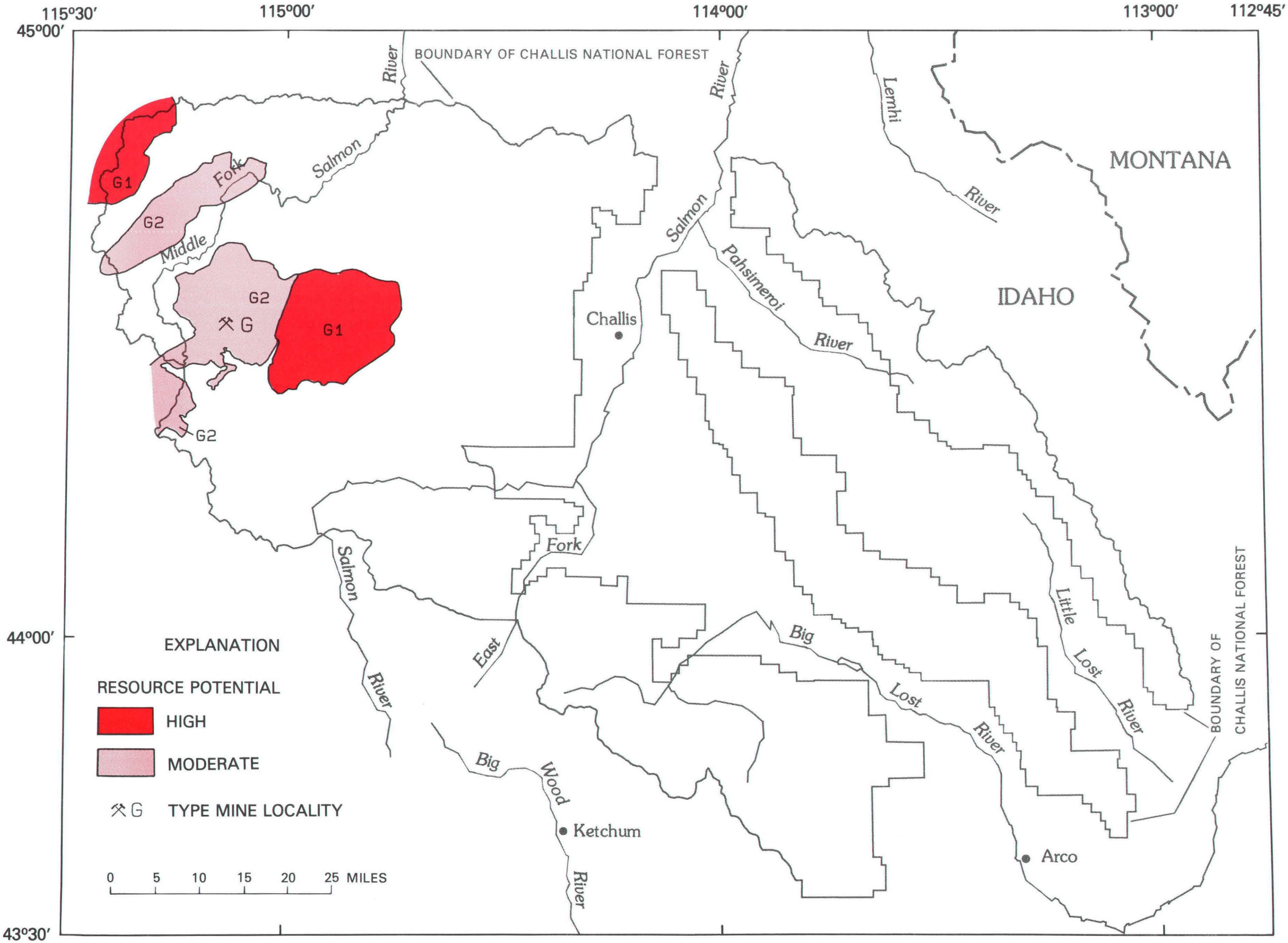


Figure 19. Mineral resource potential map for base-metal veins (G) in the Challis National Forest and adjacent areas, Idaho. Areas (G1, G2) of mineral resource potential are described in table 4.

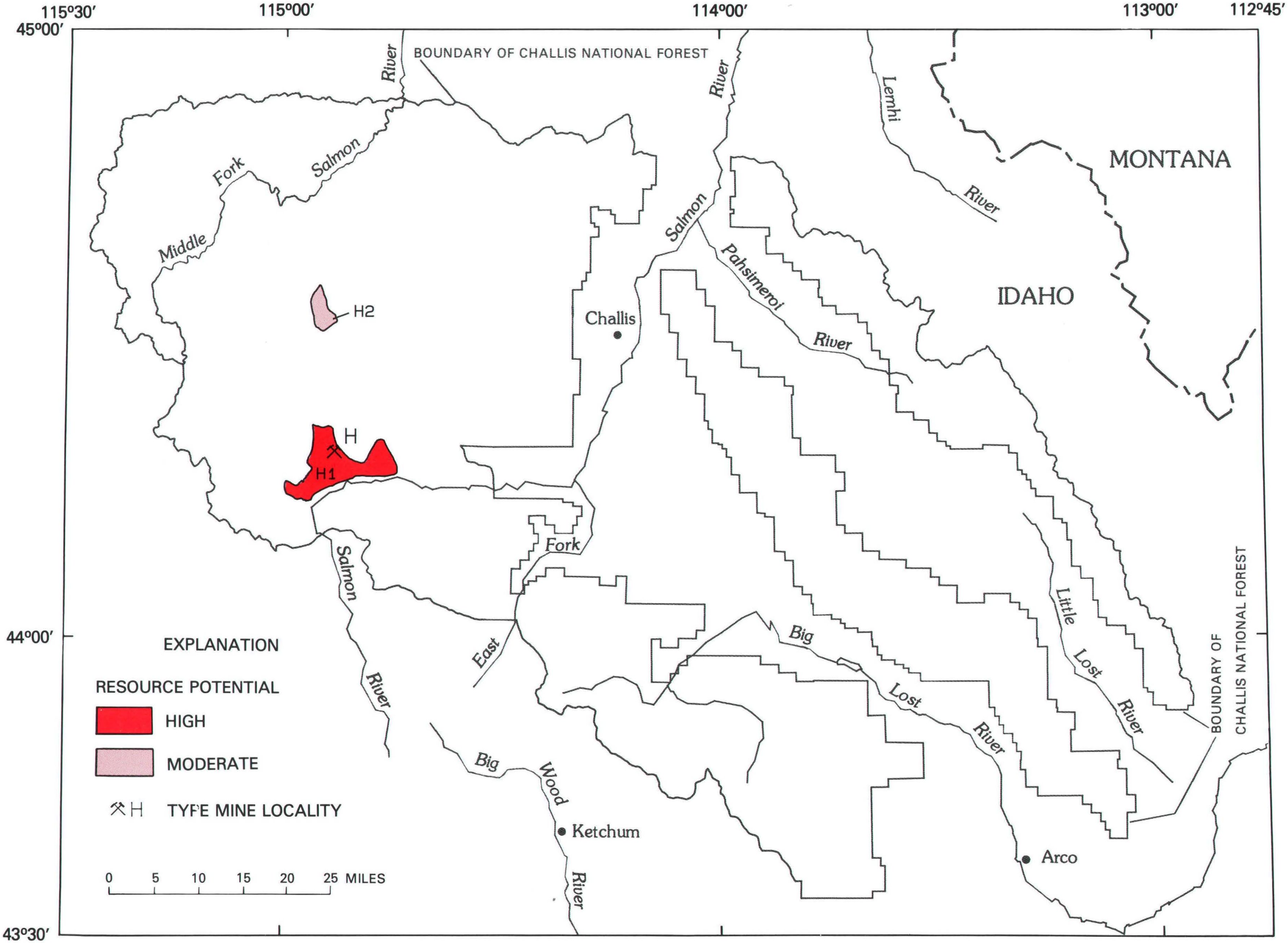


Figure 20. Mineral resource potential map for vein uranium deposits (H) in the Challis National Forest and adjacent areas, Idaho. Areas (H1, H2) of mineral resource potential are described in table 4.

Host Rocks

Known deposits are in the granitic rocks of the Cretaceous Idaho batholith, Tertiary granite, dolomitic marble, graphitic argillite, and quartzite.

Structural Control

The deposits are in or along fracture zones.

Lithologic Control

The deposits in the Stanley area are commonly at the intersection of aplitic or pegmatitic dikes and steeply dipping fractures.

Age

Unknown, probably Tertiary, although those near Stanley could be related to pegmatites of the Cretaceous Idaho batholith.

Deposit Description

Most of the occurrences consist of secondary uranium minerals with or without quartz along fault systems. The occurrence at the Sullivan uranium prospect on the Middle Fork of the Salmon River, in the north-central part of the Forest, includes sugary quartz, fluorite, arsenopyrite or pyrrhotite, thorite(?), chalcopyrite, azurite, and malachite. The deposits in the Stanley area are pitchblende stringers with or without quartz. Uraninite (mostly as pitchblende), uranophane, meta-autunite, and rare coffinite and brannerite are the uranium minerals. Gangue is quartz and chalcedony with minor amounts of pyrite, chalcopyrite, stibnite, galena, sphalerite, molybdenite, gold, and silver. A variety of secondary uranium minerals also occur in these deposits. The Lightning mines (H, fig. 20), Stanley district (fig. 4), are the type locality for this model.

Geochemical Signature

The Lightning mines type locality is within the boundaries of the geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). No elements were anomalous in the stream sediments, but the elements Th, Mo, Pb, and Sn were anomalous in the heavy-mineral fraction of the stream sediments (table 7). A geochemical signature commonly associated with uranium mineralization in epithermal veins is U, Hg, As, Sb, F, Mo, and W. This common signature does not appear to be reflected by the signature of the heavy minerals collected near the type mine locality.

Geophysical Signature

No significant magnetic signature. Gamma-ray spectrometer surveys may be applicable for exploration.

Assessment Criteria

1. Evidence of uranium mineralization.
2. Presence of steeply dipping fractures and joints.
3. Presence of aplite or pegmatite dikes in medium- to coarse-grained granites (for Stanley-type deposits).

Assessment

Assessment for this model type is only for that portion of the Forest within the Challis $1^\circ \times 2^\circ$ quadrangle. Data are inadequate for assessment of the remainder of the Forest. The type of uranium vein deposit with resource potential is that found in the Stanley area. One area (H1) around the Stanley deposits is assigned a high potential (H/D), and another area (H2) to the north is assigned a moderate potential (M/D). The other types of uranium vein deposits are thought to have low resource potential in the Challis National Forest. The areas of resource potential for vein uranium deposits (H) are shown on plate 3 and figure 20 and summarized in table 4.

Economic Significance

The uranium industry in the United States is currently nearly inactive and may remain in this condition in the near future. It would take a major increase in the demand for uranium for small mines to become competitive.

Tungsten Stockwork and Vein Deposits (I)

Commodities, By-products, and Trace Metals

Tungsten; antimony, gold, silver, or molybdenum are potential by-products.

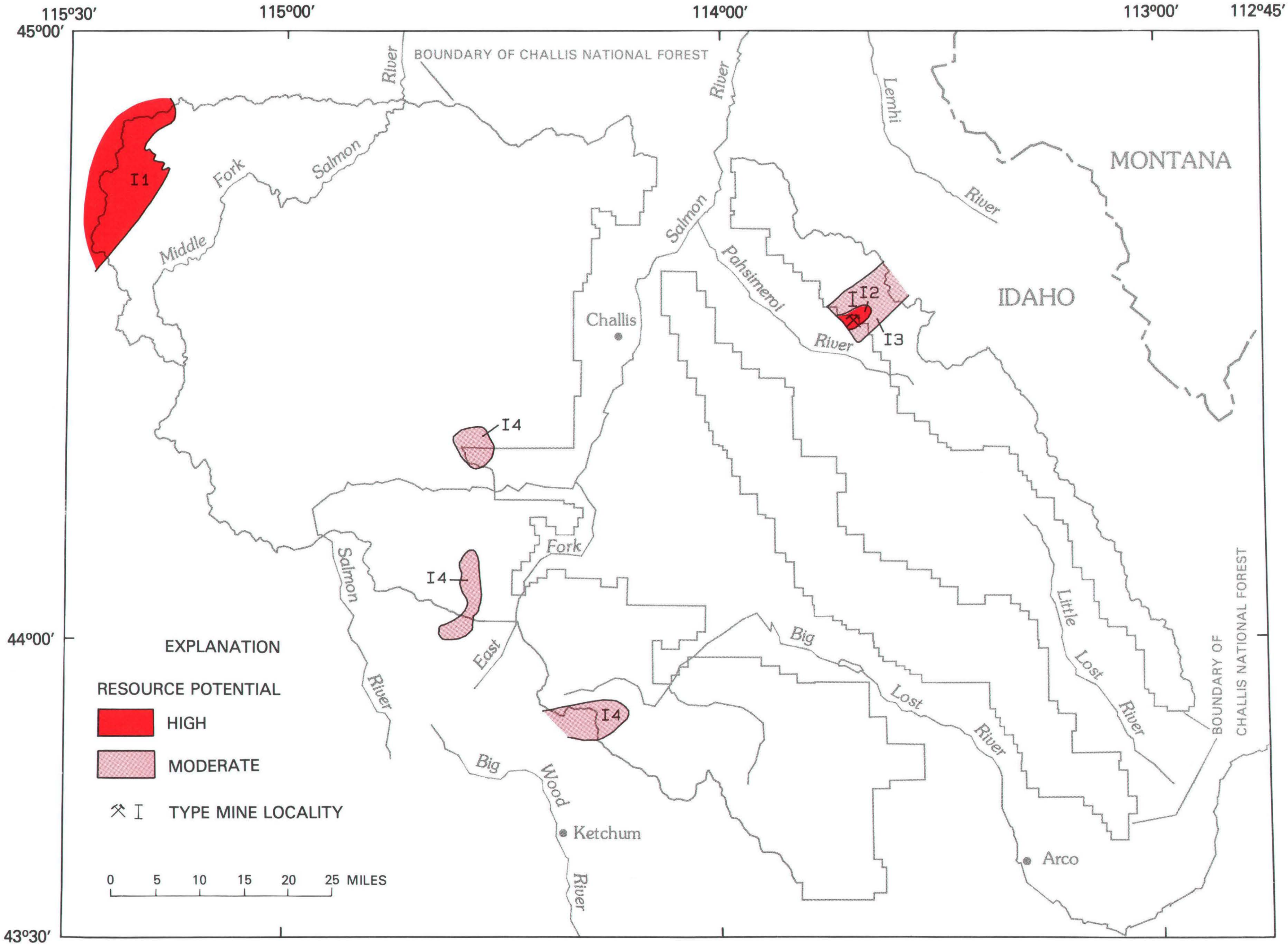


Figure 21. Mineral resource potential map for tungsten stockwork and vein deposits (I) in the Challis National Forest and adjacent areas, Idaho. Areas (I1–I4) of mineral resource potential are described in table 4.

Host Rocks

Host rocks are mainly altered granitic plutonic rocks and sedimentary and metasedimentary rocks including quartzitic and carbonate-rich rocks. Wall rock is strongly brecciated, silicified, and sericitized. The plutonic rock is bleached and vuggy, and the feldspars have been altered to clay.

Structural Control

These deposits are localized along major high-angle faults, most of which trend north to northwest. Many of these faults have strong shear components. Deposits are best developed at the junctions of faults and their eastward-branching splays.

Lithologic Control

The vein deposits of the Ima mine, Blue Wing district (fig. 4), which is the major tungsten producer in the Forest, are above and genetically related to a felsic intrusive body. There are several skarn-type tungsten deposits, described elsewhere, in the Forest that are associated with similar intrusive bodies.

Age

Cretaceous and Tertiary.

Deposit Description

The deposits are fissure-filled quartz veins and veinlets that form a stockwork pattern in broad areas of shearing. In addition to quartz, the veins contain variable amounts of fluorite, arsenopyrite, calcite, rhodochrosite, sericite, vein feldspar, pyrite, sphalerite, chalcopyrite, tetrahedrite, galena, and cinnabar. Ore minerals are wolframite (including ferberite and huebnerite), some scheelite, stibnite, gold, and silver. Manganese oxides are ubiquitous. The ore minerals occur in the veins and stockworks, as replacement of carbonate minerals in the vicinity of calcareous rocks, and as a coating on the manganese oxides. Some of the deposits are related to stockwork molybdenum deposits in porphyritic plutons. The Ima mine (I, fig. 21), Blue Wing district (fig. 4), is the type locality for this deposit model.

Geochemical Signature

The Ima mine type locality is within the Dubois NURE study boundary (fig. 5). A stream sediment collected from the alluvium in the valley adjacent to the Ima mine had anomalous concentrations of Cu, Pb, Sb, and W (table 7). This signature is based on only one sample and may reflect contamination from mine dump material. A geochemical signature commonly associated with tungsten veins is W, Mo, Sn, Bi, As, Cu, Pb, Zn, Be, and F.

Geophysical Signature

The deposits themselves have no geophysical expression, but the major shear zones and related intrusive bodies show on regional magnetic and gravity surveys.

Assessment Criteria

1. North-trending major shear-fault zones.
2. Secondary silica enrichment.
3. Evidence of tungsten mineralization.
4. Proximity to plutonic rock.

Assessment

Vein tungsten deposits are part of a group of tungsten deposits in south-central Idaho that extend from the Craters of the Moon northwestward through the Challis National Forest (Cook, 1956). Tungsten vein and skarn deposits, described under skarn deposits, are genetically related. Many of the vein and skarn deposits are confined to rocks of the Idaho batholith and related stocks, whereas others are associated with Tertiary plutons. The potential for tungsten vein and skarn deposits is difficult to assess in view of the present state of knowledge. There are numerous tungsten occurrences, some of which have had production, and tungsten geochemical anomalies are common, especially in rocks of the Idaho batholith. Much of the area of the Idaho batholith has potential for small tungsten deposits mainly where major north-trending high-angle faults cut carbonate inclusions. Mapping detail is not sufficient to delineate individual locations. One area (I1) of high potential (H/C) is shown along the northwest border of the Forest. A small area (I2) of high potential (H/C) is in the vicinity of the Ima mine. A larger area (I3) of moderate potential (M/B) is drawn to include a set of northeast-trending structures in the vicinity of the Ima mine. Several areas (I4) of moderate potential (M/C) generally correspond to areas of potential for stockwork molybdenum deposits. The areas of resource potential for tungsten stockwork and vein deposits (I) are shown on plate 3 and figure 21 and summarized in table 4.

Economic Significance

Tungsten is a strategic and critical metal; the United States is almost entirely dependent upon foreign sources for supplies. Although known foreign deposits are very large, smaller isolated, domestic tungsten deposits may be in critical demand in times of national emergency.

Stockwork Molybdenum Deposits (J)

Commodities, By-products, and Trace Metals

Molybdenum; copper, silver, or gold are potential by-products.

Host Rocks

The deposits are in or associated with granitic plutons that range from quartz diorite to granite and hypabyssal bodies of rhyolite. The deposits may be entirely within the intrusive rock, entirely within the adjacent metamorphosed country rock, or within both. The ore is in pods of intensely silicified and pyritized rock surrounded by envelopes of potassic, argillic, and propylitic altered rocks.

Structural Control

Stockwork veins may be controlled by joint patterns within the pluton or by bedding, joints, or faults outside the pluton. Some of the deposits associated with hypabyssal rhyolite bodies are aligned along major high-angle fault systems as are the hypabyssal bodies.

Lithologic Control

These deposits are all associated with low-fluorine I-type compositionally zoned or expanded granitic magmatism, which is characterized by subduction-related plutons with low fluorine concentrations, high ratios of strontium to rubidium, and low niobium concentrations as compared to average granites.

Age

Cretaceous and Tertiary.

Deposit Description

The deposits consist of stockworks of quartz veins and veinlets containing molybdenite and pyrite and locally chalcopyrite, galena, scheelite, arsenopyrite, stibnite, pyrrhotite, biotite, muscovite, gold, and silver. Molybdenite occurs with the quartz stockworks as rosettes, flakes, fracture fillings, intercalations with secondary mica, and selvages, and as disseminations in tactite. The Cretaceous orebodies are arched or domed, elongate tabular in shape, and associated with plutons. The best known Cretaceous orebody is at Thompson Creek (Ja, fig. 22), Bayhorse district (fig. 4). The Tertiary deposits are elongate oval in shape and generally within hypabyssal bodies. The better known Tertiary deposits are located a few miles south of the Challis National Forest at the Little Falls and CUMO Prospects. The Thompson Creek mine (Ja, fig. 22) is the type locality for Cretaceous stockwork molybdenum, and the Walton–White Mountain prospect (Jb, fig. 22) in the Alto district (fig. 4) is the type locality for Tertiary stockwork molybdenum.

Geochemical Signature

The Thompson Creek type locality is within the boundaries of a geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and the stream sediments had anomalous concentrations of W, Mo, Bi, and Cu. The stream sediments were also anomalous in Ag, and the heavy minerals were also anomalous in Pb, Sn, B, and Th (table 7). The Walton–White Mountain type locality is within the boundary of the Boulder-Pioneer Wilderness Study Area (fig. 5). Stream-sediment samples from this area had anomalous concentrations of Cu, Pb, Mo, Ag, and Zn. A geochemical signature commonly associated with low-fluorine porphyry molybdenum deposits is W, Mo, Cu, Au, Ag, Pb, Zn, and F (less than 1,000 ppm).

Geophysical Signature

The known Cretaceous deposits at Thompson Creek (Ja, fig. 22) and in the Boulder Creek district (fig. 4) are on the flanks of positive magnetic anomalies that probably indicate buried granitic plutons. The Tertiary intrusive at the Walton–White Mountain prospect (Jb, fig. 22) is also on the flank of a large positive magnetic anomaly. However, the Tertiary intrusive at the Ima mine, Blue Wing district (fig. 4), exhibits only low magnetic gradients, possibly due to insufficient resolution of the survey.

Assessment Criteria

1. Proximity to granitic plutons or hypabyssal bodies, especially differentiated or expanded, low-fluorine, I-type granitic plutons or multiple plutons.
2. Extensive hydrothermal alteration in and around the deposit.

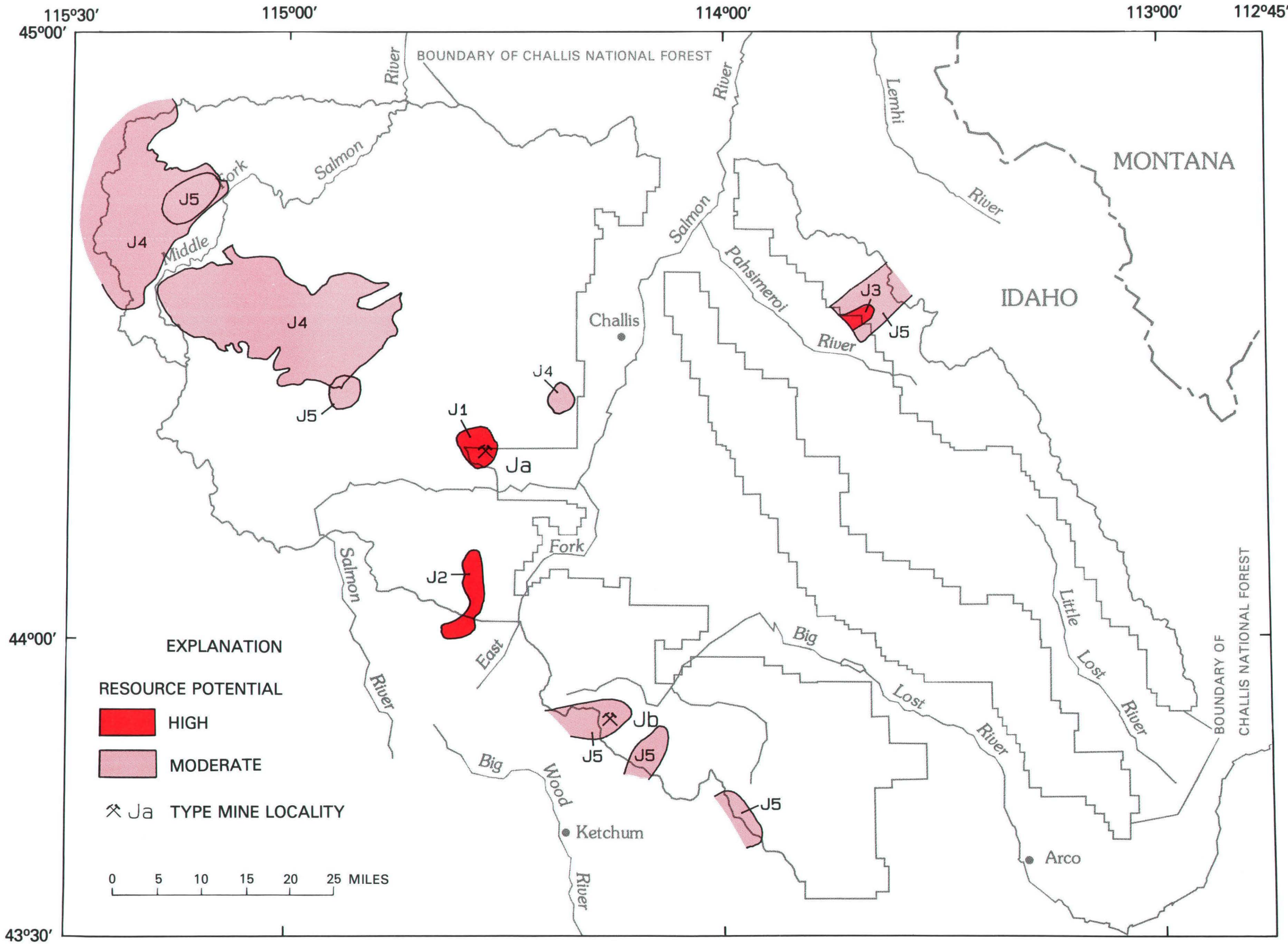


Figure 22. Mineral resource potential map for stockwork molybdenum deposits (J) in the Challis National Forest and adjacent areas, Idaho. Areas (J1, J2, and so forth) of mineral resource potential are described in table 4.

3. Presence of molybdenite in veins and veinlet stockworks and as disseminated flakes.
4. Local anomalous molybdenum concentrations.

Assessment

A late Mesozoic-Tertiary magmatic arc extending from southeast California to southeast Alaska contains many economically significant molybdenum stockwork deposits. This broad arc extends through the Challis National Forest. In addition to numerous small deposits and occurrences associated with Tertiary granitoid stocks, there are two large, well-known, molybdenum stockwork deposits and numerous prospects associated with Cretaceous granitoid stocks in the Forest. Two areas (J1, J2) of high potential and certainty level of D (H/D) are indicated. Area J1 is in the vicinity of the Thompson Creek molybdenum deposit (Ja, fig. 22), and area J2 contains the molybdenum deposit at Little Boulder Creek in the Boulder Creek district (fig. 4). One area (J3) of high potential with a certainty level of B (H/B) is drawn around the vicinity of the Ima tungsten mine in the Blue Wing district (fig. 4). The intrusive below the tungsten veins contains stockwork molybdenum, but the extent of mineralization and alteration is unknown. Several areas of moderate potential are shown; those marked J4 (M/D) are for Cretaceous deposits, and those marked J5 (M/C) are for Tertiary deposits. The areas of resource potential for stockwork molybdenum deposits (J) are shown on plate 3 and figure 22 and summarized in table 4.

Economic Significance

One of the large Cretaceous stockwork molybdenum deposits, Thompson Creek, is presently (July 1988) being mined. Molybdenum is a commodity needed by technologically advanced societies, and although there is currently an overabundance of supply in the world, many of the deposits discussed here will probably be exploited in the future.

High-Level, Rhyolite-Hosted, Precious-Metal Deposits (K)

Commodities, By-products, and Trace Metals

Gold and silver.

Host Rocks

The deposits are in high-level rhyolite intrusives and the surrounding, altered country rock. The term "high-level" implies uncertainty as to how close these intrusives came to the surface—some breached it, others did not (Fisher and Johnson, 1987, p. 163). Where mineralized, the rhyolites are bleached, iron stained, and silicified. Sanidine and quartz are the most abundant phenocryst minerals.

Lithologic Control

The intrusive rocks are massive to flow-laminated, porphyritic to aphyric, alkali rhyolites that were intruded as domes or dikes.

Structural Control

The rhyolite bodies are along or near bounding faults of major volcanotectonic features, mainly within the trans-Challis fault system. The individual mineralized zones are on fracture systems and shattered zones that reflect the major structural trends.

Age

Tertiary, Eocene or younger.

Deposit Description

Deposits are quartz-veinlet stockwork zones and disseminations in altered rock, in places associated with major quartz veins. Ore minerals are electrum, native gold, and native silver, with a gangue of secondary silica, clay minerals, and pyrite, and minor amounts of zircon, apatite, fluorite, and amethystine quartz. The orebodies are irregular in shape but generally elongate and narrow downward into fault systems. Mineralized rock occurs mainly in the rhyolites but also in the country rock. The type locality for this model is the Golden Sunbeam mine (K, fig. 23), Yankee Fork district (fig. 4).

Geochemical Signature

The Golden Sunbeam mine type locality is within the boundary of a geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and the stream sediments had anomalous concentrations of Ag, Cu, and Pb. The stream sediments were also anomalous in Be, Mo, and Zn, and the heavy minerals were also anomalous in Au, As, Ba, Sn, and W (table 7). A geochemical signature commonly associated with precious-metal veins is Au, As, Sb, Hg, Ag, Pb, Zn, Cu, W, Bi, Te, and Tl.

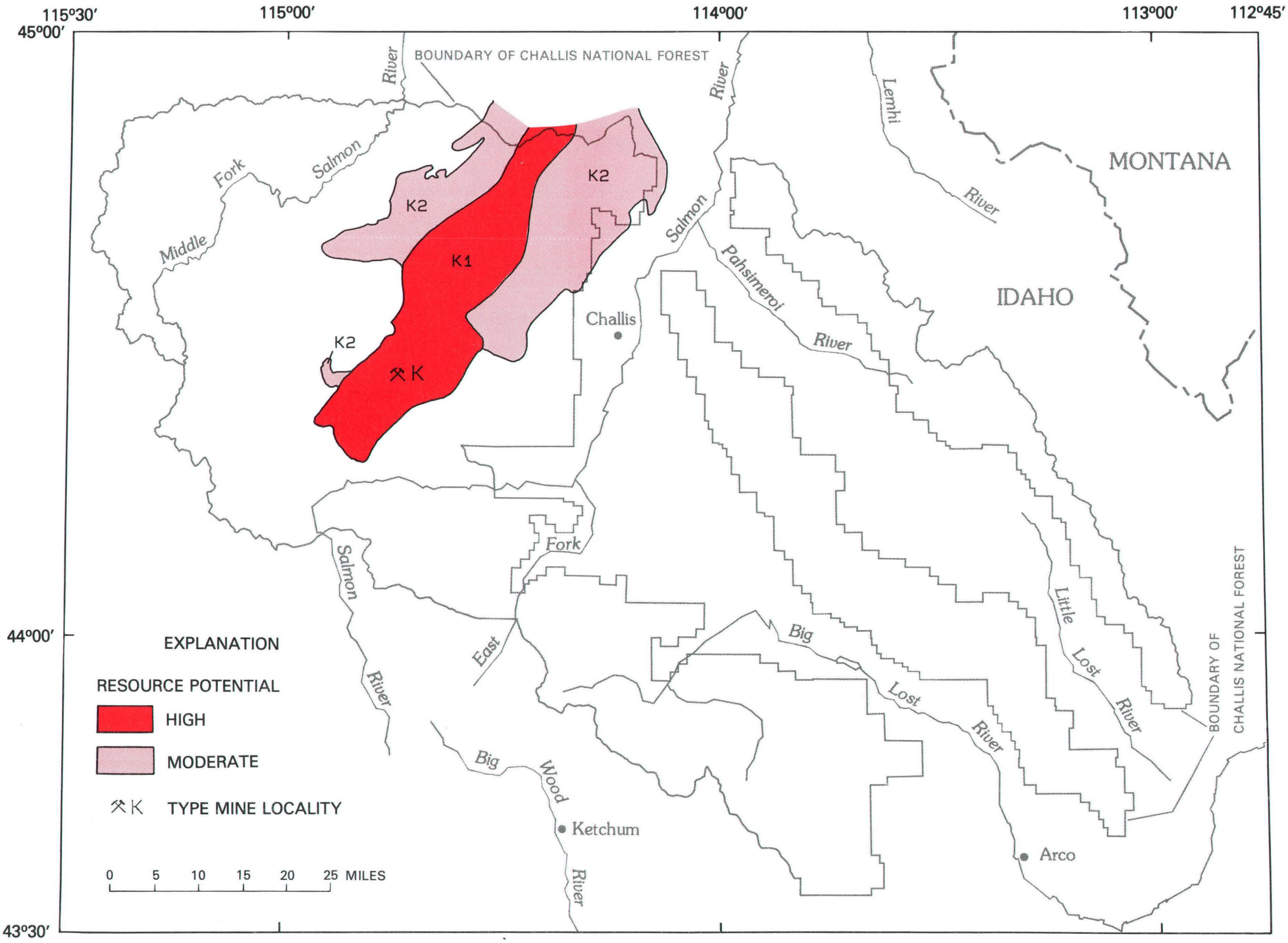


Figure 23. Mineral resource potential map for high-level, rhyolite-hosted, precious-metal deposits (K) in the Challis National Forest and adjacent areas, Idaho. Areas (K1, K2) of mineral resource potential are described in table 4.

Geophysical Signature

The deposits themselves have no geophysical expression, but some major faults show on regional magnetic and gravity surveys. The magnetic data exhibit regional northeast trends and intersections with northwest and east trends in the areas of mineral resource potential (K1, K2).

Assessment Criteria

1. Evidence of precicus-metal mineralization.
2. In or associated with high-level rhyolite bodies.
3. In or near bounding faults or major volcano-tectonic features.
4. Presence of anomalous concentrations of secondary and remobilized silica.
5. Within the trans-Challis fault system, especially in the north-central parts of the Forest.

Assessment

Assessment for this model type is only for that portion of the Forest within the Challis 1°×2° quadrangle. Data are not adequate for an assessment of the remainder of the Forest. Much of the area of Challis Volcanic Group in the trans-Challis fault zone has moderate or high potential for discovery of deposits of this type. High potential (H/C) is shown as area K1, and moderate potential (M/C) is shown as area K2. The areas of resource potential for high-level, rhyolite-hosted, precious-metal deposits (K) are shown on plate 3 and figure 23 and summarized on table 4.

Economic Significance

Precious metals are currently in demand, and throughout the Western United States they are being economically extracted from large low-grade deposits. This mining trend and demand will probably continue into the future.

Polymetallic Skarn Deposits (L)

Commodities, By-products, and Trace Metals

Tungsten, copper, zinc, lead, and silver; trace amounts of gold and bismuth.

Host Rocks

Host rocks are carbonate-bearing rocks, mainly clean to impure limestone, carbonaceous micritic limestone, or limey sandstone, in contact with intrusive rocks. Carbonate rocks in the contact zone are altered to Fe-Mg-Mn-silicate mineral assemblages that may include: diopside-hedenbergite, grossularite-andradite, wollastonite, idocrase, calcite, epidote, chlorite, and quartz.

Lithologic Control

The deposits occur where receptive carbonate strata were replaced by silicate and ore minerals within, next to, or close to a felsic intrusive body.

Structural Control

The contact between the intrusive body and the carbonate host rock, local bedding planes, faults, and breccia zones controlled location of the orebodies. At the Empire mine Alder Creek district (fig. 4) the ore-forming solutions apparently penetrated the skarn rock along preexisting fractures (Ross, 1930, p. 16).

Age

Same as that of the related intrusive body; variable, from Cretaceous to Miocene.

Deposit Description

This classification includes several types of skarn (tactite) deposits of different ages and igneous rock associations that could be further subdivided if data were adequate. These deposits vary from irregular- to pod-shaped to tabular to pipelike bodies, in which the ore may be coarse to fine grained. Ore deposits in skarn are massive replacements, disseminations, podiform bodies, stringers, or fracture fillings. In some deposits, such as at the Empire mine, part of the ore occurs as replacement of altered intrusive rock. Associated polymetallic veins are common. Deposits range in size from small pods to bodies as much as 1,000 ft long. Ore minerals include scheelite, sphalerite, molybdenite, chalcopyrite, galena, tetrahedrite, and bornite; gangue minerals include pyrite, pyrrhotite, arsenopyrite, specularite, calcite, fluorite, magnetite, and quartz, in addition to the silicate skarn minerals. At the Empire mine the principal commodity produced from skarn deposits was copper, with minor lead, zinc, silver, and gold. Skarns in the northwestern part of the Forest have produced mainly tungsten. In the Windy Peak area, Spring Mountain district (fig. 4), some skarns are magnetite and hematite rich. A large variety of minerals may occur in the weathered zone of skarns, including azurite, malachite, brochantite, calamine, chalcanthite, chrysocolla, native copper, copper pitch, covellite, cuprite, gypsum, hematite, limonite, kaolinite, opal,

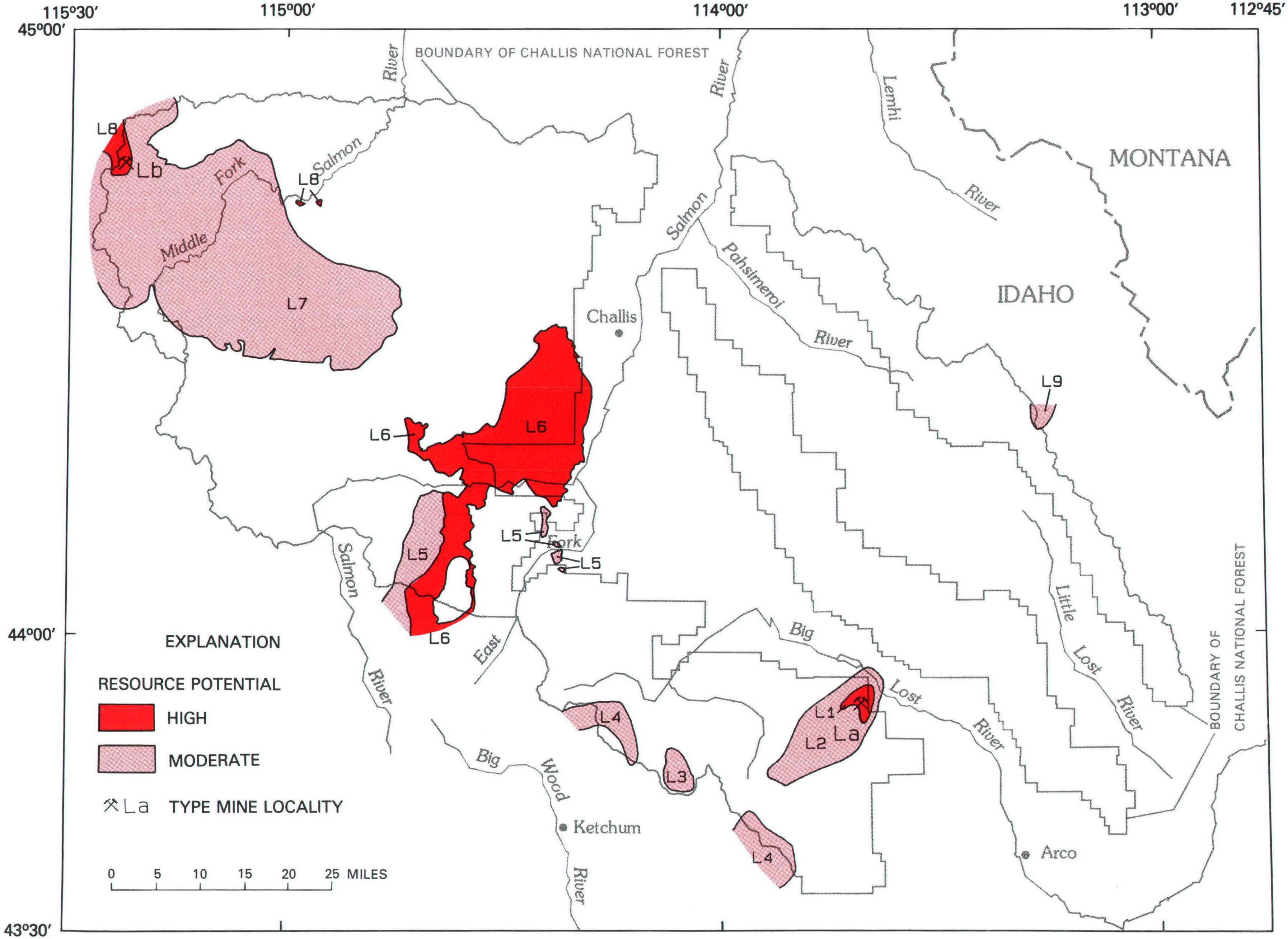


Figure 24. Mineral resource potential map for polymetallic skarn deposits (L) in the Challis National Forest and adjacent areas, Idaho. Areas (L1, L2, and so forth) of mineral resource potential are described in table 4.

pyrolusite, smithsonite, and tenorite. The type locality for base-metal skarns associated with Tertiary intrusive bodies is the Empire mine (La, fig. 24) Alder Creek district (fig. 4) and that for tungsten skarns is the Springfield mine (Lb, fig. 24) just south of the Yellow Pine district (fig. 4).

Geochemical Signature

The Empire mine type locality is within the boundary of the Idaho Falls NURE study area (fig. 5). Few samples were collected near the type mine locality, but one stream-sediment sample collected near the type locality had anomalous Cu (table 7). The Springfield mine type locality is within the boundary of the Idaho Primitive Area (fig. 5). Stream-sediment samples collected near the type locality had anomalous concentrations of Zn, Mn, Cu, Mo, Be, and As (table 7). A geochemical signature commonly associated with polymetallic skarn deposits is Zn, Pb, Mn, Cu, Co, Au, Ag, As, W, Sn, F, and Be.

Geophysical Signature

Magnetic anomalies indicate intrusive bodies in Paleozoic rocks in several areas, namely the Alto district, Bayhorse district, Star Hope area of the Copper Basin district, and Windy Peak area of the Spring Mountain district (fig. 4). The magnetic data suggest that the Mackay stock in the White Knob Mountains is more extensive to the west in the subsurface in Paleozoic carbonate rocks than is shown by its surface exposure. The individual bodies would probably have local electrical and magnetic expression, depending upon the mineralogy and composition of the host rock.

Assessment Criteria

1. Intrusive contact with sedimentary or metasedimentary carbonate-bearing strata.
2. Skarn mineral assemblage.
3. Geochemical anomalies including W, Zn, Cu, Pb, or Mo.

Assessment

The Forest has numerous intrusive bodies in contact with carbonate strata, many of which have skarn mineral assemblages in their border zones. Although only a few of the numerous prospects have produced ore, there is potential for significant deposits of this type. A large area (L7) underlain by the Idaho batholith is assigned moderate potential (M/D) for tungsten skarn deposits in calcareous roof pendants. Several small areas (L8) of high potential (H/D) are drawn around Tertiary intrusive bodies in the northwestern part of the Forest. Areas L5 and L6 are moderate (M/D) and high (H/D) potential areas, respectively, in the black-shale belt. The black-shale belt contains possible ore-receptive (host) carbonate beds, source beds for metals, and numerous felsic intrusive bodies. Areas marked L4 have moderate potential (M/B) for contact skarn deposits at depth. Area L3 (M/C) is a special case that represents the Wildhorse tungsten deposits which are in small, isolated tactite lenses in a gneissic intrusive. The areas (L1) around the Empire mine (La, fig. 24) and Copper Basin mine, Alder Creek district (fig. 4), are assigned a high potential (H/C). A larger area in the White Knob Mountains (L2) is assigned moderate potential (M/C). The Windy Peak area (L9), Spring Mountain district (fig. 4), is assigned a moderate potential (M/B) with low certainty level because of the lack of information on deposit types. The areas of resource potential for polymetallic skarn deposits (L) are shown on plate 3 and figure 24 and summarized in table 4.

Economic Significance

See discussions under tungsten stockwork and vein deposits (I) and base-metal veins (G).

Irregular Replacements of Base and Precious Metals (M)

Commodities, By-products, and Trace Metals

Silver, lead, and zinc; copper and gold are by-products.

Host Rocks

The ores occur in selectively replaced carbonate strata of the Bayhorse Dolomite, Ella Dolomite, and Saturday Mountain Formation. The host rocks are all calcareous or dolomitic and contain various amounts of impurities such as sand or silt. There was local dolomitization in the vicinity of orebodies but no pervasive hydrothermal alteration.

Lithologic Control

Impervious shale zones and siltstones trapped ascending ore-forming solutions in the underlying carbonate strata.

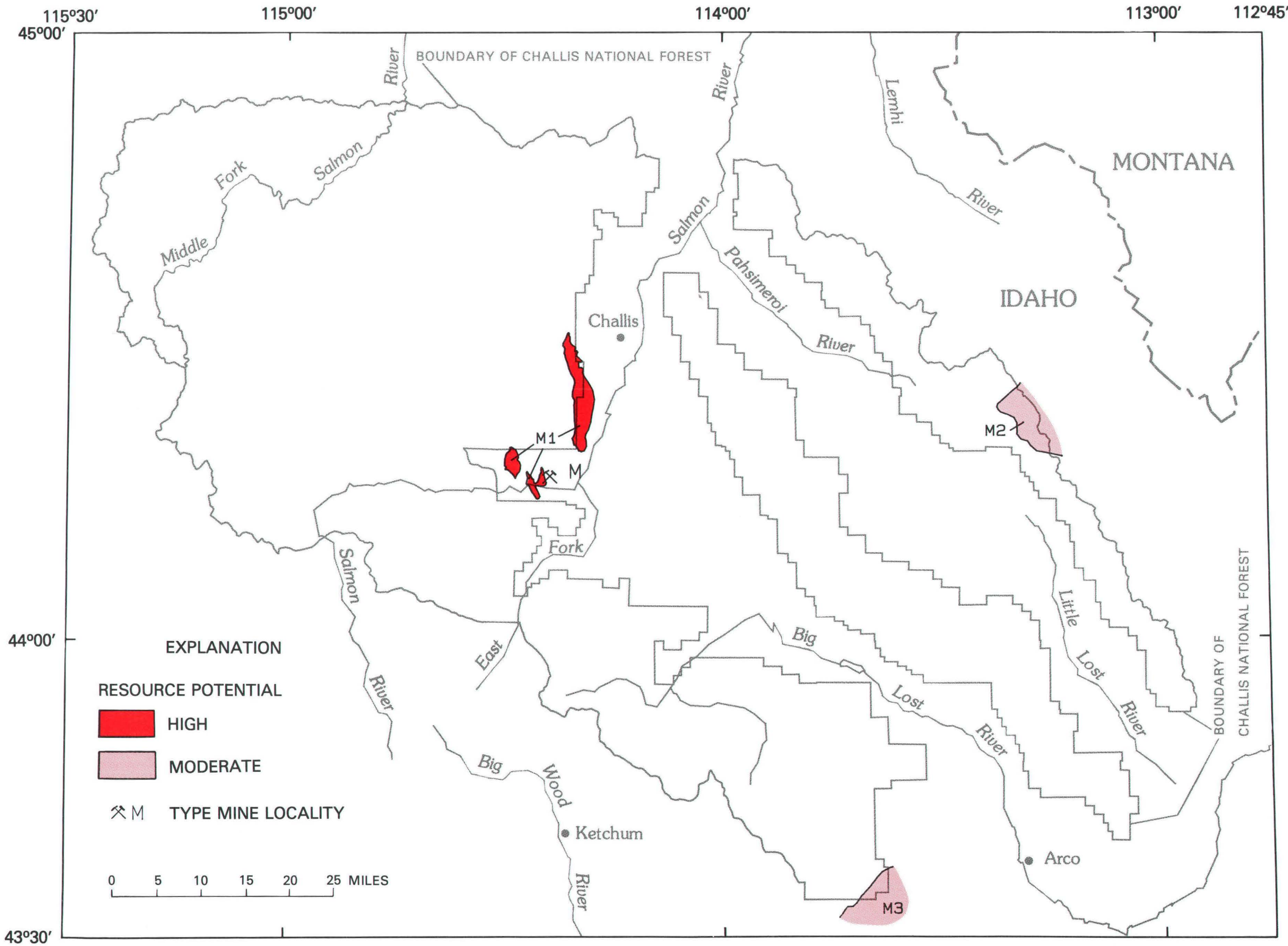


Figure 25. Mineral resource potential map for irregular replacements of base and precious metals (M) in the Challis National Forest and adjacent areas, Idaho. Areas (M1, M2, M3) of mineral resource potential are described in table 4.

Structural Control

Steep faults, shear zones, and brecciated zones served as channels for ore-forming solutions. Thrust faults in some areas placed impervious strata over the receptive carbonate beds. Anticlinal folds formed large solution traps below the impervious strata.

Age

Deposits in the Bayhorse district (fig. 4) are thought to be of Late Cretaceous age and related to the Idaho batholith (Fisher and Johnson, 1987). Potential deposits in other areas could be Cretaceous or Tertiary.

Deposit Description

Deposits are elongated lenses or ovoid pipelike bodies that follow the bedding of the host rock but are generally very irregular and discontinous. Ore occurs as numerous veinlets, disseminations, breccia fillings, and massive or discontinous replacements. Primary ore minerals are galena, tetrahedrite, sphalerite, and minor chalcopyrite, which have been locally oxidized to cerussite, anglesite, cerargyrite, and smithsonite. Gangue is quartz, barite, calcite, fluorite, and pyrite. Grade ranges from a few percent lead and zinc and a few ounces per ton of silver to 30–40 percent lead and 40–60 ounces per ton of silver. The type locality for this model is the Clayton Silver mine (M, fig. 25), Bayhorse district (fig. 4).

Geochemical Signature

The Clayton Silver mine type locality is within the boundary of a geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and the stream sediments had anomalous concentrations of B, Ag, Cu, Zn, and Pb. The stream sediments were also anomalous in As, and the heavy minerals were also anomalous in Ba, Bi, Mo, Cd, Sn, and W (table 7). A geochemical signature commonly associated with polymetallic replacement deposits is Cu, Zn, Pb, Mn, Ag, Au, As, Sb, Bi, and Ba.

Geophysical Signature

None known, but local detailed electrical surveys might detect individual orebodies.

Assessment Criteria

1. Presence of carbonate strata, especially in the Bayhorse Dolomite, Ella Dolomite, or Saturday Mountain Formation.
2. Steep north-trending faults.
3. Evidence of base- and precious-metal mineralization.

Assessment

Three areas (M1) classified as high potential (H/D) are in the vicinity of known deposits in the Bayhorse Mining district (fig. 4). The Windy Peak area (M2) of the Spring Mountain district (fig. 4) and Leadbelt Creek area (M3) of the Lava Creek district (fig. 4) are assigned moderate potential (M/B). In both areas carbonate beds are cut by mineralized high-angle faults. In the Windy Peak area the possible deposits may be at depth below a cap of quartzite. The areas of resource potential for irregular replacements of base and precious metals (M) are shown on plate 3 and figure 25 and summarized in table 4.

Economic Significance

This type of deposit in the past has been a major producer in the Challis National Forest, primarily from the Clayton Silver mine, which was not operational in 1986. Considerable reserves would be needed to support a new mining venture.

Fluorspar Breccia Manto Deposits (N)

Commodities, By-products, and Trace Metals

Fluorspar; base and precious metals are potential by-products.[37]

Stratigraphic Control

All known occurrences are in the upper few hundred feet of the Bayhorse Dolomite below a cap of Ramshorn Slate. The dolostone and the slate have been silicified in the vicinity of the ore deposits. Because of an unconformable contact between the Bayhorse Dolomite and the overlying Ramshorn Slate, different parts of the dolostone are mineralized.

Structural Control

Associated fluorspar veins are in high-angle regional faults that probably served as channels for the ore solutions. All the known deposits are on the crest and flanks of a major north-trending anticline.

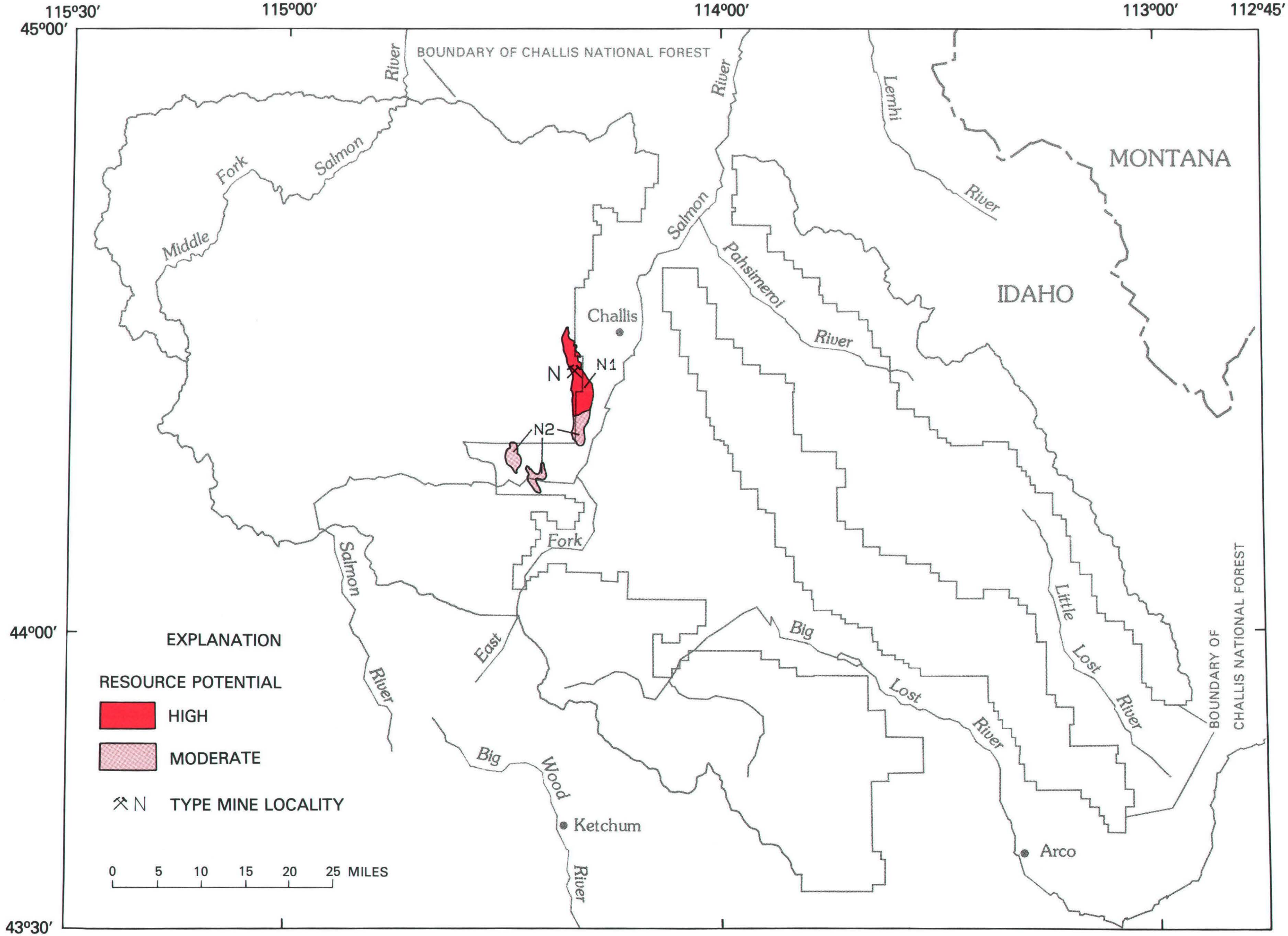


Figure 26. Mineral resource potential map for fluorspar breccia manto deposits (N) in the Challis National Forest and adjacent areas, Idaho. Areas (N1, N2) of mineral resource potential are described in table 4.

Age

Tertiary, probably same as fluorspar veins; associated sulfides may be Cretaceous.

Deposit Description

Deposits are stratabound, stratiform to irregular breccia fillings and replacements in the Bayhorse Dolomite. The deposits roughly parallel the unconformable contact between Bayhorse Dolomite and Ramshorn Slate. The tabular bodies range from less than 1 ft to 15–20 ft thick and as much as 3,000 ft long in the planar dimension. Fluorite, quartz, chalcedony, sandy dolomite, calcite, and minor barite and sulfide minerals make up the deposits. Type locality for this deposit model is the fluorspar deposits on Keystone Mountain (N, fig. 26), Bayhorse district (fig. 4).

Geochemical Signature

The Keystone Mountain deposits type locality is within the boundary of a geochemical survey conducted specifically for the USGS Challis CUSMAP project (fig. 5). Samples of both the heavy-mineral fraction of the stream sediments and the stream sediments had anomalous concentrations of B, Ag, and Pb. The heavy minerals were also anomalous in Bi, Be, Cd, Cu, Mo, Sb, and Zn (table 7). A geochemical signature commonly associated with fluorite gangue is Sb, Fe, As, Au, Ag, Hg, W, Pb, and Zn.

Geophysical Signature

The deposits themselves have no geophysical expression, but some major controlling faults show in the regional magnetic anomaly data.

Assessment Criteria

1. Presence of carbonate rocks.
2. Breccia horizons.
3. Deep-seated high-angle faults.
4. Proximity to Tertiary intrusive rocks.
5. Evidence of fluorspar in country rock, faults, or breccias.

Assessment

This is a type of deposit that is dependent upon several factors for development: brecciated and permeable zones in carbonate rock below a solution trap, deep-seated high-angle faults, and hypabyssal felsic intrusive rock of the correct composition and magmatic evolution. These factors could occur in conjunction with any receptive carbonate host. Assessment criteria are satisfied only in one area (N1) that contains known deposits. This area is assigned high resource potential (H/D) for fluorspar breccia manto deposits. Three small nearby areas (N2) are assigned moderate potential (M/D). The areas of resource potential for fluorspar breccia manto deposits (N) are shown on plate 3 and figure 26 and summarized in table 4.

Economic Significance

See discussion under Fluorspar Veins (A).

Sediment-Hosted, Jasperoid-Associated, Precious-Metal Deposits (O)

Commodities, By-products, and Trace Metals

Gold and silver; trace amounts of arsenic, antimony, mercury, and thallium.

Host Rocks

The most common hosts for deposits of this type in the Western United States include carbonaceous limestone and dolostone, calcareous carbonaceous shale and siltstone, and bioclastic limestone. Host rocks are silicified, commonly enough to be termed jasperoids.

Lithologic Control

Intermediate to silicic plutonic or hypabyssal intrusive rocks are generally present in the immediate area, although their relationship to the precious-metal mineralization is unknown. Many of the deposits are in thin-bedded carbonate and siltstone.

Structural Control

High-angle faults are present in all known deposits of this type and apparently served as conduits for the solutions that formed the jasperoids and the mineralized areas.

Age

Probably Cretaceous to middle Tertiary.

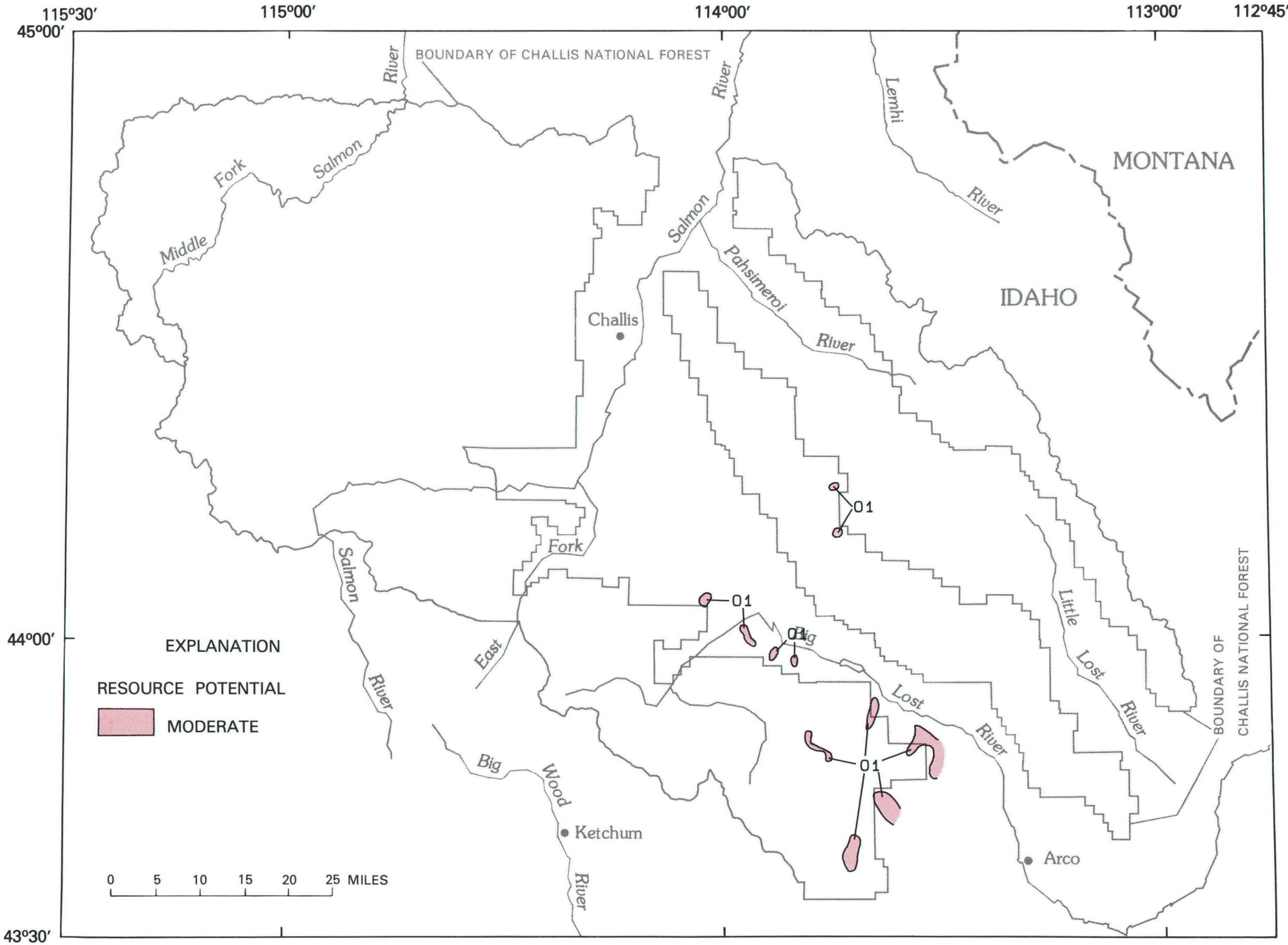


Figure 27. Mineral resource potential map for sediment-hosted, jasperoid-associated, precious-metal deposits (O) in the Challis National Forest and adjacent areas, Idaho. Areas (O1) of mineral resource potential are described in table 4.

Deposit Description

Bagby and Berger (1985, p. 169) recognized two subsets of sediment-hosted, disseminated precious-metal deposits: jasperoidal type and Carlin type. Jasperoidal-type deposits are those in which the precious metals are hosted in highly siliceous rocks including jasperoids and associated quartz veins and silicified wall rocks; this type of deposit occurs mainly along fault zones. Carlin-type deposits are those in which the precious metals are evenly distributed in the host rocks which do not always appear to be silicified, although jasperoids are generally present; this type of deposit occurs as a podlike body that extends several tens of meters away from a fault. There is a complete gradation between the two subtypes, and there are both gold- and silver-rich end members of each type. Veins of quartz, calcite, and barite are common, especially with the jasperoidal type, and late calcite veins and veinlets are present in most deposits. Jasperoidal breccias and jasperoid veins generally occur near ore, even though they may not carry precious-metal values. Pyrite is usually present, and cinnabar, stibnite, arsenopyrite, fluorite, barite, calcite, and various thallium and arsenic sulfides and sulfosalts may be present. Gold is typically submicroscopic (1–5 micrometers) and associated with pyrite, clay, silica, and organic matter. Organic matter is present in the primary ore of all known deposits as amorphous carbonaceous material, pyrobitumen, graphite, or kerogen. These are large-tonnage, low-grade deposits; median grade of 30 deposits in the Western United States is 0.088 oz (ounce) per ton, and most deposits contain 1–24 million tons of ore (Bagby and Berger, 1985, p. 197).

Geochemical Signature

The trace-element association of Au, As, Sb, Hg, and Tl is well known for deposits of this model type. The element association is important in defining target areas, not high values of individual elements. Other elements that may be present include W, Te, Se, Cd, and F.

Geophysical Signature

Several of the areas of jasperoid (pl. 1) show an association with deep negative magnetic anomalies of unknown origin.

Assessment Criteria

1. Presence of carbonaceous sedimentary rocks.
2. Jasperoid, especially as breccia or veins.
3. Presence of high-angle faults.
4. Indications of hydrothermal activity.
5. Presence of the geochemical suite, arsenic, antimony, mercury, and thallium in rock or soil samples.

Assessment

Assessment for this model type is based on criteria developed for deposits elsewhere in the Western United States. There are no known deposits of this type within the region, although several areas within and next to the Forest have geologic characteristics that meet all the criteria (Wilson and others, 1988a). Areas (O1) shown on plate 3 and figure 27 have a moderate potential but with a low level of certainty (M/B) because of a lack of adequate geological and geochemical data. Jasperoid as used in this report indicates a rock composed predominantly of silica, mainly aphanitic to fine-grained quartz, formed by replacement of the enclosing rock (Lovering, 1972). Jasperoids can form by several mechanisms, not all of which are related to hydrothermal mineralization. Detailed studies to determine the origin of the jasperoids in the Forest are in progress. The areas of resource potential for sediment-hosted, jasperoid-associated, precious-metal deposits (O) are shown on plate 3 and figure 27 and summarized in table 4.

Economic Significance

Large, low-grade, fine-grained "invisible-gold" deposits of this type are currently in production at several locations in the Western United States. Exploration activity for similar deposits is still active and will continue into the future. This activity will lead to an increased understanding of the jasperoids of the Forest and may delineate areas of potential not recognized today.

Precious-Metal Deposits in Volcanic Tuffs (P)

Commodities, By-products, and Trace Metals

Gold and silver.

Host Rocks

Host rocks may be volcanic or epiclastic carbonaceous sediments. Volcanic host rock at the known deposit of this type is highly fractured, nonwelded porous rhyolite tuff characterized by abundant rounded pumice fragments that are only slightly flattened. Phenocryst content is 15–40 percent, with quartz composing 35–48

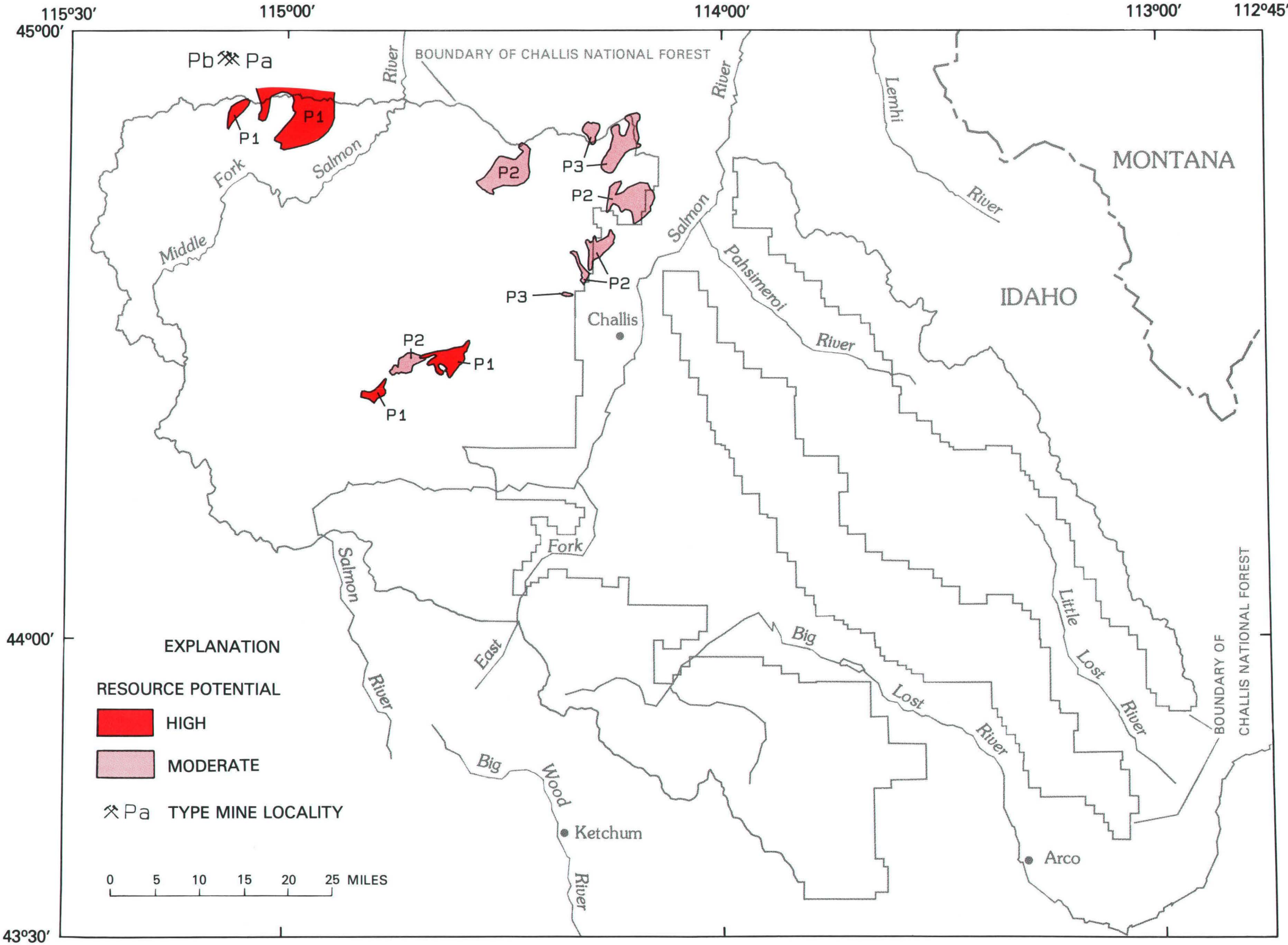


Figure 28. Mineral resource potential map for precious-metal deposits in volcanic tuffs (P) in the Challis National Forest and adjacent areas, Idaho. Areas (P1, P2, P3) of mineral resource potential are described in table 4.

percent, sanidine 50–70 percent, and biotite 0–3 percent of the phenocrysts (Fisher and Johnson, 1987). Host rocks are fractured, oxidized, and stained with iron oxides, with extensive argillic alteration in the vicinity of the deposits.

Deposits in epiclastic rocks are in black, carbonaceous mudflow breccia and carbonaceous volcanic sandstone.

Lithologic Control

The highest grade ores in volcanic rocks are concentrated beneath less permeable mudstones or clay-rich strata. Those in epiclastic rocks are associated with brecciated carbonaceous material.

Structural Control

Deposits are associated with northeast- and northwest-trending high-angle fracture zones.

Age

Tertiary.

Deposit Description

The only known deposit in volcanic rock is at the Sunnyside mine (Pa, fig. 28) in the Thunder Mountain district, just northwest of the Forest. The ores are stratabound and blanketlike and composed of fine-grained gold, silver, and electrum, and sparse acanthite and naumannite (Ag_2Se), dispersed along fractures and cracks. Ore distribution is uneven throughout the host rocks. Gangue is drusy quartz, clay, jarosite, sericite, illite, and sparse pyrite and arsenopyrite. The known deposit in epiclastic rock is at the Dewey mine (Pb, fig. 28) also located just northwest of the Forest. The deposit consists of fine-grained gold and silver in seams, cracks, and bedding-plane laminations distributed unevenly through the rock. Pyrite and clay minerals accompany the precious metals.

Geochemical Signature

The Sunnyside mine type locality is within the boundary of the Idaho Primitive Area (fig. 5). Both stream-sediment and rock samples collected near the type mine locality contained anomalous concentrations of As and Mo. Rock samples also had high concentrations of Ag, and stream-sediment samples had high concentrations of Cu (table 7). The Dewey mine type locality is within the boundary of the Idaho Primitive Area (fig. 5). Both stream-sediment and rock samples collected near the type mine locality contained anomalous concentrations of As. Rock samples also had high concentrations of Mo and Ag (table 7). A geochemical signature commonly associated with precious-metal veins, regardless of host rock, is Au, As, Sb, Hg, Ag, Pb, Zn, Cu, W, Bi, Te, and Tl.

Geophysical Signature

No recognizable magnetic signature.

Assessment Criteria

1. Evidence of precious-metal mineralization.
2. Within volcanotectonic subsidence structures.
3. Presence of nonwelded rhyolitic tuff and (or) epiclastic sedimentary rocks containing carbon trash.
4. Proximity to high-angle faults.

Assessment

Although the only known deposits are located just northwest of the Forest, there is potential for this type of deposit within the Forest. Geologic conditions in that part of the Forest within the Challis $1° \times 2°$ quadrangle indicate four areas (P1) of high resource potential (H/C) and five areas (P2) of moderate resource potential (M/C) for deposits in volcanic rock and one area (P3) of moderate resource potential (M/C) for deposits in epiclastic rocks. The remainder of the Forest cannot be assessed for this model type because of the lack of adequate data. The areas of resource potential for precious-metal deposits in volcanic tuffs (P) are shown on plate 3 and figure 28 and summarized in table 4.

Economic Significance

The potential is for large low-grade deposits that could be worked by some of the new techniques developed for the large low-grade deposits now being worked in the Western United States.

Stratabound Syngenetic Deposits of Precious and Base Metals (Q)

Commodities, By-products, and Trace Metals

Zinc, lead, silver, gold, and barite; trace amounts of vanadium and molybdenum.

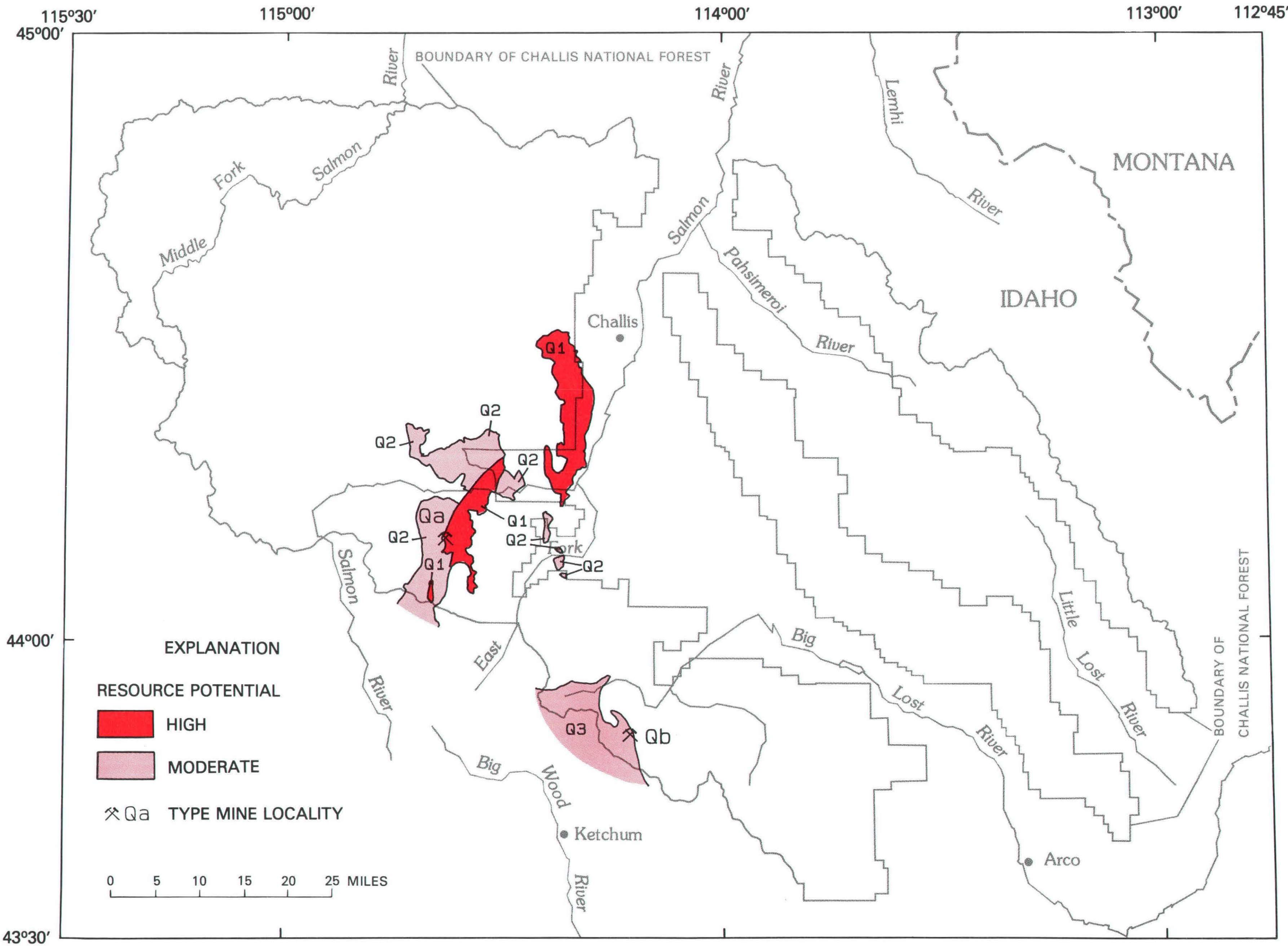


Figure 29. Mineral resource potential map for stratabound syngenetic deposits of precious and base metals (Q) in the Challis National Forest and adjacent areas, Idaho. Areas (Q1, Q2, Q3) of mineral resource potential are described in table 4.

Host Rocks

Black siliceous-facies carbonaceous argillite and fine- to medium-grained gray limestone or micritic carbonaceous limestone that were deposited in an euxinic environment. Alteration adjacent to known orebodies is not distinctive and, where present, was produced by contact metamorphism near Cretaceous and Tertiary plutonic bodies.

Lithologic Control

The deposits formed in restricted depositional basins in which metal-bearing geothermal brines accumulated.

Age

Mineralization is the same age as the enclosing host rock.

Deposit Description

Deposits are composed of stratiform-bedded masses and lenses rich in sphalerite and galena with pyrite, pyrrhotite, barite, arsenopyrite, quartz, calcite, clay minerals, and tremolite. The orebodies can be several hundred feet in length. Associated stringers and disseminations of sulfide minerals may reflect feeder zones for the metal-bearing brines. Metals in these deposits have been remobilized where cut by plutonic and hypabyssal intrusive bodies and by hydrothermal solutions moving along faults and fractures. Two type localities are shown: the Hoodoo mine (Qa, fig. 29), Boulder Creek district (fig. 4), in the Salmon River assemblage, and the Phi Kappa mine (Qb, fig. 29), Alto district (fig. 4), in the Copper Basin Formation and undivided Ordovician and Silurian argillites.

Geochemical Signature

The Hoodoo mine type locality is within the eastern part of the Sawtooth Recreation Area (fig. 5). Both stream-sediment and rock samples collected near this type mine locality contained anomalous concentrations of Sb, Zn, Pb, and Ag. Rock samples also had high concentrations of Hg, Sn, Bi, and Cu, and stream-sediment samples also had high concentrations of Cd, Mo, and Au (table 7). The Phi Kappa mine type locality is within the boundary of the Boulder–Pioneer Wilderness Study Area (fig. 5). Stream-sediment samples collected near this type locality contained anomalous concentrations of Pb, Mo, Zn, and B (table 7). A geochemical signature commonly associated with stratiform sulfide deposits is Cu, Pb, Zn, and Mn. Compared to the common geochemical signature, the type localities have higher concentrations of precious metals and elements such as Hg and Sb that are usually associated with precious-metal deposits.

Geophysical Signature

Detailed magnetic, electromagnetic, and gravity surveys have been used successfully in exploration for similar types of orebodies elsewhere.

Assessment Criteria

1. In black-shale terrane.
2. Anomalous concentrations of zinc and (or) lead.
3. Evidence for presence at time of deposition of a basin to localize metalliferous brines.

Assessment

Large areas in the Challis National Forest are underlain by units containing black shales. The units include the Ramshorn Slate, Trail Creek Formation, Phi Kappa Formation, Milligen Formation, Salmon River assemblage, and Wood River Formation. The lower part of the Copper Basin Formation and the McGowan Creek Formation also contain black shales. Stratiform zinc deposits are known in the Forest in at least two locations, the Hoodoo and Livingston mines in the Boulder Creek district (fig. 4), and are known in the same belt of rocks to the south in the Hailey area. In addition, many of the metal occurrences in the black shales are suspected to be stratiform deposits. The polymetallic veins in black-shale terrane may be remobilized ore from stratiform beds or may be feeders for the stratiform deposits. Two areas (Q1), mainly underlain by the Salmon River assemblage, are assigned high (H/D) resource potential. Several other areas (Q2 and Q3) are assigned moderate (M/D and M/B, respectively) potential. The known deposits are in the Salmon River assemblage and undivided Ordovician and Silurian argillites, and perhaps the lower part of the Copper Basin Formation. South of the Forest the Milligen and Wood River Formations contain stratiform base- and precious-metal deposits. An unknown potential is assigned to the black-shale units in the Copper Basin and McGowan Creek Formations. These units are mostly outside the black-shale belt but are of the right lithology and were formed in the correct deposition environments. The areas of resource potential for stratabound syngenetic deposits of precious and base metals (Q) are shown on plate 3 and figure 29 and summarized in table 4.

Economic Significance

There is not sufficient knowledge about this type of deposit in the Forest to speculate on grades or tonnages, but grades could be high and tonnages could be as much as tens of millions of tons. See the discussions in the several sections on Polymetallic Vein Deposits (B, C, D, E).

Stratiform Vanadium Deposits (R)

Commodities, By-products, and Trace Metals

Vanadium; zinc, lead, silver, or barite are potential by-products; trace amounts of molybdenum, nickel, chrome, selenium, and arsenic.

Host Rocks

Black shales; fine-grained siliceous mudstone, siltite, micritic limestone, chert, and dolomitic siltstone. Veinlets of chalcedony and opaline silica-filled fractures are common.

Stratigraphic Control

The known vanadium-rich horizons are in the Salmon River assemblage (Fisher and May, 1983) and the Glide Mountain plate of the Copper Basin Formation (Simons, 1981). Concentration of metals is thought to have occurred during deposition of organic-rich fine-grained marine clastic sediments in a euxinic environment.

Age

Mineralization is the same age as the host rock.

Deposit Description

Disseminated and bedded deposits in organic-rich horizons with pyrite, marcasite, sphalerite, chalcedony, vanadium, and molybdenite. Highly anomalous vanadiferous beds contain greater than 1 percent vanadium (Fisher and May, 1983). Weathered zones have a distinct pink vanadium "bloom."

Geochemical Signature

Probably same as for stratabound syngenetic deposits of precious and base metals.

Geophysical Signature

None known, but detailed geophysical methods may be useful in delineating deposits of this type.

Assessment Criteria

1. Anomalous concentrations of vanadium in rock or stream-sediment samples.
2. In black-shale terrane with organic-rich horizons.
3. Evidence of synsedimentary structures that may have localized metalliferous brines.

Assessment

There are no known deposits of this type in the Challis National Forest, and although they do occur elsewhere in the Western United States, none have been mined. The area (R1) along the Slate Creek lineament in the Salmon River assemblage is assigned high potential (H/D). Other areas (R2 and R3) underlain by black shale are assigned moderate potential (M/C and M/B, respectively). The areas of resource potential for stratiform vanadium deposits (R) are shown on plate 3 and figure 30 and summarized in table 4.

Economic Significance

In the future this type of deposit may become an exploitable resource (millions of tons) for vanadium and associated metals.

Gold Placer Deposits (S)

Commodities, By-products, and Trace Metals

Gold and silver; radioactive minerals, niobium, tantalum, and rare-earth elements are potential by-products.

Host Rocks

Gold placers are in fluvial deposits consisting of sand, gravel, and boulders. Most clasts are less than 2 ft in diameter, and clay is common locally. These deposits are commonly in terraces a few to several hundred feet above the present stream.

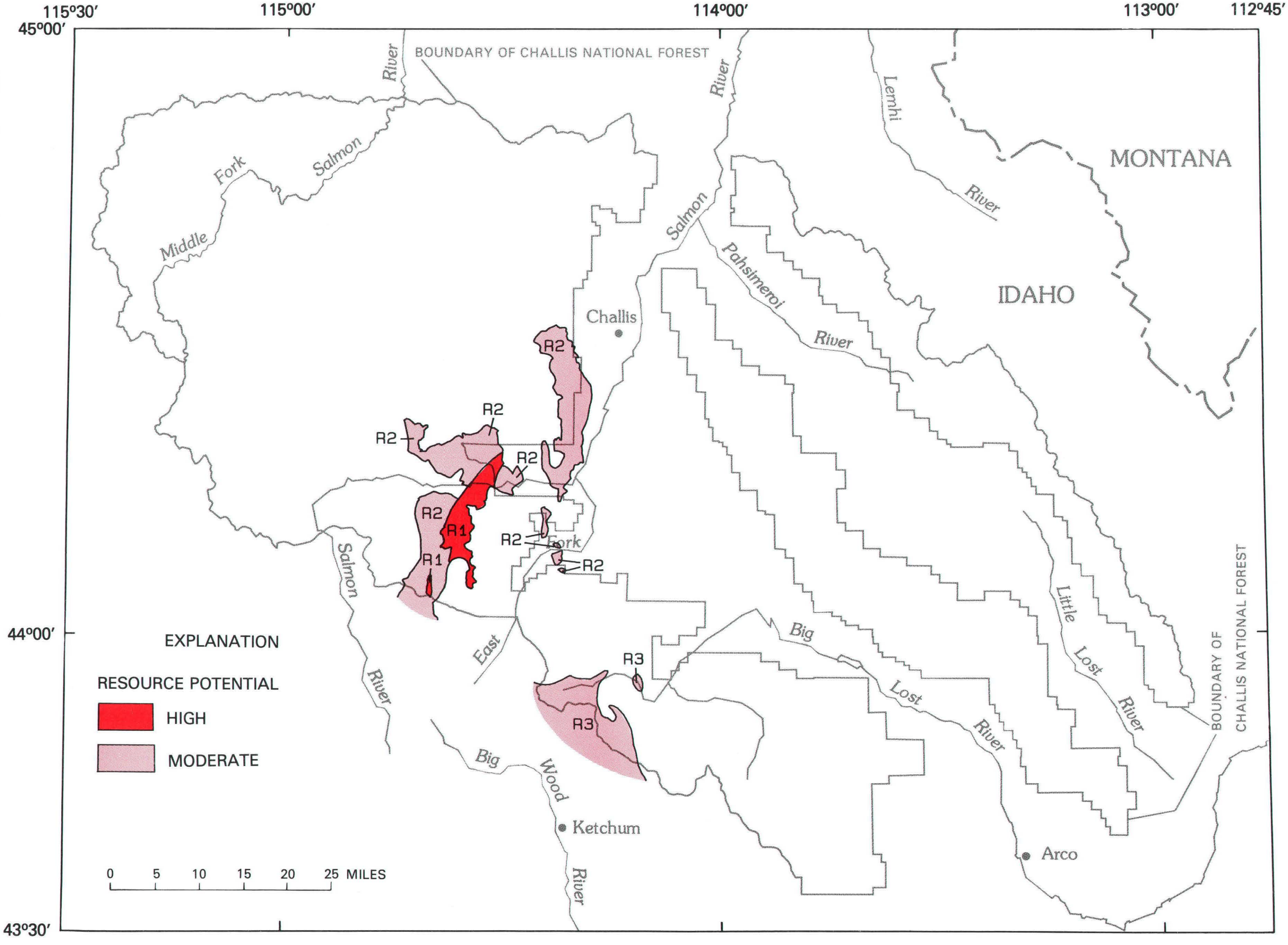


Figure 30. Mineral resource potential map for stratiform vanadium deposits (R) in the Challis National Forest and adjacent areas, Idaho. Areas (R1, R2, R3) of mineral resource potential are described in table 4.

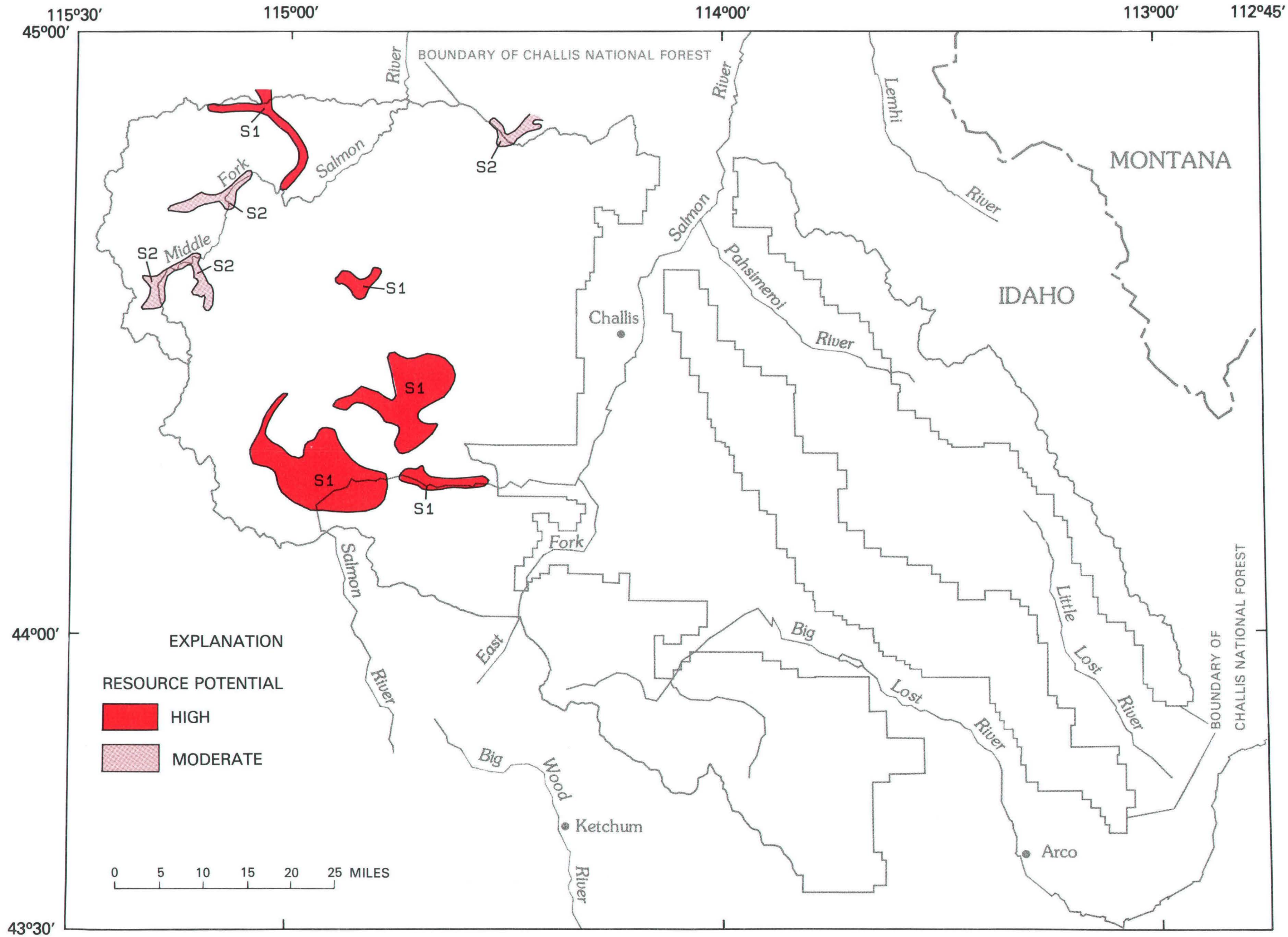


Figure 31. Mineral resource potential map for gold placer deposits (S) in the Challis National Forest and adjacent areas, Idaho. Areas (S1, S2) of mineral resource potential are described in table 4.

Lithologic Control

The major placers are directly downstream from known lode precious-metal deposits. The highest concentrations of placer gold are in pay streaks just above bedrock.

Age

The alluvial deposits are Pleistocene to Holocene.

Deposit Description

Placer deposits formed in streams where turbulent and irregular flow patterns separated light from heavy components of bedload. Gold is not dispersed throughout but is concentrated in pay streaks that constitute only a small part of the gravels. Both free gold and electrum are present. Other heavy components associated with the gold placers are ilmenite, magnetite, euxenite, brannerite, zircon, monazite, cinnabar, stibnite, and garnet. Gold in these placer deposits ranges in size from grains a few millimeters in diameter to nuggets as much as 1 inch in diameter. The placers range in size from a few acres to several thousand acres and are a few feet to more than 100 ft thick. Grades range from 0.09 to 0.005 oz per yd^3.

Geochemical Signature

Gold and silver, and black-sand minerals.

Geophysical Signature

Regional geophysical surveys are of little use, but local seismic surveys may be of use in defining gravel depths. Ground magnetometers could be used to detect magnetite and ilmenite that may be concentrated in the gold placers and could serve as a prospecting tool in search of shallowly buried placers.

Assessment Criteria

1. Evidence of precious-metal mineralization.
2. Within 5 mi downstream from known precious-metal lode deposits.
3. Presence of adequate amounts of alluvium.

Assessment

Placer deposits in the Forest have been worked intermittently since 1860. Major operations were prior to 1900, in the 1930's, and most recently (the Yankee Fork dredge) in the late 1940's and 1950's. Substantial amounts of placer gold still remain in areas previously unmined and also in areas already mined because earlier operations were very inefficient. Large known resources exist in several areas (Fisher and others, 1987). Five areas (S1) are assigned high potential (H/D) and three areas (S2) are assigned moderate potential (M/D) for gold placer deposits of sufficient size (100–100,000 ounces Au) to justify development. All areas are within the Challis 1° × 2° quadrangle which is where most of the known major gold lode deposits are located. Areas outside the Challis quadrangle may have some potential for smaller placer deposits, especially in drainage basins that contain other types of deposits where gold is a by-product. The areas of resource potential for gold placer deposits are shown on plate 4 and figure 31 and summarized in table 4.

Economic Significance

Gold is a commodity that is always in demand, and placer deposits can commonly be worked with a minimum of overhead expenses. However, placer mining is an environmentally disruptive process and any mining operation must adhere to State and Federal regulations that govern all forms of placer mining.

Radioactive Black-Sand Placer Deposits (T)

Commodities, By-products, and Trace Metals

Thorium dioxide, rare-earth oxides, niobate and tantalate pentoxides, U_3O_8, ilmenite, zircon, garnet, and gold.

Host Rocks

Alluvium, consisting chiefly of clay, sand, pebbles, and a few boulders of granitic rock. Black-sand minerals are found throughout but are most abundant in lenses and beds of coarse sand and fine gravel in which the larger pebbles are generally less than 1 inch in diameter.

Structural Control

Streams that carry weathered material off of the Idaho batholith terrane formed these deposits where stream flow was blocked or impeded by faults, Pleistocene ice or moraines, landslides, or basalt flows.

Age

The richer deposits formed during the early Pleistocene when an abundance of pre-Pleistocene weathered

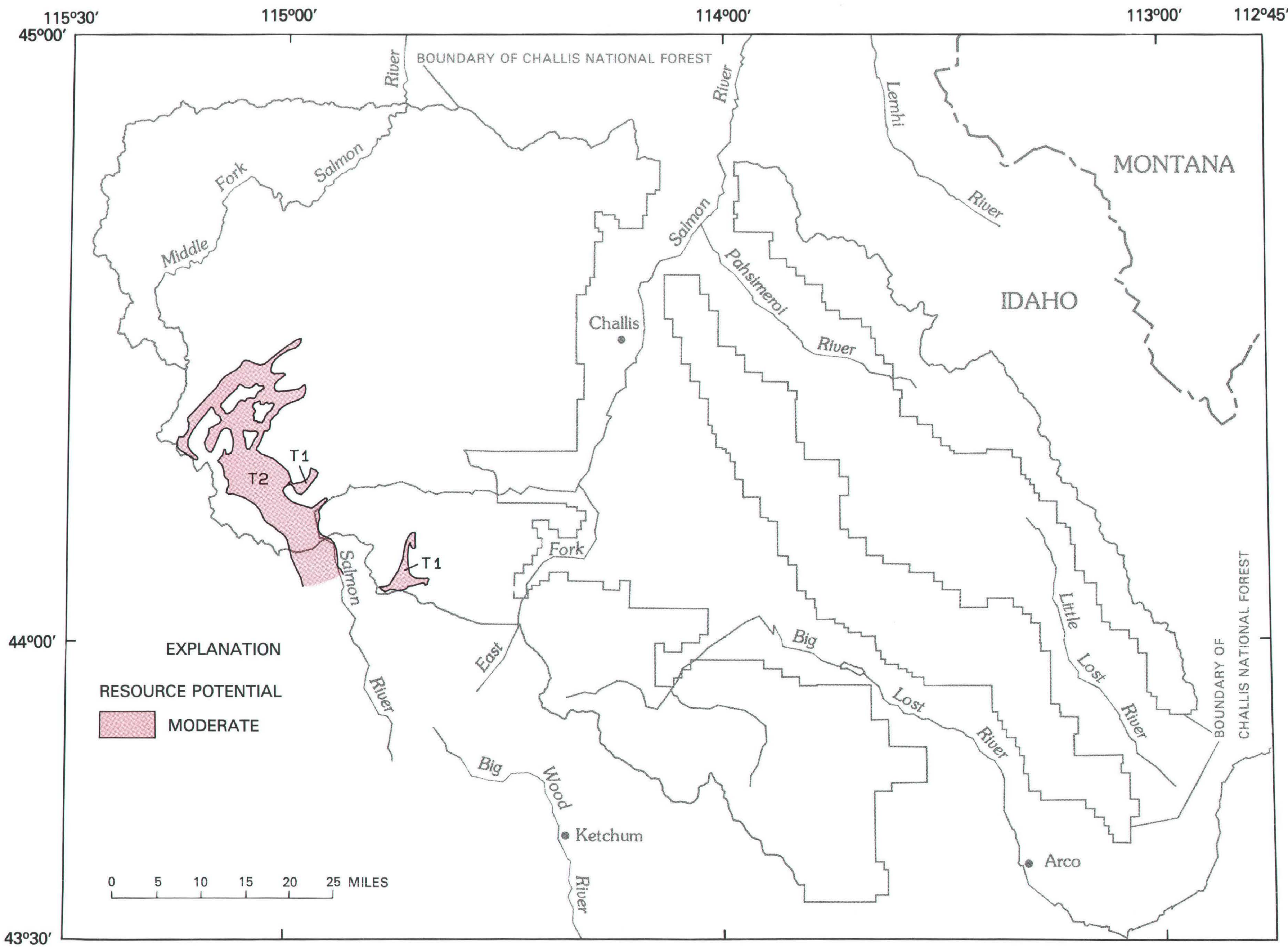


Figure 32. Mineral resource potential map for radioactive black-sand placer deposits (T) in the Challis National Forest and adjacent areas, Idaho. Areas (T1, T2) of mineral resource potential are described in table 4.

mantle was transported by accelerated glacial erosion. Later deposits contain lesser amounts of heavy minerals, except where such minerals are concentrated through winnowing by streams.

Deposit Description

Deposits are alluviual blankets that range considerably in size, shape, and thickness, and that contain lenses and beds rich in black-sand minerals. An exploitable deposit should contain at least 1 million yd^3 of alluvium and a minimum of 0.5 lb per yd^3 of monazite or other radioactive minerals. The ore minerals include monazite, euxinite-polycrase, brannerite, samarskite, xenotime, fergusonite, uranophane, columbite, allanite, ilmenite, magnetite, zircon, garnet, and gold, of which ilmenite is by far the most abundant. These minerals occur in the black sands as individual crystals and are mostly minus-16-mesh in size, which means they are easily separated by various methods. Black-sand minerals are present in the alluvium in amounts ranging from less than 1 lb per yd^3 to more than 30 lb per yd^3.

Geochemical Signature

The best indicator in a stream bed is black sand. Mineralogy of the black sand can be determined by a variety of methods including visual inspection, magnet, geiger counter or gamma-ray spectrometer, and chemical analyses.

Geophysical Signature

Detailed gravity, magnetic, seismic, and radiometric surveys can provide information on depth of alluvium and presence of radioactive minerals and can aid in delineating the course of enriched paleochannels.

Assessment Criteria

1. Large amount of alluvium, more than 10 million yd^3.
2. Contains monazite or radioactive minerals.
3. Derived from Idaho batholith terrane that was extensively glaciated.
4. In valley of low-gradient stream.

Assessment

The major known radioactive black-sand placer deposits are just west of the Forest. Within the Forest known deposits are at Williams Creek–Gold Creek southeast of Stanley and at Warm Springs Creek–Pigtail Creek (Meadows) northwest of Stanley. The vicinities (T1) of the known deposits are assigned a moderate (M/D) potential. The Sawtooth Valley (T2) is assigned a moderate potential with low certainty (M/B) because much of the alluvium is overlain by glacial materials. The areas of resource potential for radioactive black-sand placer deposits (T) are shown on plate 4 and figure 32 and summarized in table 4.

Economic Significance

Some of the commodities in these deposits, mainly niobium and tantalum, are of critical importance to the United States because of this Nation's total dependence upon foreign sources and lack of domestic reserves. At the present time, large low-grade foreign sources control the market. Rare-earth metals are also in demand. The major problem in extracting rare earths from these deposits is the presence of thorium in the monazite. Thorium is not in demand now, and the accumulation of this radioactive by-product from rare-earth extraction causes a major disposal problem.

Other Commodities

Several other mineral deposit types need to be mentioned, but because they are not yet commercially valuable, or because available information is not sufficient, they cannot be assessed in the same way as the major deposit types.

Manganese

Manganese minerals are common in small amounts in many mineral deposits in the Forest but are not present in sufficient quantity to be considered as a potential resource. Most of the manganese is present as oxides that are mainly a surface coating or as a mixture with iron oxides called wad. A few of the hydrothermal deposits have some rhodochrosite.

Semiprecious Gemstones

Opal occurs in small veins and veinlets in fractures in volcanic rock in several places in the Forest. The opals are brittle and not of gem quality. The "pink" granites of Tertiary age of Idaho, such as the Sawtooth batholith, have miarolitic cavities with crystals of smoky quartz, microcline, topaz, and beryl (aquamarine), along with fluorite, carpholite, bertrandite, helvite, and ilmenite. Smoky quartz and microcline are the most common minerals; the others are rare. The occurrences are widely scattered and the access is difficult; thus there is little likelihood of commercial production. Jasper, chalcedony, and agate (the variegated form of chalcedony) are found in many places in the Forest, but there has been little commercial production.

Limestone

Production of lime-bearing rock in the United States is greater in volume than that of any metallic mineral and is exceeded only by coal and sand and gravel (Savage, 1961, p. 111). The value of lime-bearing rocks as a resource depends upon their chemical and physical characteristics and accessibility to markets. There is significant production of these rocks in other parts of Idaho, but within and close to the Forest there has been little production. Several carbonate units of Paleozoic age are exposed in the Forest. The lower Paleozoic units are generally very siliceous and dolomitic. Some of the upper Paleozoic units, mainly the Madison and White Knob Limestones, are widespread and relatively pure limestones. These upper Paleozoic units do contain chert layers and nodules and intercalated lenses of shale and sandstone which make parts of them commercially unusable.

Iron

Three areas within or close to the Forest have been prospected for iron resources. The contact metamorphic skarn deposits in the Alder Creek district near Mackay are locally rich in magnetite and hematite, as are the skarns just north of Windy Peak in the Lemhi Range. Deposits in both areas, although high grade in places, are probably not large enough to constitute major resources. Magnetite and hematite also occur as small, irregular replacement bodies in dolostone and limestone in the central and southern parts of the Lemhi Range.

Graphite in Metamorphic Rocks

Graphite is common in some metamorphic rocks in the Forest, especially in the Stanley area. The known occurrences are low grade, although they may contain large tonnages. The ready availability and low demand for graphite, plus logistics of mining the local occurrences, suggest that these mineral occurrences are not potential resources.

Pegmatite Minerals

Pegmatites are coarse-grained igneous dikes and irregular-shaped bodies that are common in some parts of the Forest. They are composed mainly of feldspar, quartz, and mica, but they locally contain minerals of commercial importance, including beryl, columbite-tantalite, cassiterite, scheelite, spodumene, tourmaline, uranium minerals, and rare-earth minerals. Pegmatites elsewhere in the world have been a commercial source for these minerals, but there is no recorded production in the Forest. Although pegmatites are common in the Forest, most are simple pegmatites a few inches thick and a few feet long that do not contain mineable quantities of economic minerals.

Mercury

Mercury has been produced at several locations in the Yellow Pine district just north of the Forest, and one area of mercury resource potential lies on the northern boundary of Boise National Forest lands administered by Challis National Forest. Cinnabar occurs in jasperoid or chalcedonic quartz along high-angle faults that cut calcareous metasedimentary rocks. Cinnabar has been reported in float and placer deposits in the Stanley area (Choate, 1962) and in panned concentrate samples from the Lava Creek district (fig. 4) (Erdman and others, 1988).

Zeolites

Minerals of the zeolite group (hydrated silicates of Al, Ca, Na, and K) have been identified in altered volcanic rocks of the Challis Group in the Twins Peaks area (Fisher and Johnson, 1987). The altered area is 8 mi long and three-quarters of a mile wide, but the zeolite resource potential is unevaluated. Similar altered volcanics are common in the Forest; some of these rocks may contain significant amounts of zeolite minerals. Identification of most zeolite minerals in the field is difficult, if not impossible.

Barite

Barite ($BaSO_4$) is a common mineral in many of the base- and precious-metal deposits in the Forest and composes 2–3 percent of the fluorspar ore from the Meyers Cove deposits. There are a few barite vein occurrences in the Forest, the most notable being the small veins in the Borah Peak area. More importantly, bedded barite occurs in the black-shale terrane. Deposits near Hailey have been mined, and there is a bedded barite occurrence at the Hoodoo mine in the Challis National Forest. Pan-concentrated samples from the black-shale terrane contain anomalous amounts of barite, which could come from either bedded deposits or barite gangue in the base- and precious-metal deposits. A large, and accessible, bedded barite deposit would be a significant resource.

Uranium in Sedimentary Rocks

Several occurrences of uranium minerals in Tertiary sedimentary rocks are in and near the Forest. These are in the Basin Creek area, northeast of Stanley, and on the northeast side of the Pahsimeroi Valley, south of Ellis. The uranium occurs in channel-filling deposits of carbonaceous arkose and mudstone. There has been minor production from the deposits near Stanley. Other deposits similar to those near Stanley may exist, but none have been found, even though the region was extensively explored in the late 1950's and late 1970's.

Cobalt

Cobalt, along with copper, is mined at the Blackbird mine just north of the Forest and occurs at several other localities in the same area. The deposits are stratiform and are in the Middle Proterozoic Yellowjacket Formation. Appreciable amounts of bismuth, arsenic, nickel, iron, and gold are also present. The areas of resource potential for cobalt do not extend into the Forest. However, known cobalt occurrences are on the northeast side of the Lemhi Range at the Wells cobalt property. There is also some question as to how far the Yellowjacket Formation extends to the south. If the Yellowjacket Formation is present at or near the surface along the northeastern edge of the Lemhi Range, there may be an unrecognized potential for cobalt deposits in this area.

Alunite

Vein and replacement alunite deposits are found in volcanic terranes throughout the world, and in the Western United States, they are most commonly associated with Tertiary volcanic rocks. The calderas and volcano-tectonic grabens of the Challis volcanic field are potentially favorable localities for alunite deposits, but this resource potential is unknown.

Silver

Calderas and grabens of the Challis volcanic field contain carbonaceous volcaniclastic rocks, most of which predate the precious-metal vein deposits and associated alteration. Permeable beds in sequences of alternating permeable and impermeable beds may have been receptive hosts for precious-metal solutions moving outward from the vein zones. These speculative deposits, which might contain silver, would be somewhat analogous to those at Creede, Colo.

Gold

Large-tonnage low-grade gold deposits of several types are currently being mined or evaluated in the Western United States. The types of deposits include epithermal sediment-hosted deposits, volcanic-hosted deposits, and deposits associated with flat faults and hot springs. Most of the important geologic parameters that define these deposits are present in the Forest: evidence of large-scale hydrothermal activity; major high-angle faults; major low-angle faults; carbonaceous, calcareous, and quartzitic sedimentary rocks; extensive areas of silicic volcanic rocks; hypabyssal intrusive bodies; and alteration assemblages generally associated with epithermal gold deposits. Areas of resource potential for these deposit types cannot be defined, but there is a moderate potential with low certainty that somewhere in the Forest conditions were right for the formation of a large-tonnage low-grade precious-metal deposit. Localities of interest are the altered quartzites in the southern Lemhi Range, altered volcanic rocks north and south of Mackay, and altered carbonate rocks within the trans-Challis and parallel fault systems.

Areas of Unknown Resource Potential

Some areas within and close to the Forest have some suggestion of the presence of mineralization but lack definitive data to indicate the type or kind. These areas are assigned an unknown resource potential and are discussed separately in this section by area. Areas of unknown resource potential are shown on plate 3 and figure 33.

Area U1—Lone Cedar Creek

This area in the Lone Cedar Creek and Sawmill Canyon areas of the west-central part of the Lost River Range had some base- and precious-metal production in the past from hydrothermal vein-type deposits in carbonate rock. Hydrothermal barite stringers and felsic to intermediate dikes and pods are common along high-angle faults. The unknown resource potential is for base- and precious-metal veins, replacements, and disseminations at depth.

Area U2—Iron Bog and Leadbelt Creeks

This area just north of the Lava Creek district (fig. 4) has a thin to moderate cover of Challis Group volcanic rocks overlying a black-shale terrane and is at the intersection of northwest- and northeast-trending zones of faults, dikes, and altered zones. A positive magnetic anomaly in the eastern part of the area suggests

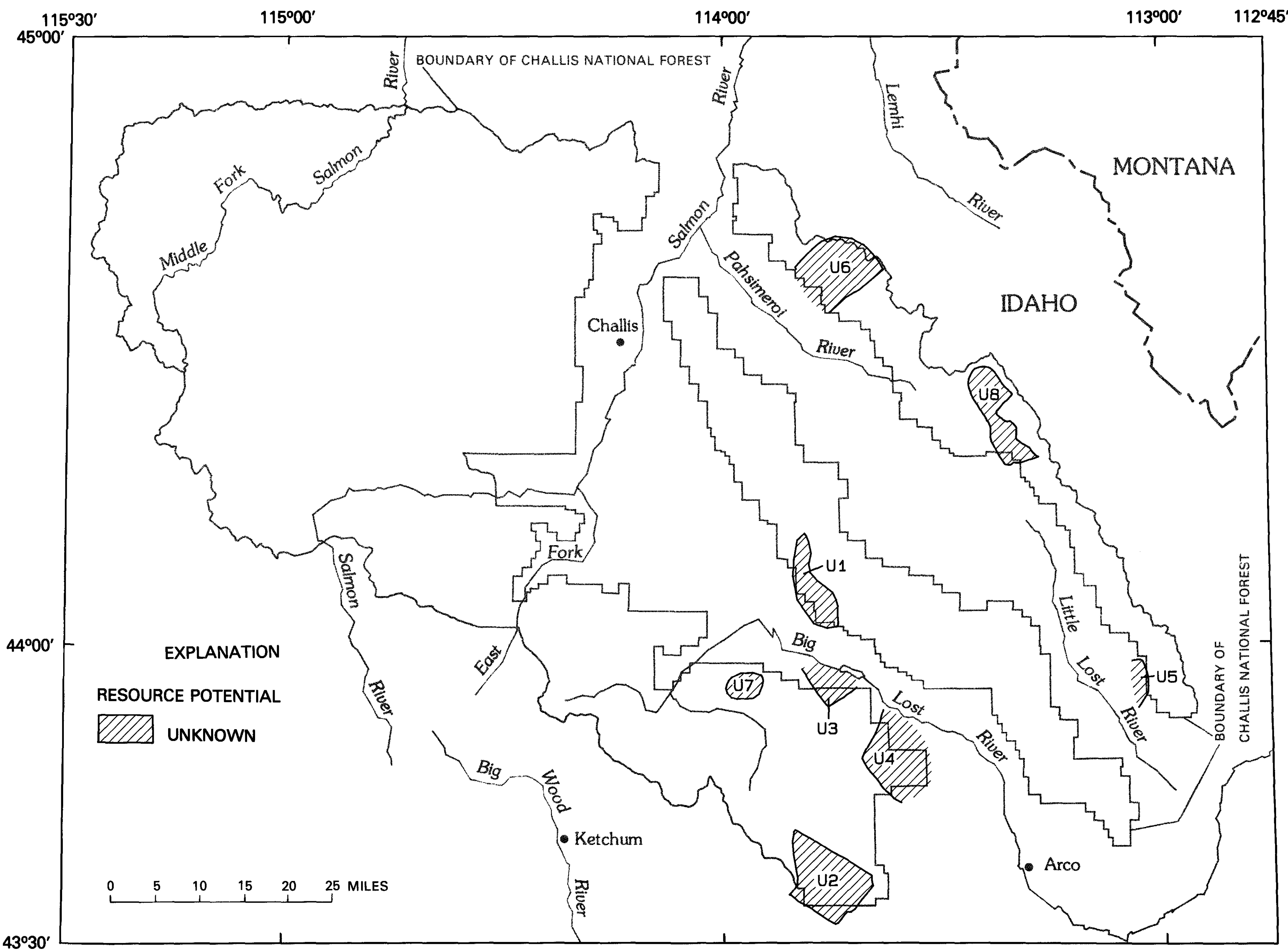


Figure 33. Map showing areas of unknown resource potential in the Challis National Forest and adjacent areas, Idaho. Areas (U1, U2, and so forth) of unknown resource potential are described in the text.

a buried intrusive. Known base- and precious-metal mineral occurrences are in Paleozoic rocks on both the northwest and southeast sides of the volcanic rocks. The unknown resource potential is for base- and precious-metal veins, skarns, and replacements in the Paleozoic rocks at depth beneath the volcanic rocks.

Area U3—Hamilton Creek–Burma Road

This area just west of Mackay Reservoir has a moderate to thin cover of volcanic rocks over carbonate terrane. Altered and mineralized fault zones of northwest trend in the volcanic rocks contain some base and precious metals. The unknown resource potential is for veins, skarns, replacements, and jasperoid-associated deposits in the Paleozoic carbonate rocks at depth below the volcanic cover.

Area U4—Sheep Mountain

This area just south of the Alder Creek district (fig. 4) has a moderate to shallow cover of volcanic rocks over carbonate terrane. Altered zones and intrusive rocks in the volcanic piles and the aeromagnetic data suggest an intrusive at depth. The unknown resource potential is for veins, skarns, replacements, and jasperoid-associated deposits in the Paleozoic rocks at depth below the volcanic cover and for veins and disseminations in the altered volcanic rocks.

Area U5—North Creek

This area is just west of the Wilbert mine (C1, fig. 15) and on the edge of a broad positive aeromagnetic anomaly. The anomaly may reflect a buried intrusive body related to the mineralization in the Wilbert and other mines in the near vicinity. Much of area U5 is a pediment surface, and exposures are very sparse. The unknown resource potential is for base- and precious-metal vein and stockwork deposits.

Area U6—Mahogany Creek

This area in the Blue Wing district (fig. 4) is along a ring-fracture system that was thought by Ruppel (1978) to have controlled emplacement of the intrusive body and related mineralization at the Ima mine. The unknown resource potential is for vein and stockwork mineral deposits along or close to one of the ring fractures.

Area U7—Porphyry Peak

Porphyry Peak is an Eocene volcanic vent region northwest of Mackay with comagmatic intrusive phases. Rocks in much of the area are bleached and iron stained, and there are zones of intense silicification. The country rocks are highly fractured, and felsic dikes are abundant. Little is known of the geology, and no geochemical data are available. The unknown resource potential is for base- and precious-metal stockworks and disseminations in altered volcanic rocks.

Area U8—Squaw Creek

This area is just west of the mineral deposits in the Windy Peak area, Spring Mountain district (fig. 4), and contains numerous prospects, but is not mapped in detail. Quartzite and underlying carbonate beds are intruded by a Tertiary felsic pluton. Exposures are sparse. The unknown resource potential is for base- and precious-metal veins and replacement deposits in the carbonate rocks and precious-metal veins in the quartzites.

MINERAL RESOURCES—LEASABLE MINERALS

Oil and gas, oil shale, potash, sodium, native asphalt, bitumen or bituminous rock, phosphate, and coal are leasable commodities or "mining act minerals." They were excluded from the General Mining Law of 1872 by the Mineral Leasing Act of 1920 which set up laws requiring prospect permits and leases to control their exploration, development, and production. Geothermal energy was added to the list of leasable commodities by the Geothermal Steam Act of 1970.

There is no recorded production of any of these commodities within the Forest and adjacent lands administered by the Forest.

A thin coal (lignite?) seam is about 1 mi outside the Forest in the northwest part of the Lemhi Range. The seam has been prospected for uranium but is not large enough to mine for its coal. Graphitic material, assumed to be metamorphosed coal, crops out near Ketchum, nearly 10 mi outside the Forest boundary. This is in an area of contact and regional metamorphism, and any coal beds present are probably thermally altered to carbonaceous graphitic material.

Oil and gas have not been identified within the Forest or nearby areas. Presence of hydrocarbons requires porous reservoir rocks; organic-rich source beds; stratigraphic, lithologic, or structural traps; and favorable thermal history. Whereas the first three criteria may be met several places in the eastern portion of the Forest, the thermal history has not been favorable for accumulation of hydrocarbons. Conodont studies indicate that the Color Alteration Index of the region is about 5, whereas the limit for oil is 2–3 and that for gas is 4–4.5. Mineral-resource potential for oil and gas resources in the Forest is low.

Thermal springs in the Forest, especially in the western part, are used for recreation, irrigation, and space heating. There may be potential for greater exploitation of the springs as hot-water and steam resources.

RESOURCE POTENTIAL—LEASABLE MINERALS

Geothermal Resources (V)

Commodities

Hot water and steam.

Host Rocks

Thermal springs emerge from rocks of all ages (Precambrian to Holocene), especially in the vicinity of Cretaceous and Tertiary volcanic or plutonic rocks.

Structural Control

Geothermal springs generally occur along faults and fractures near igneous intrusive bodies. The intrusions themselves may have been emplaced along major fault zones. Springs not associated with igneous rocks are related to deep-seated high-angle fault zones.

Age

Holocene. The hot springs are heated by currently active hydrothermal systems.

Deposit Description

Thermal springs are most common in areas of high regional geothermal gradients or in the vicinity of young intrusions or magma bodies. They are abundant in the western part of the Forest where they are almost entirely related to large intrusive bodies. In the southern and eastern portions of the Forest they are less common and are hosted by Paleozoic rocks; these springs may be associated with intrusive bodies at depth. Surface-water temperature ranges from 28 °C (an arbitrary cut-off of what is considered to be thermal) to 88 °C (82–190 °F) (Waring, 1965; Ross, 1971; Breckenridge and others, 1980).

Geochemical Signature

Geothermal waters in the Forest are alkaline with pH ranging from 7 to 9. They are very low in specific conductivity and thus low in dissolved solids considering their temperatures. Water from volcanic rocks has a slightly higher conductance than that from granitic rocks. Sodium and bicarbonate are common as are calcium and magnesium in areas underlain by carbonate rock. Sulfate and chloride are generally low, and silica is nearly the same as in nonthermal waters (Ross, 1971).

Geophysical Signature

Geophysical methods are not practical for exploration or assessment of thermal springs. The areas known to have geothermal springs are also known to be regions of high heat flow and locally high thermal gradients.

Assessment Criteria

1. Presence of naturally occurring warm or hot water.
2. Proximity to areas of Eocene or younger volcanism or magmatism.
3. Presence of regional high-angle faults.

Assessment

Thermal springs are located throughout the western part of the Forest. This area (V) has high potential (H/C) for small hot- and warm-water springs that could be used by homes and small businesses, including agriculture. This area (V) has moderate potential (M/C) for steam (pl. 4). To date, drilling and exploration have focused on hot water and not steam.

Economic Significance

As Idaho is deficient in conventional forms of fuel there is an incentive to develop steam-generated electricity as an alternative, inexpensive energy source. Steam resources have not been as thoroughly explored as hot water. In fact, exploration for hot-water sources has avoided areas with high steam potential. Increased exploitation in the future of small springs by private residences and small business entrepreneurs for hot water, space-heating, swimming pools, spas, greenhouses, and irrigation seems assured.

MINERAL RESOURCES—SALABLE MINERALS

By Robert C. Sykes
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The General Mining Law of 1872 declared "all valuable mineral deposits in lands belonging to the United States . . . to be free and open to exploration and purchase." It authorized placer and lode mining claims to be located on lands containing valuable minerals. This Act still forms the bulk of present-day mining law. In 1892, lands chiefly valuable for building stone came under the purview of the mining law. The Mineral Materials Act of July 31, 1947, permitted the Secretary of Interior to sell sand, stone, gravel, and common clay through a contract of sale. The Multiple Surface Use Act of July 23, 1955, removed common varieties of sand, stone, gravel, pumice, pumicite, cinders, and clay from the category of locatable minerals and placed them under the Minerals Material Act as salable minerals. Several exceptions to the salable category are block pumice, perlite, and forms of dimension stone such as travertine, high-quality marble, and micaceous meta-quartzite ("Oakley Stone"). Determination that a particular mineral is a salable mineral must be reviewed on a case-by-case basis in light of past legal decisions. To determine if the mineral material is salable or locatable, an evaluation of the mineral deposit must be done. For a mineral such as dimension stone to be locatable, it must exhibit a unique property that will give the mineral material a distinct and special value in the market place. Salable commodities generally have low unit value (value per ton); their exploitation is dependent on easy access to transportation, and generally they are used near the site of production.

Sand and gravel, dimension stone, and riprap are the only salable mineral commodities located on the Forest. These commodities are only in certain areas. The potential for their development is low; deposits of sand and gravel and riprap are much more abundant and more accessible on private and Bureau of Land Management lands. These off-Forest deposits presently meet the needs of the local communities.

Sand and gravel deposits are not abundant on the Forest. There are 22 sand and gravel pits on the Forest which are exploited mainly for road fill and resurfacing material. None of the sites is used on a regular basis. The Pleistocene and Holocene gravel deposits are composed mostly of Cretaceous granitic and Tertiary granitic and volcanic rock. The Yankee Fork drainage and Cape Horn area are the principal sources of sand and gravel for construction purposes. Major production is from alluvial deposits, but special needs for aggregate are met by crushing coarse alluvium and colluvial material.

Dimension stone has been quarried from the Challis Volcanic Group and from talus slopes consisting of the Ramshorn Slate in Bayhorse Creek and the Kinnikinic Quartzite in Squaw Creek. A mineral materials deposit containing quartz monzonite boulders in Summit Creek has been mined, and the boulders from there have been used for landscaping and building facing. Other sites are in the Kane and Mill Creek drainages and in an area next to the Burma Road.

Ten riprap sites are in the northern portion of the Forest, and seven sites are in the southern portion of the Forest. Most of the sites are talus slopes consisting of volcanic rock of Eocene age and quartzite of Ordovician age. Copper Basin, Cape Horn, Kane and Summit Creeks, and Bonanza–Yankee Fork areas contain the majority of the riprap sites. None of the riprap sites is used on a regular basis.

RESOURCE POTENTIAL—SALABLE MINERALS

Income from the sale of salable mineral commodities will vary according to accessibility, unit value, cost, and amount produced. Environmental factors, such as other resource disturbances due to bulk mining, and reclamation costs have not been considered in this assessment.

The potential for the development of salable-mineral material sites beyond those that already exist on the Challis National Forest is very low. This is due to the remoteness, inaccessibility, location, and lack of demand for these deposits on the Forest. Private and Bureau of Land Management lands contain mineral material deposits that are more readily available to meet the needs of other Federal and State agencies and the public.

Sand and Gravel

Sand and gravel for road construction, road resurfacing, and aggregate are available in the Forest in quantities adequate for most Forest Service needs. Almost all bedrock units disaggregate on weathering to form alluvial and colluvial deposits, some of which are suitable for construction. The majority of the talus material (colluvial) sites consist of welded tuff and (or) rhyolite, although one area consists of Ramshorn Slate. The talus material is crushed and used for road fill and resurfacing material. Most of the talus material that is used is not good surfacing material as it breaks down quickly. Generally the talus material is more readily used than sand and gravel (alluvial) deposits because talus is more widely distributed on the Forest. However, in areas where the alluvial sand and gravel deposits are present, they are exploited much more readily than the colluvial talus material. The distribution of colluvial talus and alluvial deposits is shown on plate 4.

The distribution of all the alluvial and colluvial units on the Forest cannot be shown at 1:250,000 scale; only those alluvial units that are substantial and (or) contain existing mineral material sites are shown. The geologic map should not be used to inventory all sources of materials.

Dimension Stone

The majority of the dimension stone exploited on the Forest is the Ramshorn Slate of Ordovician(?) age and volcanic rock of Eocene age. These deposits are principally talus. In the Summit Creek area, granitic boulders of the Tertiary Sawtooth batholith have been produced from alluvial deposits for use as dimension stone, as have Kinnikinic Quartzite boulders from talus slopes in the Squaw Creek area. Those areas of the Forest that have potential for dimension stone are shown on plate 4 (existing sites). There are several factors that must be considered when evaluating a potential area and the proposed use of the material: shape and size, aesthetic qualities, distance to market, strength and durability, and ease of quarrying and utilization.

Riprap

Riprap sites occur in most areas of the Forest where major access is readily available. A majority of the riprap sites occur in colluvium and talus consisting of volcanic rock, mostly welded tuff; some sites occur in granitic alluvium and Kinnikinic Quartzite. Riprap is produced from these sites intermittently by the U.S. Forest Service for use on Forest projects. Riprap areas are shown on plate 4.

RECOMMENDATIONS FOR FUTURE STUDIES OF MINERAL RESOURCE POTENTIAL

The Challis National Forest contains several geologic terranes, which are hosts to a variety of mineral resources that have been extensively mined and prospected. A few of the mineral deposits and occurrences have been studied in detail, and most have been examined in a reconnaissance manner. However, many of the geologic terranes in the Forest have not yet been studied in sufficient detail to assess mineral resource potential adequately. In addition, many of the geologic studies on the mineral deposits, although classic studies, were undertaken before modern geologic mapping and investigative techniques were developed. The U.S. Geological Survey CUSMAP project to study and evaluate the mineral resources of the Challis $1° \times 2°$ quadrangle (Fisher and Johnson, 1987) is the type of study that provides the background data needed for resource assessment. Information from this project provides the foundation for detailed, sophisticated studies directed toward understanding the processes that form mineral deposits. Geologic knowledge in that portion of the Forest outside the Challis $1° \times 2°$ quadrangle needs to be brought to the same level of sophistication and reliability as that available in the Challis $1° \times 2°$ quadrangle. The present disparity in the quality and quantity of data between the two areas is evident in the higher levels of confidence assigned to areas of resource potential within the Challis $1° \times 2°$ quadrangle.

Geologic mapping detail varies greatly within the Forest; some parts have adequate coverage at 1:24,000 scale, whereas other parts that are essentially unmapped are not adequately covered, even at 1:500,000 scale. Many of the known mineralized and altered areas need to be mapped in detail. Mineral exploration and assessment is a continuing process. As new concepts are formulated, new mineral deposit types recognized, and supply and demand fluctuates, various geologic terranes will be examined and reexamined many times. The importance of adequate geologic maps in this process cannot be overstated.

The black-shale belt of central Idaho, much of which is in the Challis National Forest, is an enormous reservoir of metals. These metals were concentrated in certain stratigraphic beds at the time of deposition. Several major deposits, which are thought to have formed from material remobilized from the black shales, have been exploited in the belt (Hall, 1985). The potential for large sediment-hosted, stratabound deposits has not been thoroughly examined. Detailed studies to define the metal-bearing horizons and depositional environments of the black-shale units are needed. The lower parts of the Copper Basin and McGowan Creek Formations should be included, although they are not usually considered as parts of the black-shale belt.

The importance of the trans-Challis fault system in localization of ore deposits was only recently recognized (Fisher and Johnson, 1987). Most of the major precious-metal and fluorspar deposits are within this fault zone, commonly at the intersections with north- to northwest-trending structures. A similar, parallel fault system may extend through the Pioneer and White Knob Mountains. A detailed structural and lineament analysis as related to ore deposits is needed for the region. A study of that type, combined with regional geology and geochemical and geophysical data, may reveal other structural trends and intersections.

Some of the larger orebodies that have been exploited to date were formed by irregular replacement of carbonate rock; the best examples are at the Clayton Silver mine. Extensive carbonate terrane in the eastern and southern parts of the Forest is cut by major faults and contains exposed and postulated buried intrusives. Occurrences of irregular-replacement-type orebodies are hard to predict, but detailed stratigraphic and rock geochemistry studies, detailed geophysical surveys, alteration studies, and structural studies would help define areas of potential.

The Challis volcanic field is adequately described and studied within the Challis 1°×2° quadrangle, but little is known of these rocks outside the quadrangle. Possible volcanic-vent areas north and south of Mackay are of particular interest, because they may have been the source of mineralizing solutions. Petrologic and geochemical studies along with detailed mapping is needed in these areas.

Sediment-hosted disseminated precious-metal deposits, which are common in Nevada, are not known to occur north of the Snake River Plain. However, geologic conditions in parts of the carbonate terrane in the Forest are favorable for this deposit type. Several areas of jasperoid in the Lemhi and Lost River Ranges, and especially in the White Knob Mountains, should be studied and sampled in detail and related to the regional geology and mineral occurrences. Some of the carbonate host rocks for the jasperoids are thought to be correlative with the Roberts Mountains Formation, which is a common host for deposits of this type in Nevada. Therefore, definitive stratigraphic studies need to accompany the examination of the jasperoids.

Geochemical surveys adequate for mineral resource assessment are lacking in about 40 percent of the Challis National Forest, mostly in the Dubois and Idaho Falls 1°×2° quadrangles. Even in areas where geochemical coverage is adequate, data from different surveys cannot be easily integrated because of differences in sample media and analytical techniques. In order to get a consistent data set, some lands in and associated with the Forest would have to be resampled and sample splits, if available, from previous surveys would have to be reanalyzed. Rocks, stream sediments, and heavy-mineral (panned concentrate) fractions of stream sediments should be collected and the samples analyzed for elements such as tungsten, silver, arsenic, antimony, cadmium, copper, lead, zinc, gold, bismuth, and molybdenum. Semiquantitative emission spectrography should be used to analyze the heavy-mineral fraction of the stream sediments. An ICP instrument, which has better precision than the spark-source emission spectrograph, should be used to analyze the rocks and stream sediments.

The entire Forest should be surveyed by modern aeromagnetic methods with flight-line spacings of 0.5 mi. Excellent surveys are available for part of the Forest, but several areas of resource potential and structural complexity lack adequate coverage. Aeromagnetic data are very useful for outlining structural elements and also for indicating the presence of buried plutons.

Eight separate areas in the Lemhi Range, Lost River Range, and White Knob Mountains have unknown potential for mineral resources. Studies designed to develop the data base for each of the areas should be undertaken as a first priority. Detailed geologic mapping and limited geochemical surveys are needed in some areas, whereas geophysical, petrologic, isotopic, or stratigraphic studies in addition to mapping and geochemistry may be needed in other areas.

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APPENDIXES 1 AND 2
DEFINITIONS OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT
AND
SIZE CLASSIFICATION OF DEPOSIT TYPES

APPENDIX 1. DEFINITIONS OF LEVELS OF MINERAL RESOURCE POTENTIAL AND CERTAINTY OF ASSESSMENT

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

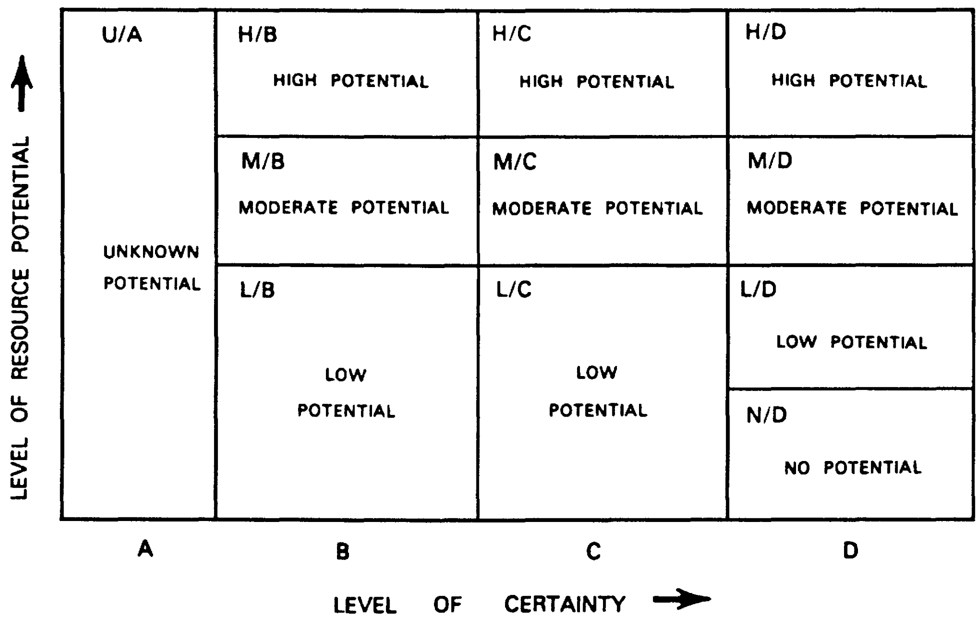
MODERATE mineral resource potential is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence, where interpretations of data indicate a reasonable likelihood of resource accumulation, and (or) where an application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

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

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

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

Levels of Certainty



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

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

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RESOURCE/RESERVE CLASSIFICATION

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

Major elements of mineral resource classification, excluding reserve base and inferred reserve base. Modified from McKelvey, 1972, Mineral resource estimates and public policy: American Scientist, v.60, p.32-40, and U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, p.5.

GEOLOGIC TIME CHART
Terms and boundary ages used in this report

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

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

[2] Informal time term without specific rank.

APPENDIX 2. SIZE CLASSIFICATION OF DEPOSIT TYPES

Sizes of deposit types are discussed throughout the text. Table 8 lists the approximate tonnages of various sizes of deposit types (small, medium, large) for locatable commodities (A–T).

Table 8. Size classification of deposit types

[<, less than; >, greater than]

Type of deposit	Size of deposit (short tons)		
	Small	Medium	Large
A. Fluorspar veins	<25,000	25,000-1,000,000	>1,000,000
B. Polymetallic veins in black-shale terrane.	<5,000	5,000-100,000	>100,000
C. Polymetallic veins in quartzite terrane.	<5,000	5,000-100,000	>100,000
D. Polymetallic veins in carbonate terrane.	<10,000	10,000-250,000	>250,000
E. Polymetallic veins in Tertiary extrusive terrane.	<10,000	10,000-250,000	>250,000
F. Precious-metal veins	<10,000	10,000-250,000	>250,000
G. Base-metal veins	<5,000	5,000-100,000	>100,000
H. Vein uranium deposits	<5,000	5,000-100,000	>100,000
I. Tungsten stockwork and vein deposits.	<20,000	20,000-500,000	>500,000
J. Stockwork molybdenum deposits.	<10,000,000	10,000,000-100,000,000	>100,000,000
K. High-level, rhyolite-hosted, precious-metal deposits.	<100,000	100,000-1,000,000	>1,000,000
L. Polymetallic skarn deposits.	<25,000	25,000-1,000,000	>1,000,000
M. Irregular replacements of base and precious metals.	<20,000	20,000-2,000,000	>2,000,000
N. Fluorspar breccia manto deposits.	<25,000	25,000-2,000,000	>2,000,000
O. Sediment-hosted, jasperoid-associated, precious-metal deposits.	<1,000,000	1,000,000-5,000,000	>5,000,000
P. Precious-metal deposits in volcanic tuffs.	<100,000	100,000-5,000,000	>5,000,000
Q. Stratabound syngenetic deposits of precious and base metals.	<500,000	500,000-5,000,000	>5,000,000
R. Stratiform vanadium deposits.	500,000	500,000-5,000,000	>5,000,000
S. Gold placer deposits	<25,000	25,000-1,500,000	>1,500,000
T. Radioactive black-sand placer deposits.	<25,000	25,000-1,500,000	>1,500,000