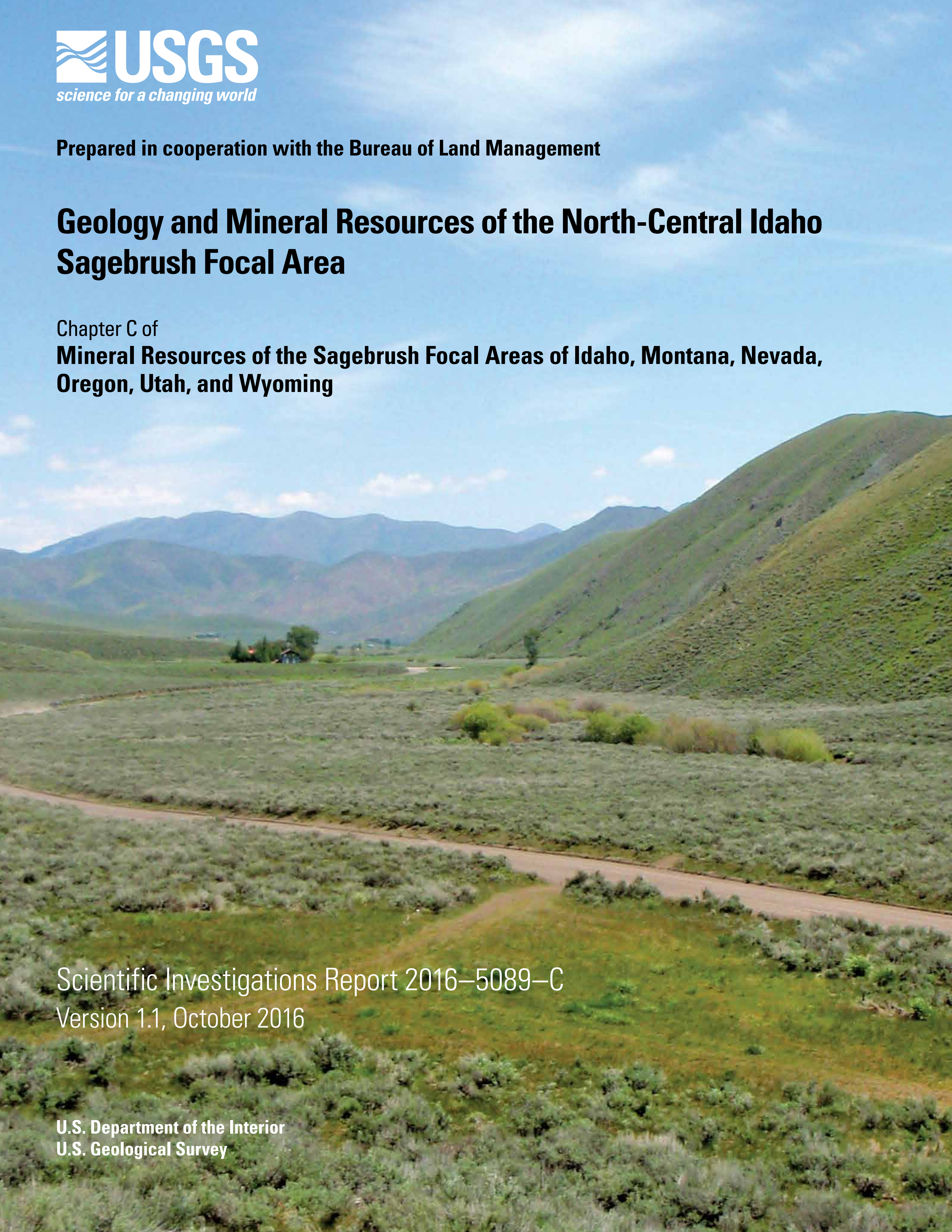

Prepared in cooperation with the Bureau of Land Management

Geology and Mineral Resources of the North-Central Idaho Sagebrush Focal Area

Chapter C of
Mineral Resources of the Sagebrush Focal Areas of Idaho, Montana, Nevada, Oregon, Utah, and Wyoming

Scientific Investigations Report 2016–5089–C
Version 1.1, October 2016

U.S. Department of the Interior
U.S. Geological Survey

Cover. Photograph looking eastward across western part of the North-Central Idaho Sagebrush Focal Area. Foreground is in the Hailey Gold Belt, which is underlain by Cretaceous granitic rocks of the Idaho batholith, and background extends into the Muldoon mining district, underlain by late Paleozoic sedimentary rocks of the Milligen Formation and Sun Valley Group. Photograph by Karen Lund, U.S. Geological Survey.

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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Conversion Factors

[U.S. customary units to International System of Units]

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square inch (in^2)	6.452	square centimeter (cm^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
barrel (bbl; petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m^3)
	Mass	
ounce, troy (oz)	31.103	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	metric ton (t)
ton, long (2,240 lb)	1.016	metric ton (t)

[International System of Units to U.S. customary units]

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	247.1	acre
square centimeter (cm^2)	0.001076	square foot (ft^2)
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Multiply	By	To obtain
	Volume	
cubic meter (m^3)	6.290	barrel (petroleum, 1 barrel = 42 gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
	Mass	
gram (g)	0.032	ounce, troy (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
metric ton (t)	1.102	ton, short [2,000 lb]
metric ton (t)	0.9842	ton, long [2,240 lb]
	Density	
kilogram per cubic meter (kg/m^3)	0.06242	pound per cubic foot (lb/ft^3)
gram per cubic centimeter (g/cm^3)	62.4220	pound per cubic foot (lb/ft^3)

Supplemental Information

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F = (1.8 \times °C) + 32.$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as

$$°C = (°F - 32) / 1.8.$$

Datums

Vertical coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations

Ad	andradite (iron-rich garnet)
AMIS	Automated Minerals Information System
AOC	Assessment Oversight Committee
API	American Petroleum Institute
AR	“as received”
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTM	American Society for Testing and Materials
AU	assessment unit (oil and gas)
BCF, BCFG	billion cubic feet (of gas)
BHT	bottom-hole temperature
BLM	Bureau of Land Management
BRW	Bear River Watershed (Sagebrush Focal Area)
BV	“best value”
CAGR	compound annual growth rate
CAI	conodont alteration index
CFR	Code of Federal Regulations
CIGS	copper-indium-gallium selenide
CSA	Canadian Standards Association
CSM	clay-sulfate-mica
CSAMT	controlled-source audiofrequency magnetotellurics
DLA	Defense Logistics Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EGS	enhanced geothermal system
EIS	Environmental Impact Statement
ETM+	Landsat 7 Enhanced Thematic Mapper Plus
FLPMA	Federal Land Policy and Management Act of 1976
f.o.b.	free on board
FWS	U.S. Fish and Wildlife Service
g/t	gram per metric ton
Ga	giga-annum or billions of years ago
GFTZ	Great Falls Tectonic Zone

GHC	Geo-Heat Center
GIS	geographic information system
HSSR	Hydrogeochemical and Stream Sediment Reconnaissance
IDW	inverse distance weighted
LEDs	light-emitting diodes
LLD	lower limit(s) of determination
m.y.	millions of years
Ma	mega-annum or millions of years ago
MAS	Minerals Availability System
MCF	thousand cubic feet of gas
MILS	Mineral Industry Location System
MMBO	million barrels of oil
MMBNGL	million barrels of natural gas liquids
MOP	muriate of potash
Moz	million troy ounces
MRDS	Mineral Resources Data System
Mt	million metric tons
MTU	metric ton unit
MVT	Mississippi-Valley-type
MW	megawatt
MWe	megawatt electricity
NASGLP	North American Soils Geochemical Landscape Project
NBMG	Nevada Bureau of Mines and Geology
NDS	National Defense Stockpile
NEPA	National Environmental Policy Act of 1989
NGDB	National Geochemical Database
NGL	natural gas liquids
NGS	National Geochemical Survey
NMIC	USGS National Minerals Information Center
NOAA	National Oceanic and Atmospheric Administration
NOGA	USGS National Oil and Gas Assessment
NURE	National Uranium Resource Evaluation
NWR	National Wildlife Refuge
opt	troy ounce per short ton
oz	troy ounce

PGE	platinum-group element
PGM	platinum-group metal
PLSS	Public Land Survey System
ppm	parts per million
REE	rare earth element
REOE	rare earth oxide equivalent(s)
RMOTC	Rocky Mountain Oilfield Testing Center
ROD	Record of Decision
RTP	reduction-to-the-pole or reduced-to-pole
SaMiRA	Sagebrush Mineral-Resource Assessment
SEDAR	Canadian System for Electronic Document Analysis and Retrieval
SEDEX	sedimentary exhalative
SFA	Sagebrush Focal Area
SG	specific gravity
SI	structural index
SOP	sulfate of potash
SWIR	shortwave-infrared (region of the electromagnetic spectrum)
t	metric ton
TCM	Tax Court Memorandum
Th/K	thorium/potassium ratio
TMI	total magnetic intensity
TOMS	Topographically Occurring Mine Symbols
TPS	total petroleum system
UMOS	Utah Mineral Occurrence System
USBM	former U.S. Bureau of Mines
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USMIN	USGS Mineral Deposit Database
VMS	volcanogenic massive sulfide
wt.%	weight percent
WYO	Southwestern and South-Central Wyoming (Sagebrush Focal Area)

Chemical Symbols and Formulas Used

Ag	silver
Al	aluminum
Al_2O_3	aluminum oxide
Ar	argon
As	arsenic
Au	gold
B	boron
Ba	barium
$BaSO_4$	barium sulfate
Be	beryllium
Bi	bismuth
Br	bromine
C	carbon
C_{org}	organic carbon
CO	carbon monoxide
CO_2	carbon dioxide
Ca	calcium
CaO	calcium oxide
Cd	cadmium
Ce	cerium
CH_4	methane
Cl	chlorine
Co	cobalt
Cr	chromium
Cs	cesium
Cu	copper
Dy	dysprosium
Er	erbium
Eu	europium
F	fluorine
Fe	iron
Fe_2O_3	ferric iron oxide
Ga	gallium
GaAs	gallium arsenide
GaN	gallium nitride
Gd	gadolinium
Ge	germanium
H	hydrogen
H_2S	hydrogen sulfide
Hf	hafnium
Hg	mercury
Ho	holmium
In	indium
Ir	iridium
K	potassium
K_2O	potassium oxide
La	lanthanum
Li	lithium
Lu	lutetium
Mg	magnesium
MgO	magnesium oxide
Mn	manganese
Mo	molybdenum
N	nitrogen
NH_3	ammonia
Na	sodium
NaCl	sodium chloride
Na_2O	sodium oxide
Nb	niobium
Nd	neodymium
Ni	nickel
O	oxygen
Os	osmium
P	phosphorous
P_4	elemental (white) phosphorus
PO_4	phosphate
P_2O_5	phosphorous pentoxide
Pb	lead
Pd	palladium
Pr	praseodymium

Pt	platinum	Te	tellurium
Rb	rubidium	Th	thorium
Re	rhenium	Ti	titanium
Rh	rhodium	TiO_2	titanium dioxide
Ru	ruthenium	Tm	thulium
S	sulfur	Tl	thallium
Sb	antimony	U	uranium
Sc	scandium	U_3O_8	triuranium octaoxide (yellowcake)
Se	selenium	V	vanadium
Si	silicon	V_2O_5	vanadium pentoxide
SiO_2	silicon dioxide (silica)	W	tungsten
Sm	samarium	WO_3	tungsten trioxide
Sn	tin	Y	yttrium
Sr	strontium	Yb	ytterbium
Ta	tantalum	Zn	zinc
Tb	terbium	Zr	zirconium

Mineral Formulas Used

adularia	$KAlSi_3O_8$
alunite	$KAl_3(SO_4)_2(OH)_6$
andradite (garnet)	$Ca_3Fe^{3+}{}_2(SiO_4)_3$
ankerite	$Ca(Fe,Mg,Mn)(CO_3)_2$
argentite	Ag_2S
arsenopyrite	FeAsS
barite	$BaSO_4$
bornite	Cu_5FeS_4
cassiterite	SnO_2
chalcocite	Cu_2S
chalcopyrite	$CuFeS_2$
cinnabar	HgS
clinoptilolite (zeolite)	$(Ca,Na,K)_{2\text{-}3}Al_3(Al,Si)_2Si_{13}O_{36}\cdot 12(H_2O)$
coffinite	$U[SiO_4,(OH)_4]$
corderoite	$Hg_3S_2Cl_2$
dolomite	$CaMg(CO_3)_2$

erionite (zeolite)	$(Ca,Na,K)_{10}[Al_{10}Si_{26}O_{72}]\cdot\sim 30H_2O$
fluorite	CaF_2
galena	PbS
hectorite (smectite clay)	$Na_3(Mg,Li)_3Si_4O_{10}(F,OH)_2$
hematite	Fe_2O_3
ilmenite	$FeTiO_3$
kaolinite	$Al_2Si_2O_5(OH)_4$
leucite	$K(AlSi_2O_6)$
magnetite	Fe_3O_4
molybdenite	MoS_2
molybdite	MoO_3
monazite	$(Ce,La,Th,Nd)PO_4$
montmorillonite	$(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$
nepheline	$Na_3KAl_4Si_4O_{16}$
opal	$SiO_2\cdot nH_2O$
phillipsite (zeolite)	$(Ca,Na,K)_{4-7}[Al_{4-7}Si_{2\text{-}9}O_{32}]\cdot 12H_2O$
powellite	$CaMoO_4$
pyrite	FeS_2
quartz	SiO_2
rutile	TiO_2
scheelite	$CaWO_4$
siderite	$FeCO_3$
sillimanite	Al_2SiO_5
sylvite	KCl
sylvinite	$KCl+NaCl$
sphalerite	$(Zn,Fe)S$
staurolite	$Fe_2Al_9Si_4O_{23}(OH)$
stilpnomelane	$(K,Ca,Na)(Fe^{2+},Mg,Fe^{3+})_8(Si,Al)_{12}(O,OH)_{27}\cdot nH_2O$
tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
uraninite	UO_2
xenotime	YPO_4
zircon	$ZrSiO_4$

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Executive Summary

The U.S. Department of the Interior has proposed to withdraw approximately 10 million acres of Federal lands from mineral entry (subject to valid existing rights) from 12 million acres of lands defined as Sagebrush Focal Areas (SFAs) in Idaho, Montana, Nevada, Oregon, Utah, and Wyoming (for further discussion on the lands involved see Day and others, 2016).The purpose of the proposed action is to protect the greater sage-grouse (*Centrocercus urophasianus*) and its habitat from potential adverse affects of locatable mineral exploration and mining. To inform the decision on whether to withdraw the SFAs from mineral entry, the Bureau of Land Management (BLM) requires a mineral-resource assessment be completed to identify mineral resources within the proposed area of withdrawal. The USGS Sagebrush Mineral-Resource Assessment (SaMiRA) project was initiated in November 2015 and supported by the BLM to (1) assess locatable mineral-resource potential and (2) to describe leasable and salable mineral resources for the seven SFAs and Nevada additions.

Geologic Setting

The purpose of this chapter is to document the geology and mineral resources of the North-Central Idaho Sagebrush Focal Area ("study area"), which extends from east-central to south-central Idaho. The geologically complex area is composed of many different rock units that locally contain potential mineral resources, which formed from primary rock-forming processes. Furthermore, many of the rocks were affected by secondary geologic events and related processes, which produced mineral deposits in the pre-existing rocks. Rugged mountainous topography makes up the northern part of the area whereas the northeast-striking, relatively flat Snake River Plain extends across the southern part. Rocks of the area all formed as part of western edge of the Archean to Cretaceous North American continent.

The study area includes relatively small exposures of the Archean basement, which formed the western margin of the ancient North American continent, and of Mesoproterozoic sedimentary rocks, which were deposited in a basin atop the basement rocks. Widespread, thick Neoproterozoic through Paleozoic marine strata were deposited along the ancient continental margin, shelf, and deep basin (from east to west across the study area). The Mississippian Antler orogenic event disturbed the paleobasin geometry and deformed older rocks on the western side of the orogen. Although subsequent basin geometries were less long-lived compared to the older basins, marine deposition continued from the Late Mississippian until the Triassic.

In the Cretaceous, convergent tectonics west of the area caused Cordilleran-wide compression that folded and thrust-stacked the older strata. Resultant crustal melting formed the Cretaceous Idaho batholith on the western edge of the study area. Subsequent extension resulted in crustal thinning, normal faulting, and introduction of deep crustal magmas into the shallow crust, which resulted in the voluminous magmatism of the Eocene Challis volcanic and plutonic event. Postvolcanic extension changed orientation, forming the present Basin and Range topography.

Synchronous with Basin and Range extension, the Snake River Plain formed as the North American continent moved across the Yellowstone Hot Spot. Formation of the Plain concealed older rocks and created an elongate depression. The depression filled with voluminous caldera rhyolites, rift basalts, and restricted-basin lake sediments. Each of these different geologic settings and events resulted in major rock packages, and are associated with distinct mineral deposits that may be present and exploited in the North-Central Idaho Sagebrush Focal Area and are considered in this report.

Mining and Mineral Exploration Activity

Prospecting began across the study area around 1865 and silver mining began in earnest by about 1881. Peak mining activities were mainly from 1900 to 1930. Along with silver, the other important mineral commodities mined were lead, zinc, copper, and gold. More than 1,800 mines or prospects are located in the area, but records of production amounts exist for only 132 mines. Total compiled production figures for precious metals in the study area include 194,980 ounces (oz) gold (61,982 oz in proposed withdrawal area) and 8,409,460 oz silver (915,034 oz in proposed withdrawal area). Additional production from the proposed withdrawal area has been 95,210 pounds (lb) copper; 2,788,010 lb lead; and 3,425,156 lb zinc. One gold-silver mine is presently active in the study area and there are two gold prospects undergoing active exploration.

Assessment of Locatable Commodities

Mineral-resource potential assessments of the North-Central Idaho Sagebrush Focal Area for locatable minerals established that the study area contains geology permissive for 18 types of mineral deposits. Available published datasets indicate that mineral commodities for 12 of the deposit types accumulated during formation of rock units or by mineralizing processes that subsequently affected the rocks; such accumulation is not indicated for the other 6 deposit types.

The 12 locatable mineral deposit types having moderate to high mineral-resource potential in the North-Central Idaho Sagebrush Focal Area are porphyry-related (including skarn and replacement), polymetallic vein, jasperoid precious metal, epithermal precious metal, zeolite mineral specimen, precious opal (volcanic rock-hosted opal), SEDEX sedimentary exhalative zinc-lead-silver, bedded barite, unconformity uranium, lacustrine diatomite, and heavy-mineral placer. This study determined that 33 discrete geographic areas (tracts) have moderate to high mineral-resource potential for specific locatable mineral deposit types; 15 tracts have potential for polymetallic-vein types, 7 tracts have porphyry copper-molybdenum types, 3 tracts have potential for epithermal precious-metal type, 2 tracts have potential for lacustrine diatomite, and 2 tracts have potential for heavy-mineral placers. Deposit types for bedded barite, unconformity uranium, jasperoid precious metals, precious opal, zeolite mineral specimen, and epithermal gypsum each have potential in six other tracts.

Potential metal commodities in these deposit types are primarily Cu, Mo, Au, Ag, Pb, and Zn. Other potential metal commodities include Fe, W, Sb, Ti, rare earth elements (REE), Th, Nb, Ta, Zr, U, and Hf. Potential nonmetal commodities in these deposit types include barite, zeolite mineral specimen, precious opal, and diatomite.

Leasable Commodities

The eastern Snake River Plain and the bordering Basin and Range topographic domain, both of which experienced Tertiary extension and voluminous bimodal hot spot-related volcanism, form an area of higher than normal heat flow. The area straddles elevated heat flow regions along the northern margins of the Snake River Plain that are manifested by the presence of 13 low-temperature geothermal systems in the study area, but that are partly concealed by the action of shallow groundwater flow. The geothermal resource potential for high-temperature geothermal systems in the study area is among the highest in the United States.

The Retort Phosphatic Shale Member of the Permian Phosphoria Formation crops out in northeastern part of the study area. The historic permits for phosphate prospects in that area indicate potential future interest in phosphate resources from the Permian units.

The study area is not in a coal-forming region and consequently there are no coal deposits present. Exploration for oil and gas has been conducted in the study area, including the drilling of exploratory wells in four areas. To date, there are no discoveries or production of oil. Available data indicate the study area has low potential for petroleum resources.

Salable Commodities

Nine Bureau of Land Management (BLM) mineral-material sales sites for pumice, scoria, and volcanic cinder are in the study area, but none are presently active. There are 107 sand and gravel BLM mineral-material sales sites in the study area, of which about one-third are active; one active pit is in the BLM proposed withdrawal area. Twenty-six BLM mineral-material soil sales sites are in the BLM proposed withdrawal area but none are in active production. There are 54 BLM mineral-material stone sales sites (riprap, aggregate, or building stone) in the BLM proposed withdrawal area, but none are in production or being developed.

Introduction

The Department of the Interior has approved an application to withdraw approximately 10 million acres of Bureau of Land Management (BLM) and U.S. Forest Service public lands identified as Sagebrush Focal Areas in Idaho, Montana, Nevada, Oregon, Utah, and Wyoming from location and entry under the United States mining laws to protect the greater sage-grouse (*Centrocercus urophasianus*) and its habitat from potential adverse effects of locatable mineral exploration and mining, subject to valid existing rights (Department of the Interior, 2015). The intent of the proposed withdrawal was to honor all valid, existing rights, including those for oil and gas development, renewable energy, rights-of-way, locatable minerals (see definition below), and other permitted projects.

The lands proposed for withdrawal are part of seven Focal Areas (Bureau of Land Management, 2015a,b).

The purpose of this report is to summarize the current status of locatable, leasable, and salable mineral commodities and assess the occurrence potential of locatable minerals in the North-Central Idaho Sagebrush Focal Area (the study area; see the Organization of Report and Terminology section for study area terminology as used in this chapter). This report follows guidance provided in BLM Manual Sections 3031 (Bureau of Land Management, 1985) and 3060 (Bureau of Land Management, 1994) for mineral assessments and mineral reports. The information and interpretations provided herein relied on the best publically available data from published geologic sources, Federal and State agency datasets, and citable private company reports.

Lands Involved

This report describes the mineral-resource potential of the proposed withdrawal area in the BLM North-Central Idaho Sagebrush Focal Area (see the following section, and Day and others [2016] for study area terminology used in the rest of the chapter). The proposed withdrawal area is located in Idaho in parts of Blaine, Butte, Camas, Clark, Custer, Elmore, Fremont, Gooding, Jefferson, Lemhi, Lincoln, and Minidoka Counties. The proposed withdrawal area encompasses 1,558,575 acres, of which the BLM manages 1,369,235 acres and the U.S. Forest Service manages 189,340 acres. The area studied for locatable mineral-resource assessment covers 4,885,640 acres (212 townships) and completely encloses the proposed withdrawal area (fig. 1). The area studied is much larger than the proposed BLM withdrawal areas in order to provide context to the geologic and mineral-resource discussion and includes lands managed by the Bureau of Reclamation, Department of Energy, Fish and Wildlife Service, National Park Service, and the State of Idaho, as well as lands held privately.

Organization of Report and Terminology

The framework of this report is based on guidance published in BLM Manual Sections 3031 and 3060 (Bureau of Land Management, 1985, 1994). To the extent possible, we organized the information in this report to reflect BLM technical and legal language, and used the legal classification of minerals recognized by BLM. Potential for occurrence is only discussed for locatable minerals.

Several schemes are used to classify types of minerals in scientific and technical literature. For example, a distinction is made between materials from which metals are extracted (metallic) from those that are not used as a source of metal or energy (nonmetallic or industrial). Another scheme differentiates material that is extracted from solid rock (lode) from that which was concentrated by moving water through sediment (placer). Common minerals do not have a special quality, quantity, character, or location that makes them of unique commercial value, but rare minerals may have commercial value. Strategic and critical minerals are distinguished according to their importance to the Nation. Other classification schemes distinguish material based on the ultimate source of the valuable material–magma, hydrothermal fluid, surficial water, or weathered material.

The BLM uses legal definitions that group minerals into three categories—(1) locatable minerals (General Mining Act of 1872, 30 U.S.C. 22–42), including most metallic commodities and many high-unit value industrial commodities; (2) leasable minerals (Mineral Leasing Act of 1920 (30 U.S.C. 181 et seq.), including energy and fertilizer minerals; and (3) salable minerals (Mineral Materials Act of 1947, 30 U.S.C. 601 et seq.) which includes common varieties of sand, stone, gravel, pumice, pumicite, cinders and clay. A listing of the mineral commodities and their classification is given in appendix 1 of Day and others (2016).

The right to explore, develop, and extract locatable minerals is established by the location (or staking) of lode or placer mining claims. Acquisition of leasable minerals is obtained by application for a government lease and permits to mine or explore after lease issuance. Salable minerals on Federal lands are sold by sales contract. Information on mining claims, leases, and salable mineral sites, along with surface management permits in the North-Central Idaho Sagebrush Focal Area are summarized in table 1. Surface disturbance associated with mineral development must be approved and permitted according to surface-management regulations (43 CFR 3809 and 36 CRF 228 Subpart A).

The mining laws applicable to Federal lands of the United States were not developed with specific knowledge of geology and types of mineral materials. Even so, the various legal types of minerals do have some broad geologic associations. Leasable minerals include areally extensive types of valuable earth materials most commonly occurring in sedimentary basins: oil and gas fields, coal fields, oil shales, large bedded deposits of soluble sodium and potassium salts, large bedded deposits of phosphorite, and large bedded deposits of gypsum. Salable minerals are common, widely distributed earth materials with low unit value. They must be obtained near where the need exists. If the material is not leasable or salable, it is locatable. Most, but not all, of this type of material occurs in spatially restricted areas.

A glossary of terms is provided in the companion report to this assessment (Day and others, 2016). In some parts of this report, a brief discussion is provided to clarify usage of specific terms and to relate how concentrations of valuable earth materials conform to the legal definitions that determine their ownership and development. However, for other terms, like “minerals”, the intended meaning must be inferred from context.

The methodology used for the assessment for locatable mineral-resource potential and levels of certainty are reviewed in Day and others (2016) and the classification scheme is described in appendix 1. The geographic tracts found to contain mineral-resource potential during the assessment study are presented in

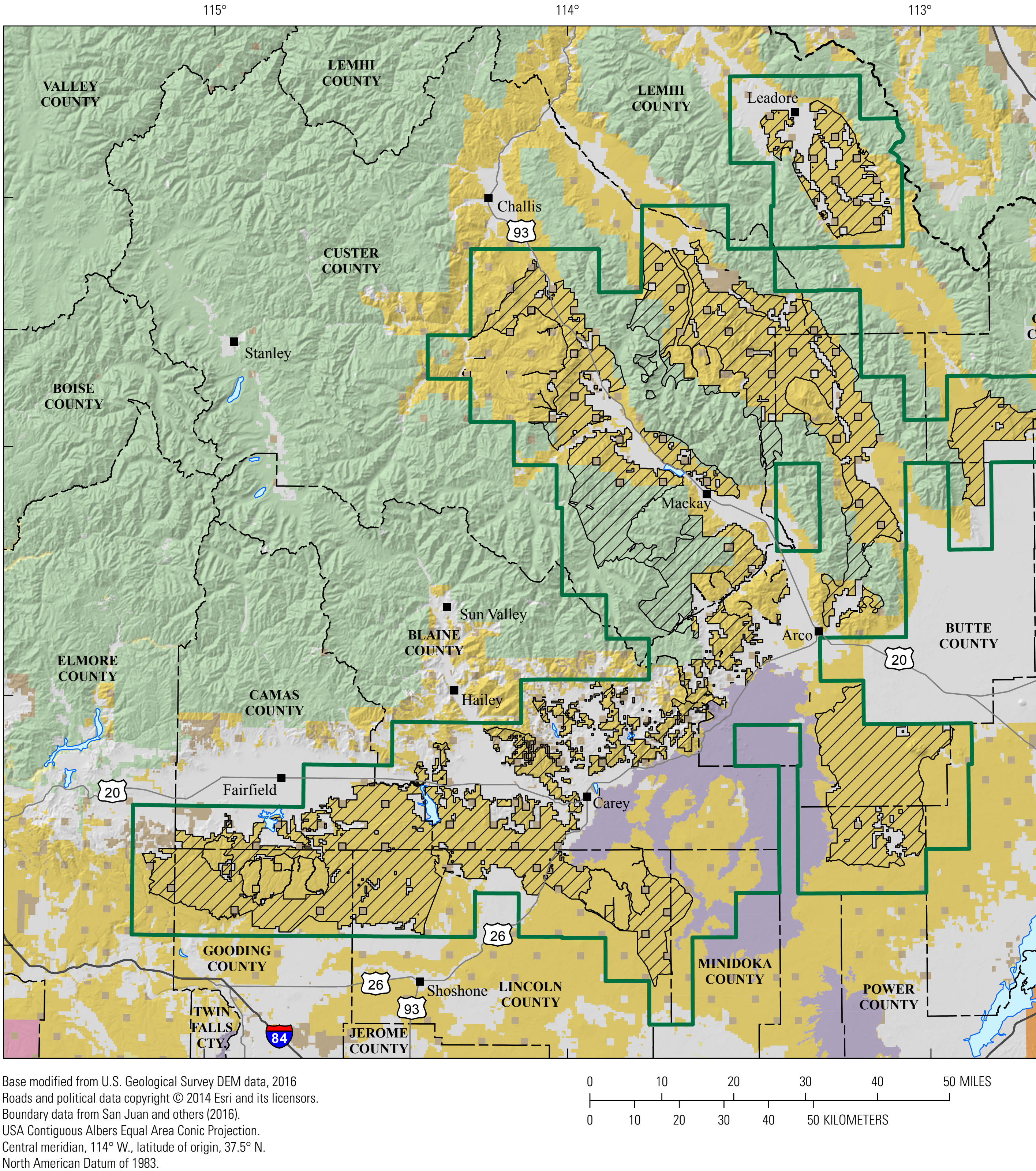


Figure 1. Surface land management map of the proposed withdrawal areas in the North-Central Idaho Sagebrush Focal Area.

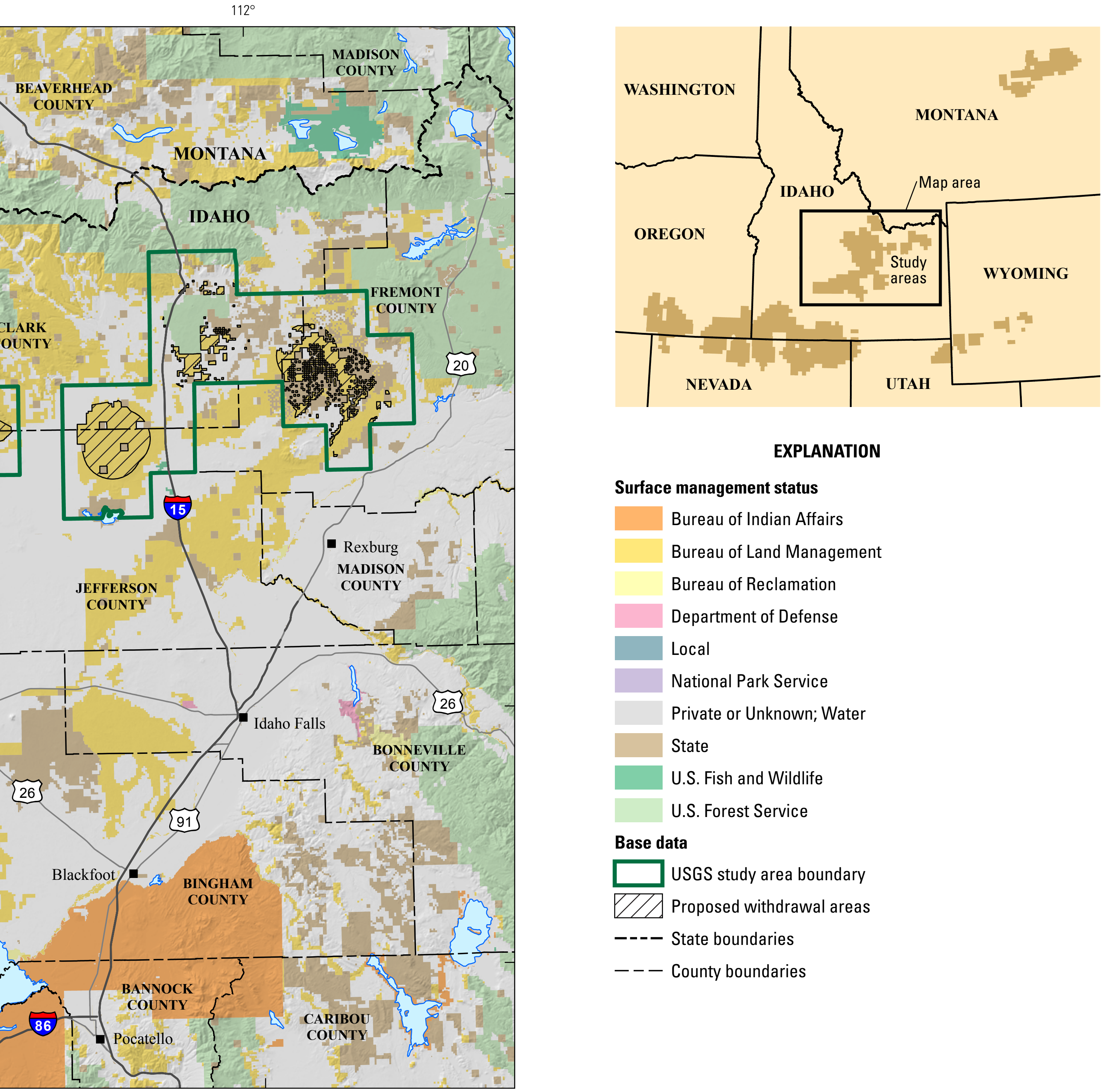

112°
MADISON COUNTY
BEAVERHEAD COUNTY
MONTANA
IDAHO
FREMONT COUNTY
CLARK COUNTY
20
15
Rexburg
MADISON COUNTY
JEFFERSON COUNTY
26
Idaho Falls
BONNEVILLE COUNTY
26
91
Blackfoot
BINGHAM COUNTY
BANNOCK COUNTY
86
Pocatello
CARIBOU COUNTY
WASHINGTON
MONTANA
IDAHO
Map area
OREGON
Study areas
WYOMING
NEVADA
UTAH
EXPLANATION
Surface management status
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Department of Defense
Local
National Park Service
Private or Unknown; Water
State
U.S. Fish and Wildlife
U.S. Forest Service
Base data
USGS study area boundary
Proposed withdrawal areas
State boundaries
County boundaries

Table 1. Summary of status and number of mining claims, mineral leases, mineral material sales sites, and surface-management (Bureau of Land Management 43 CFR 3809 and U.S. Forest Service 36 CRF 228 Subpart A) authorizations in the proposed withdrawal area within the North-Central Idaho Sagebrush Focal Area.

[Bureau of Land Management data, see Dicken and San Juan (2016); U.S. Forest Service surface management plans, Amanda Kriwox, U.S. Forest Service, written commun., March 10, 2016. ND, no data]

Type	Mineral type	Number of unique cases	Active	Authorized	Pending	Closed/ Inactive	Cancelled	Expired	Rejected	Withdrawn
Mining claims	Locatable	13,417	781	ND	ND	12,636	ND	ND	ND	ND
Coal leases	Leasable	0	ND	ND	ND	ND	ND	ND	ND	ND
Geothermal leases	Leasable	25	ND	ND	ND	25	ND	ND	ND	ND
Non-energy solid mineral leases	Leasable	9	ND	ND	ND	9	ND	ND	ND	ND
Oil and gas leases	Leasable	567	ND	ND	ND	567	ND	ND	ND	ND
Mineral materials sales sites	Salable	227	ND	54	5	165	ND	3	ND	ND
Surface-management notices and plans	ND	69	2	6	6	55	ND	2	ND	ND

the same order in the text and on the accompanying tract table (appendix 2). The order of tracts presented is grouped by mineral system (Hammarstrom and Zientek, 2016) according to deposit type (Day and others, 2016; Hammarstrom and Zientek, 2016). In each deposit-type section, tracts are described in order from those tracts ranked with the highest resource potential and the most certainty (for methods, see Hammarstrom and Zientek, 2016) to tracts ranked successively lower. In the cases where tracts of a single deposit type have equivalent ranking and certainty, they are discussed in alphabetical order. The many types of data used to identify tracts are discussed in similar order in the text and on accompanying tract table (appendix 2).

The outline of the study area is based on the townships of the Public Lands Survey System (PLSS) within the North-Central Idaho Sagebrush Focal Area that contain proposed withdrawal areas. Both the PLSS-bounded area studied and the BLM proposed withdrawal areas are shown on figure 1. The area studied and discussed in the present chapter is much larger than the BLM proposed withdrawal areas. In the rest of chapter C, the area of the PLSS that bounds the area and is discussed herein is referred to as “the study area.” In selected sections where discussion is focused on the BLM proposed withdrawal areas, the reference is specifically stated to apply to “BLM proposed withdrawal areas”.

Data Sources

Mineral-resource-potential tracts determined for the study are geographic areas that have potential for mineral resources of a specified mineral deposit type. For background and general methods of the study see Day and others (2016) and sections therein. For details of mineral-resource potential assessments, mineral deposit types, development of tracts, and tract ranking see Hammarstrom and Zientek (2016).

The data used to formulate the tracts and to assign them a ranking and certainty level are almost entirely from published sources that are available as digital data (Dicken and San Juan, 2016; Fernette and others, 2016a,b; San Juan and others, 2016). In addition, the U.S. Forest Service (USFS) provided data on surface management plans within the Salmon-Challis National Forest (Amanda Kriwox, USFS, written commun., March 10, 2016). The primary geologic map data come from versions of the geologic map of Idaho (Bond and others, 1978; Lewis and others, 2012) that provide complete coverage of the study area. Other more detailed digital maps that are used where possible include 1:250,000-scale maps (Fisher and others, 1992; Wilson and Skipp, 1994; Worl and Johnson, 1995) and 1:100,000-scale maps for local areas (Link and others, 1995; Lund and others, 2003; Kuntz and others, 2007; Skipp and Kuntz, 2009; and Othberg and others, 2012). In special cases, more detailed, non-digital geologic maps (for example Skipp, 1984, 1985; Skipp and others, 1984; Worl and others, 1991) are used to inform the interpretations presented here.

The sources of geochemical (Smith and others, 2016), geophysical (Anderson and Ponce, 2016), remote-sensing mineral alteration (Rockwell, 2016), mineral occurrence location, production records (Fernette and others, 2016a,b), and previous mineral-resource assessment tracts (Parks and others, 2016) data are noted in the text of this chapter and tabulated in the North-Central Idaho Sagebrush Focal Area tract table (appendix 2). The digital data used for individual mineral-resource assessment potential tracts, which are determined in this study, are provided as data layers for each tract (San Juan and others, 2016). The sources of data and methodologies are also documented in more detail in Day and others (2016) and the individual chapters therein.

Study Responsibilities

Introductory materials specific to the North-Central Idaho Sagebrush Focal Area were written by K. Lund, who also served as study area lead and chapter science editor. The many coauthors of this chapter were involved in the numerous integrated aspects of the study, which include geographic information systems (GIS) analysis, figure preparation, data compilation, commodity evaluation, and assessment-meeting participation. Research and writing responsibilities for geologic setting, resource descriptions, and mineral-resource potential assessment sections in this report are as follows:

Lead, Science editor—K. Lund

Description of geology—K. Lund, S.E. Box, and M.E. Benson

Leasable minerals

- Coal—B.N. Shaffer and J.E. Haacke
- Geothermal—J.M.G. Glen, J. DeAngelo, and C.F. Williams
- Oil and gas—R.M. Drake II
- Phosphate—M.E. Benson

Locatable minerals

- Exploration and mining activities—G.L. Fernette and C. San Juan
- Porphyry-related deposit type—L. Zürcher, K. Lund, E.D. Anderson, S.M. Smith, and B.W. Rockwell
- Polymetallic-vein deposit type—L. Zürcher, K. Lund, E.D. Anderson, B.W. Rockwell, and S.M. Smith
- Epithermal hot spring precious-metal vein deposit type—K. Lund, D.A. John, S.M. Smith, B.W. Rockwell, and E.D. Anderson
- Jasperoid precious-metals—A.H. Hofstra
- Epithermal gypsum—G.R. Robinson, Jr.
- Epithermal opal—G.R. Robinson, Jr.
- Zeolite mineral specimen—K. Lund
- Cobalt-copper-gold veins—K. Lund
- Thorium-rare earth element-bearing veins—B.S. Van Gosen
- Sedimentary exhalative SEDEX Zn-Pb-Ag—A.H. Hofstra and K. Lund
- Mississippi Valley-type Pb-Zn—A.H. Hofstra, S.M. Smith, and K. Lund
- Unconformity uranium—B.S. Van Gosen
- Lacustrine diatomite—M.E. Benson
- Black-shale vanadium—A.H. Hofstra, S.M. Smith, and K. Lund
- Heavy-mineral placer—B.S. Van Gosen

Salable commodities—S.E. Box

Acknowledgments

This study benefited from early discussions about mineral occurrences and resource assessments in the study area with State (Idaho) Geologist Ed Ratchford, as well as Renee Breedlovestrout, Dennis Feeney, Virginia Gillerman, Reed Lewis, William Phillips, and Christopher Tate from the Idaho Geological Survey and Dave Schwarz of the Idaho Department of Lands. At all stages of the project the advice and help from U.S. Geological Survey (USGS) project chiefs, W. Day and T. Frost, set the goals and kept the study on task and on schedule. J. Hammarstrom, USGS, organized the mineral-resource assessment meetings, systematized many aspects of the mineral-resource assessments, and answered numerous questions. C. Holm-Denoma, USGS, helped with technical aspects that improved the revision process. Thoughtful reviews by A. Bookstrom, C. Mercer, and E. Todd assisted with many particulars of the text, thereby improving the writing and refining the scientific and assessment details. The efforts of the reviewers as well as of manuscript editor K. Jacques and series editor W. Day significantly improved the organization and readability of the product.

Description of Geology

Physiography

The study area extends from south-central to southern east-central Idaho (fig. 2). The traditional physiographic regions of the U.S. described near the study area (Fenneman and Johnson, 1946) are also shown.

The topography of the study area includes the broad, northeast-striking Snake River Plain across the southern part of the area and the rugged mountains and valleys of the Basin and Range across the northern part. The broad, flat basin of the Snake River Plain slopes gradually to the southwest from an elevation of about 4,800 feet (ft) at its upper (northeastern) edge in the study area to near 3,000 ft elevation at the southwestern edge. This contrasts with the high relief Basin and Range topography in the northern part of the study area. There, mountain ranges are mostly 8,000–9,000 ft in elevation and include the tallest peak in the state (12,600-ft Borah Peak). The valleys between the ranges in the Basin and Range topography are about 6,500–7,000 ft in elevation at drainage divides, but only 3,000–4,800 ft in elevation in the Snake River Plain.

Watersheds in all but the northernmost parts of the study area drain southward into large creeks and small rivers that flow directly into the upper reaches of the Snake River in the northeastern Snake River Plain. The Snake River flows southwestward down the trough of the Snake River Plain. Streams in the mountainous northern part of the study area flow north into tributaries of the Salmon River and ultimately, by circuitous stream patterns across central and western Idaho, into the Snake River about 200 miles (mi) northwest of the study area.

Regional Geology and Tectonic Setting

The Basin and Range and Snake River Plain physiographic domains of the study area contain distinctly different geologic and tectonic settings. The northern two-thirds of the study area is underlain by all the geologic units and structures representative of the geology of the northern Cordillera of the United States. The southern one-third of the area is the Snake River Plain, a younger volcano-tectonic depression that transects the older Cordilleran geology, and is interpreted to

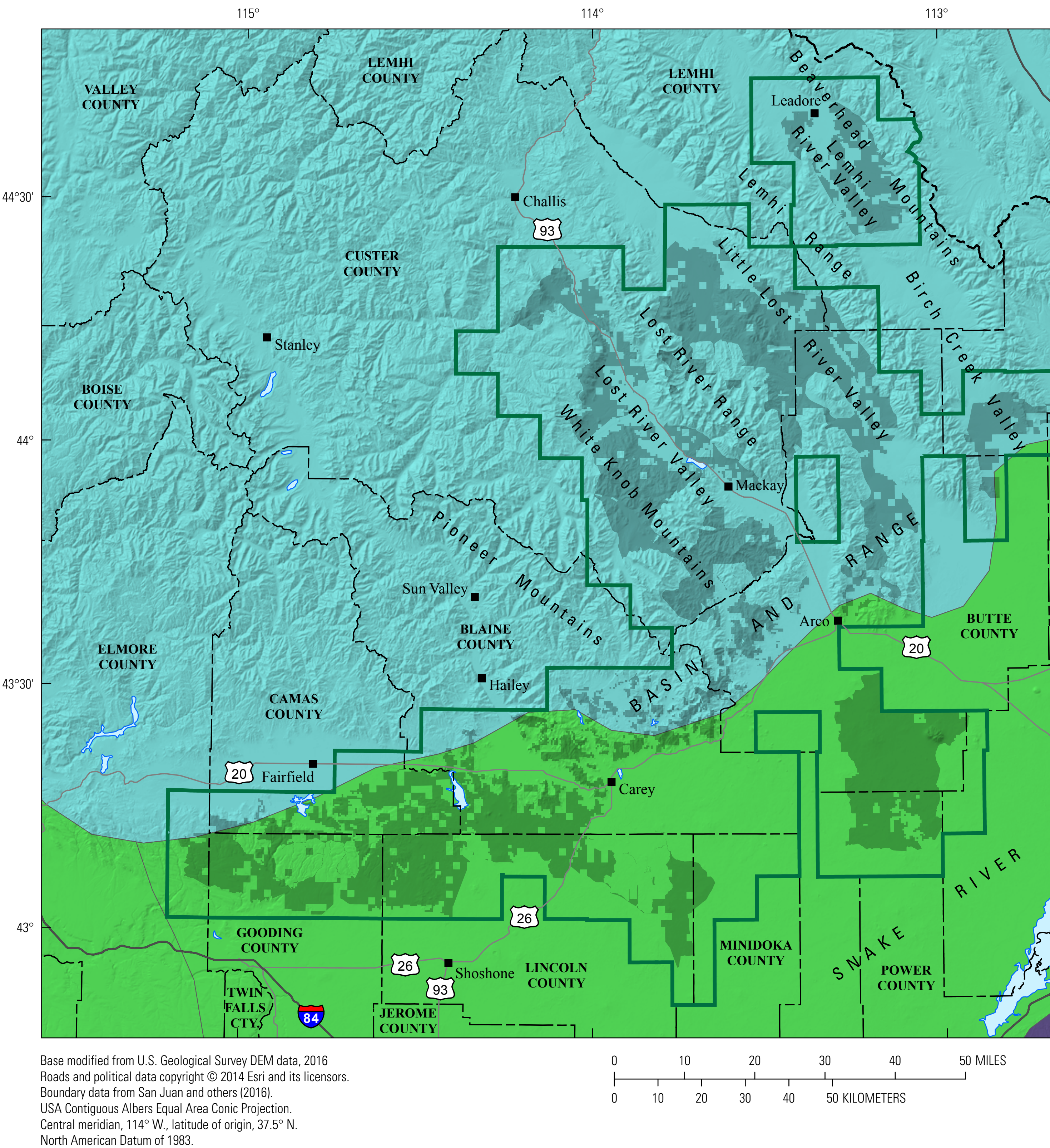
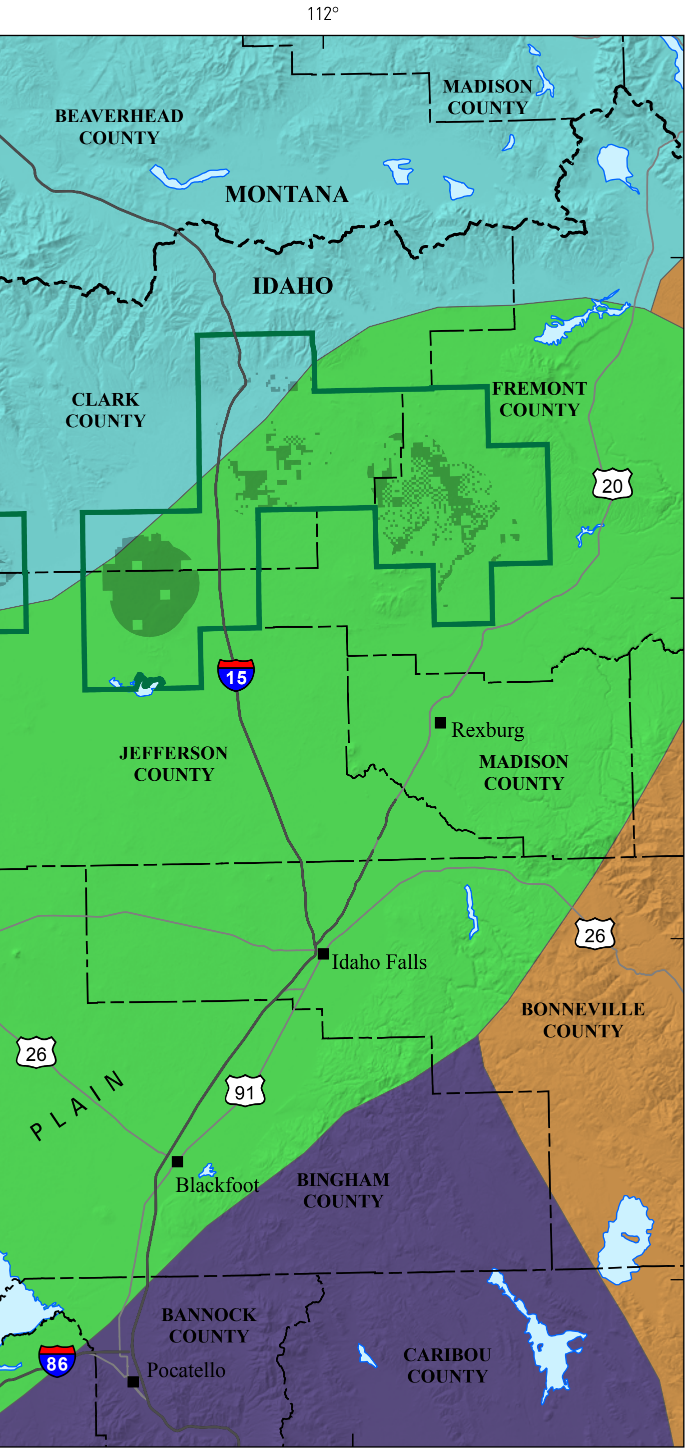
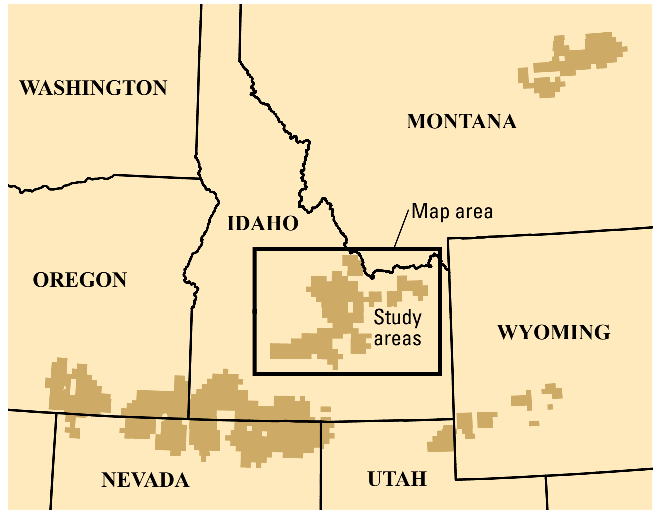


Figure 2. Map showing the physiographic regions and geographic features of the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Physiographic regions

Division, province

Rocky Mountain System, Northern Rocky Mountains

Rocky Mountain System, Middle Rocky Mountains

Intermontane Plateaus, Columbia Plateau

Intermontane Plateaus, Basin and Range

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

Physiographic regions from Fenneman and Johnson (1946).

record deep-seated hot-spot activity focused along an ancient flaw in the continental basement (Lund, 2008; Henry and others, 2012; Konstantinou and Miller, 2015) as the North American Plate moved over it (Pierce and Morgan, 1992).

More than 3 billion years of Cordilleran geologic history is recorded in rocks north of the Snake River Plain. These rocks are located along the ancient western edge of the Precambrian Laurentian continent (core of North America) and underlain mostly by basement of the 3.1 giga-annum (Ga) Wyoming craton (Lund and others, 2015). These Laurentian basement rocks were deformed and intruded by granitic rocks at 2.6–2.5 Ga. An extensional event between 1.43 and 1.38 Ga resulted in rocks of the Wyoming craton remaining exposed as a landmass (shoreline) east of the open marine, Lemhi depositional basin to the west. A thick succession of Mesoproterozoic sediments was deposited into this northwest-striking basin. The southern extent of these deposits is included in the northern part of the study area. Laurentia was stable and terrestrial for the next 700 million years until extension from 685 to 480 mega-annum (Ma), related to the breakup of the supercontinent Rodinia, profoundly affected the study area. Different types of rift structures related to the breakup were located in a broad northwest-striking zone north of the Snake River Plain and in a northeast-striking zone now occupied by the Snake River Plain. As the rift zones matured, they became the locus of thick continental-shelf and continental-slope sedimentary successions, deposited along a newly established passive margin of western Laurentia. In the study area, the rifting is expressed by minor, discontinuous Neoproterozoic to Lower Ordovician sedimentary deposits, by Late Cambrian to earliest Ordovician magmatism, and predominantly by thick Middle Ordovician through Pennsylvanian deposits. The Late Devonian- through Mississippian-aged Antler orogeny, during which rocks from the deeper continental slope and western basin were thrust-faulted eastward onto the continental shelf rocks, disrupted this passive margin. Because of the orogenic activity, a depositional trough formed between a developing Antler orogenic highland on the west and the continental margin on the east. During the Permian, an event that formed the ancestral Rocky Mountains in the Southern Rocky Mountains of Colorado, caused the miogeocline to be reorganized again, and a restricted foreland basin formed along the eastern edge of the study area.

Oblique convergence during the late Mesozoic between Laurentia and the Pacific Plates caused accretion of allochthonous terranes in western Idaho and east-northeast directed compression in western Laurentia. Resultant Late Cretaceous (about 100–80 Ma) folds and thrust faults telescoped the Precambrian through Paleozoic rocks. In the study area, these events are manifested by the stacking of deeper water Paleozoic rocks from the west onto progressively shallower water coeval rocks toward the east. Related crustal thickening in the hinterland of the western part of the study area caused metamorphism, crustal melting, and the large granitic bodies of the Cretaceous Idaho batholith (about 94–80 Ma).

In the Eocene, significant crustal extension ensued in response to changes in the rate and orientation of interactions between the North American and Pacific Plates and crustal over-thickening. Early-stage extension reduced the displacement on Cretaceous thrust faults (Link and Janecke, 1999) and was accompanied by voluminous shallow intrusions and volcanic deposits of the Challis magmatic event (about 52–45 Ma; Moye and others, 1988; Fisher and Johnson, 1995). Syn- and post-Challis event block faulting (about 55 Ma to present) created several generations of block-fault controlled basins that filled with volcanic and sedimentary deposits. Ultimately, this deformation resulted in the presently expressed, high-elevation, tilt-block ranges and basins filled with thick Oligocene to Holocene unconsolidated sediments (VanDenburg and others, 1998).

During the Miocene basin-range extensional event, the Yellowstone Hot Spot began tracking under the North American Plate, first expressed at the surface near the Nevada-southeastern Oregon border around 15 Ma. As the North American continent moved slowly southwest over the mantle hot spot, rising mantle-sourced basaltic melts rose through the continental crust, initially melting the crust to form rhyolitic lavas and ash-flow tuffs in broad caldera structures, and finally clearing a pathway for direct eruption of the basaltic mantle melts at the surface. The youngest basaltic rocks are related to a number of preserved shield volcanoes. The hot spot is presently under the Yellowstone caldera in northwesternmost Wyoming. The central and eastern Snake River Plain formed behind the hot spot as a topographic depression hosting basaltic volcanism that cut across earlier stratigraphic facies, igneous provinces, and structural trends in a direction that was generally parallel to North American Plate motion (Pierce and Morgan, 1992).

Geologic Units and Depositional History

North of the Snake River Plain

Basement

The oldest rocks in and adjacent to the study area (fig. 3) are Precambrian crystalline basement of the Laurentian continent (see Lund and others [2015] and references therein). Paleoproterozoic granite gneiss (dated at 2.4 Ga) and older schist (as old as 3.5 Ga) of the Archean Wyoming basement are exposed in thrust slivers (M'Gonigle, 1994; Kellogg and others, 2003) and in depositional contact underlying younger rocks (Tysdal and others, 2005) at the northeastern edge of the study area. Beneath the eastern boundary of the study area, both the allochthonous thrust slivers and the intact Wyoming craton basement lie at shallow crustal depths, but these rocks are at deeper levels to the west. Directly north of the western edge of the study area, Archean (2.6 Ga) gneiss also of Laurentia is exposed in the Boulder-Pioneer core complex (Dover, 1983; Cameron, 2010) but it is not clear from this very small exposure if this is a different basement terrane or an intrusion into older basement (Lund and others, 2015).

Mesoproterozoic Strata

Thick Mesoproterozoic sedimentary rocks related to the approximately 1.4-Ga intracontinental, extensional Lemhi Basin are exposed in the northeastern part of the study area (figs. 3, 4). The Lemhi depositional basin extended northwestward across central Idaho from about 1.43 to before 1.38 Ga. Exposed units consist of about 7,000 meters (m) of fine-grained arkosic metasandstone and siltite as well as quartzite, presently at lower greenschist facies (Lemhi Group and overlying Swauger Formation). In the study area, the lower Lemhi Group consists of feldspathic metasandstone, containing minor calcareous cement and thin heavy-mineral layers (Big Creek Formation) that originated as beach deposits (Tysdal, 2000). The most extensively exposed unit is thinly to thickly interlayered medium-grained siltite and fine-grained metasandstone (Apple Creek Formation) deposited in below-wavebase, marine turbidite complexes (Tysdal, 2000, 2003). The upper unit in the Lemhi Group is a fine- to medium-grained feldspathic metasandstone (Gunsight Formation) deposited partly in fluvial and mostly in tidal marine environments (Tysdal, 2000, 2003). The Apple Creek Formation and base of Gunsight Formation are the host units for both the Blackbird Co-Cu-Au and Lemhi Pass Th deposits in structurally controlled veins. The youngest Mesoproterozoic unit known in the study area is quartzite (Swauger Formation) deposited in a tidal environment (Tysdal, 2003). An exposure of possible Mesoproterozoic paragneiss in the Boulder-Pioneer Mountains (Dover, 1983; Cameron, 2010) near the northwestern corner of the study area suggests that, although the exact age and correlation of these rocks is unknown, Mesoproterozoic sedimentary deposits may have extended across most of the area north of the Snake River Plain.

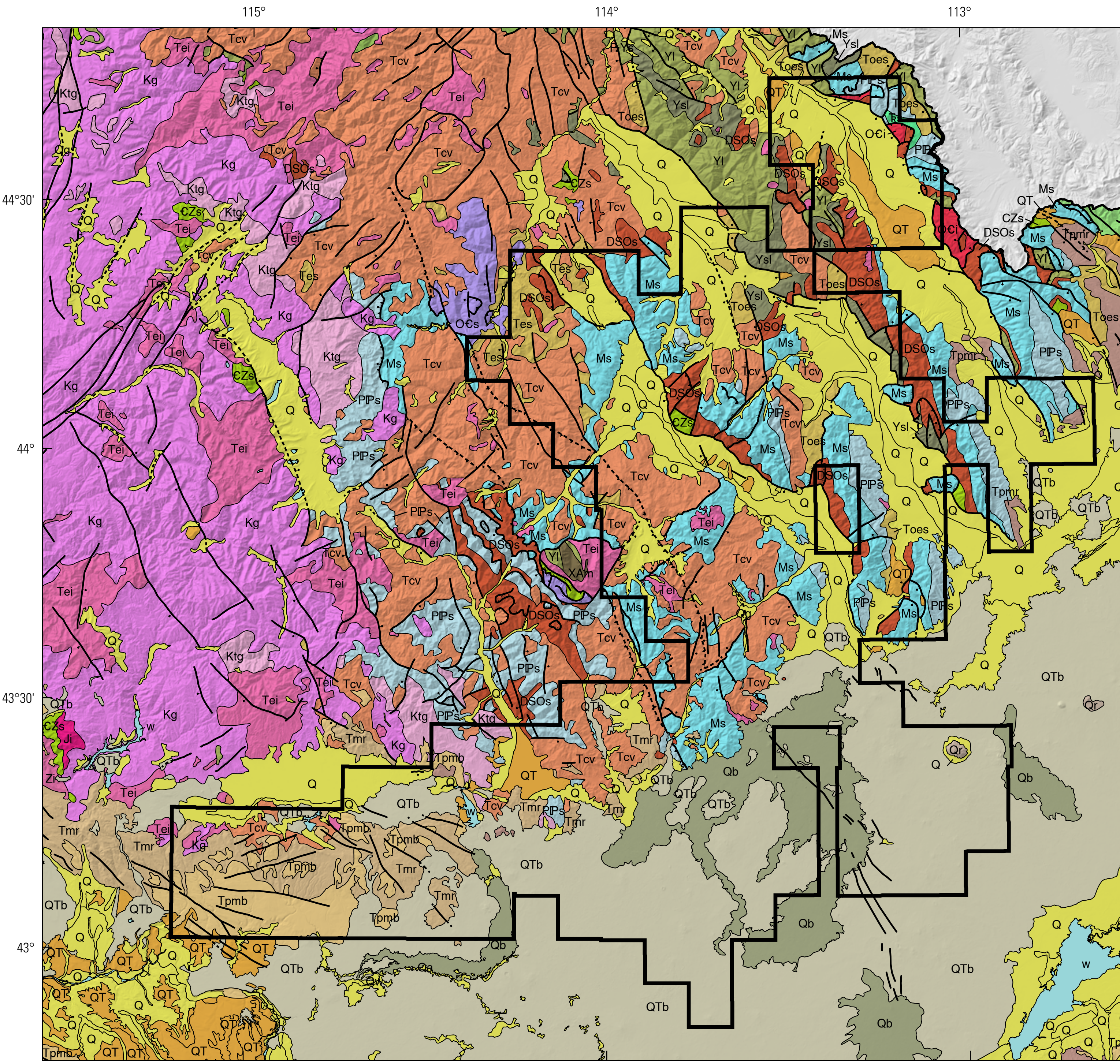
Neoproterozoic to Paleozoic Miogeoclinal Rocks

The Mesoproterozoic units were succeeded by a major period of nondeposition continuing until the late Neoproterozoic in a few localities, but until the Middle Ordovician in most areas (fig. 4). Renewed rifting of the Rodinian supercontinent from the late Neoproterozoic into the early Paleozoic initiated down-to-the-basin faulting near the eastern edge of the study area and led to the development of the paired Lemhi Arch on the east and the westward-deepening miogeoclinal basin extending across the rest of the area (Sloss, 1954; Scholten, 1957). Evidence for this is a west-thickening wedge of sedimentary rocks deposited on the developing Laurentian continental shelf (passive-margin or miogeocline). The active extension caused intermittent exposure or submergence of parts of the continental margin (in the area of the Lemhi Arch) through most of the Paleozoic.

On the west flank of the Lemhi Arch (now encompassing the eastern three mountain ranges), Neoproterozoic and Lower Cambrian quartz sandstone, quartz-pebble conglomerate, and shale (Neoproterozoic-Lower Cambrian Wilbert and Lower Cambrian Tyler Peak Formations) were deposited locally above Mesoproterozoic units (Isaacson and others, 1983; Ruppel and Lopez, 1988; Lund and others, 2003). There are no recognized sedimentary deposits of Middle or Late Cambrian age across the region except for possible minor Upper Cambrian rocks in the Salmon River assemblage in the far west side of the study area. Late Cambrian syenite, which is exposed in the Beaverhead Mountains (488-Ma Beaverhead pluton), intruded Mesoproterozoic rocks as part of the rift event. Through continued early Paleozoic extensional tectonism and erosion, the syenite was exhumed before Middle Ordovician quartzite was deposited across the syenite and older Precambrian country rocks (Lund and others, 2010).

Lower Ordovician dolostone (Summerhouse Formation) is only locally present above the regional Mesoproterozoic to lower Paleozoic unconformity in the eastern ranges (fig. 4; Ruppel and Lopez, 1988) but the Middle Ordovician quartzite (Kinnikinic Quartzite) is widespread across the study area. The quartzite is fine-grained and quartz-cemented in the east but the correlative unit in the west (basal Phi Kappa Formation) contains interbedded shales. These units represent a sheet of clastic deposits that was deposited by high-energy currents in the open-marine, inner-shelf environment in the east, changing to lower-energy currents in the deeper water, continental slope environment to the west. There are only about 30 m of the quartzite preserved in the east, where a post Middle Ordovician unconformity is most profound; about 500 m were deposited in the central area and less than 100 m of quartzite on the western side (James and Oaks, 1977). In general, these Neoproterozoic through Middle Ordovician rocks provide evidence of intermittent exposure to erosion along the migrating paleomargin on the east and slope-basin deposition on the west.

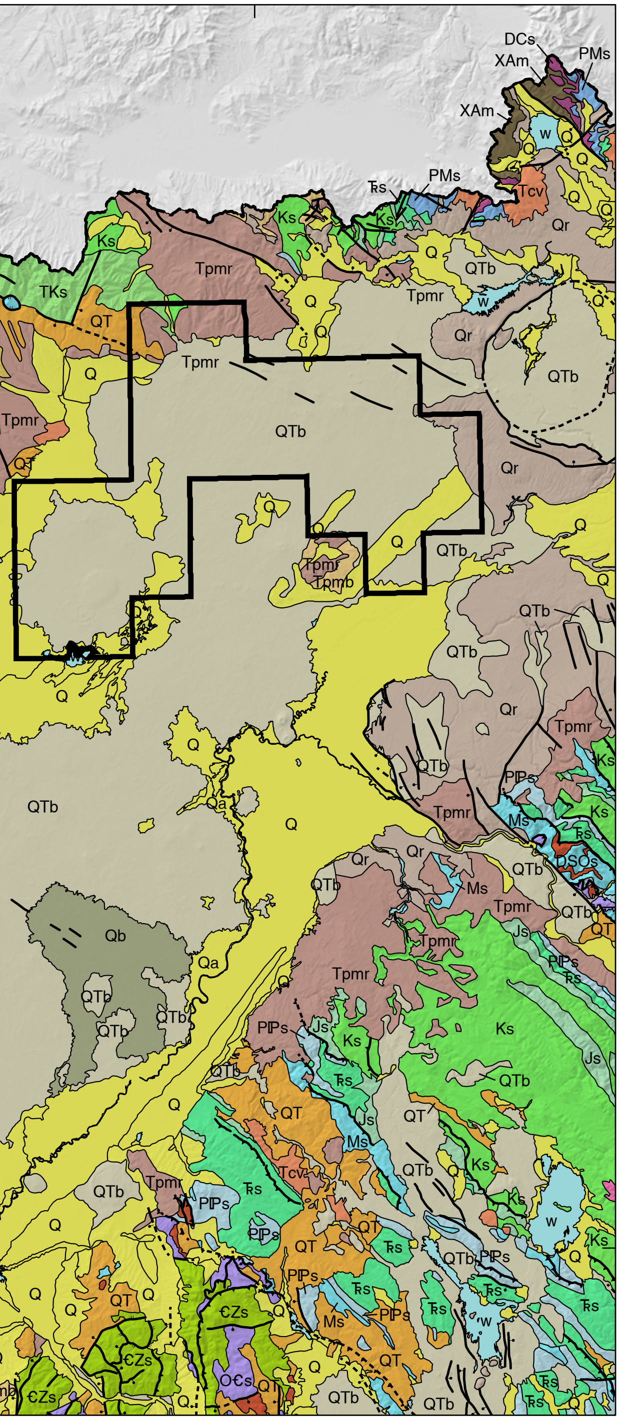
Across the eastern and central parts of the area, a widespread Middle Ordovician unconformity is overlain by Upper Ordovician rocks (Saturday Mountain Formation), which grade from dolostone on the eastern side to carbonaceous dolostone and shale in the center (Ruppel and Lopez, 1988). In the western part of the area, facies equivalent silicified shale, argillite, and thin limestone beds (middle part of the Phi Kappa Formation; Dover and others, 1980) represent more continuous deposition. Silurian deposits at the eastern extent of the study area in the Beaverhead Mountains are a discontinuous dolostone unit (upper Saturday Mountain Formation). In the central Lemhi Range, the Silurian is represented by thicker dolostones (Laketown Dolomite). Rocks older than Devonian are not exposed in the White Knob Mountains. In the Pioneer Mountains, an older wedge of Silurian reef limestone, calcareous and dolomitic siltstone, and limestone conglomerate (Roberts Mountains Formation) is overlain by the younger Silurian dolostone (dolomite of Lone Mountain). In the northwestern part of the Pioneer Mountains, Silurian rocks are argillite and siltite (Phi Kappa and Trail Creek Formations). Because of basin geometry, Silurian rocks range from only a few meters thick in the easternmost exposures to more than 600 m thick in the area of the Lost River Range (Isaacson and others, 1983) and about 200 m in the basinal setting in the far west (Link and others, 1995).

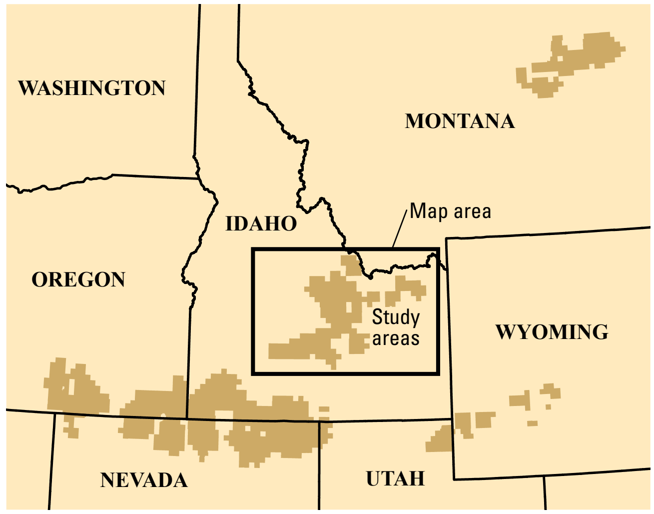


Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 3. Generalized geologic map of the study area for the North-Central Idaho Sagebrush Focal Area. Modified from Lewis and others (2012).





Geology modified from Lewis and others (2012).

EXPLANATION

Lithostratigraphy

- Q — Unconsolidated alluvial, landslide, glacial, lake, and fluvial deposits (Holocene and Pleistocene)
- Qb — Basalt (Quaternary)
- Qr — Rhyolite (Pleistocene)
- QT — Unconsolidated fan and valley-fill deposits (Pleistocene and Pliocene)
- QTb — Basalt (Pleistocene and Pliocene)
- Tpmb — Basalt (Pliocene and Miocene)
- Tpmr — Rhyolite (Pliocene and Miocene)
- Tmr — Rhyolite (Miocene)
- T — Volcaniclastic and sedimentary rocks associated with volcanic units (Miocene to Eocene)
- Tcv — Challis Volcanics (Eocene)
- Tei — Challis intrusive rocks (Eocene)
- TKs — Sedimentary rocks (Paleocene and Cretaceous)
- Ks — Sedimentary basin rocks (Cretaceous)
- Kg — Idaho batholith—Granodiorite and two-mica granite (Cretaceous)
- Ktg — Idaho batholith—Tonalite, granodiorite, and quartz diorite (Cretaceous)
- Ji — Tonalite, hornblendite, and gabbro (Jurassic)
- Js — Sedimentary rocks (Jurassic)
- ₮s — Sedimentary rocks (Triassic)
- PMs — Sedimentary rocks (Permian to Mississippian)
- P₽s — Restricted marine shale, chert, phosphorite, and limestone (Permian and Pennsylvanian)
- Ms — Shelf carbonate bank, flysch basin turbiditic limestone, and siliciclastic and deep-water carbonaceous argillite (Mississippian)
- DSOs — Shelf dolostone and deep-water carbonaceous siliciclastic rocks (Devonian to Ordovician)
- D€s — Sedimentary rocks (Devonian to Cambrian)
- O€i — Syenitic intrusive rocks (Ordovician and Cambrian)
- O€s — Dolostone and quartzite (Ordovician and Cambrian)
- €Zs — Windermere Group (Cambrian and Neoproterozoic)
- Zi — Syenite (Neoproterozoic)
- Yl — Lemhi Group arkosic siltite and metasandstone (Mesoproterozoic)
- Ysl — Swauger and Lawson Creek Formations, quartzite and meta-sandstone (Mesoproterozoic)
- Yy — Yellowjacket Formation and Hoodoo Quartzite, arkosic siltite, and quartzose metasandstone (Mesoproterozoic)
- XAm — Metamorphic rocks (Paleoproterozoic and Archean)
- w — **Water**

Contact

Fault, undivided—Includes normal, detachment, and strike-slip faults

High-angle normal fault—Includes normal, detachment, and strike-slip faults. (Bar and ball on downthrown plate)

Low-angle normal fault—Includes normal, detachment, and strike-slip faults. (Tics on downthrown plate)

Normal fault, concealed—Includes normal, detachment, and strike-slip faults. (Decoration on downthrown plate)

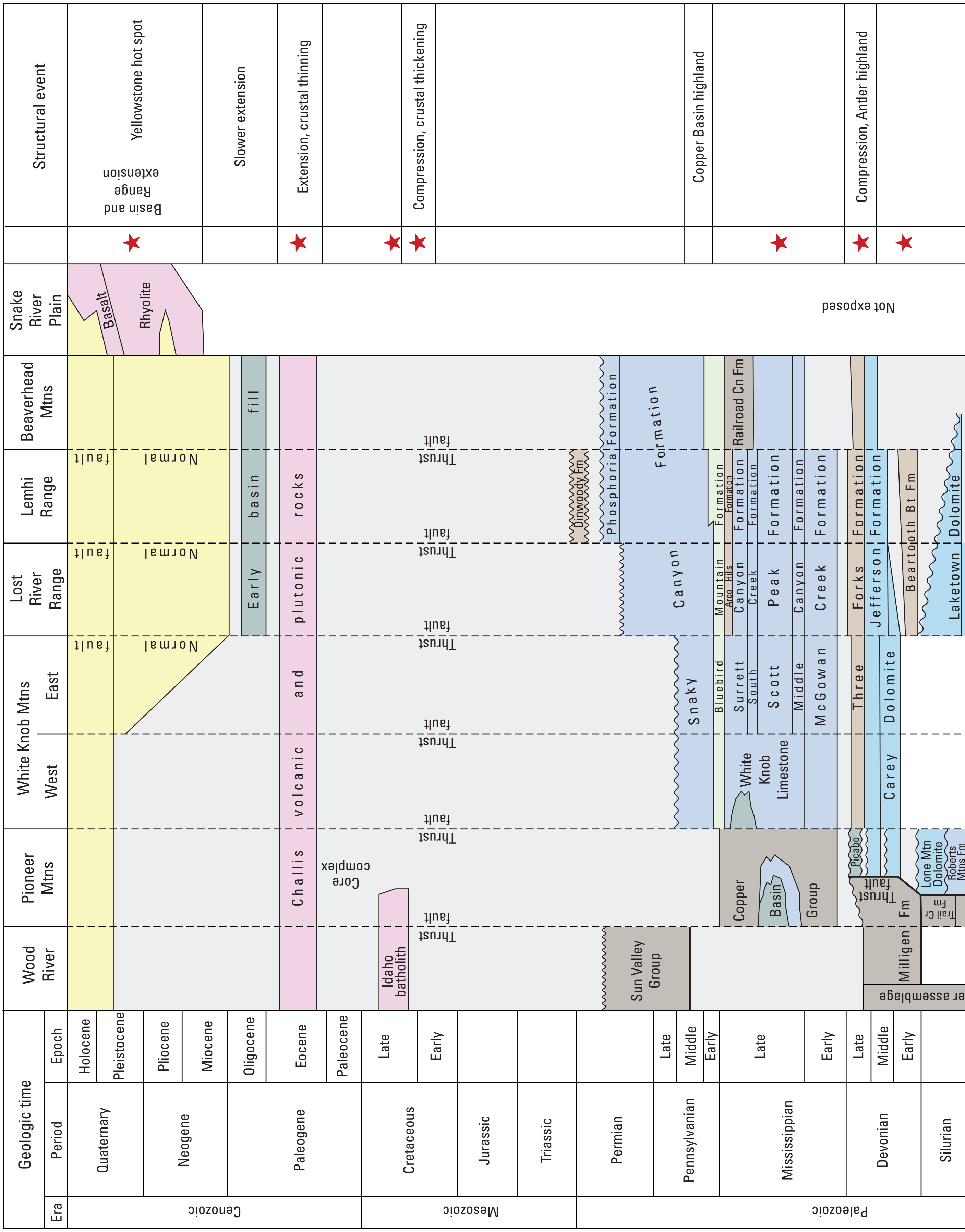
Thrust fault, certain (Teeth on upthrown plate)

Thrust fault, concealed (Teeth on upthrown plate)

Base data

USGS study area boundary

State boundary


Structural event
Basin and Range extension
Yellowstone hot spot
Slower extension
Extension, crustal thinning
Compression, crustal thickening
Copper Basin highland
Compression, Antler highland
Snake River Plain
Basalt
Rhyolite
Not exposed
Beaverhead Mtns
Lemhi Range
Lost River Range
White Knob Mtns
East
West
Pioneer Mtns
Wood River
Normal fault
Thrust fault
Early basin fill
Challis volcanic and plutonic rocks
Core complex
Idaho batholith
Dinwoody Fm
Phosphoria Formation
Snaky Canyon Formation
Sun Valley Group
Bluebird Mountain Formation
Arco Hills Formation
Railroad Cn Fm
Surrett Canyon Formation
South Creek Formation
Scott Peak Formation
Middle Canyon Formation
McGowan Creek Formation
White Knob Limestone
Copper Basin Group
Three Forks Formation
Jefferson Formation
Carey Dolomite
Picabo
Beartooth Bt Fm
Laketown Dolomite
Lone Mtn Dolomite
Roberts Mtns Fm
Trail Cr Fm
Milligen Fm
Thrust fault
Geologic time
Era
Period
Epoch
Holocene
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Late
Early
Middle
Quaternary
Neogene
Paleogene
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Cenozoic
Mesozoic
Paleozoic

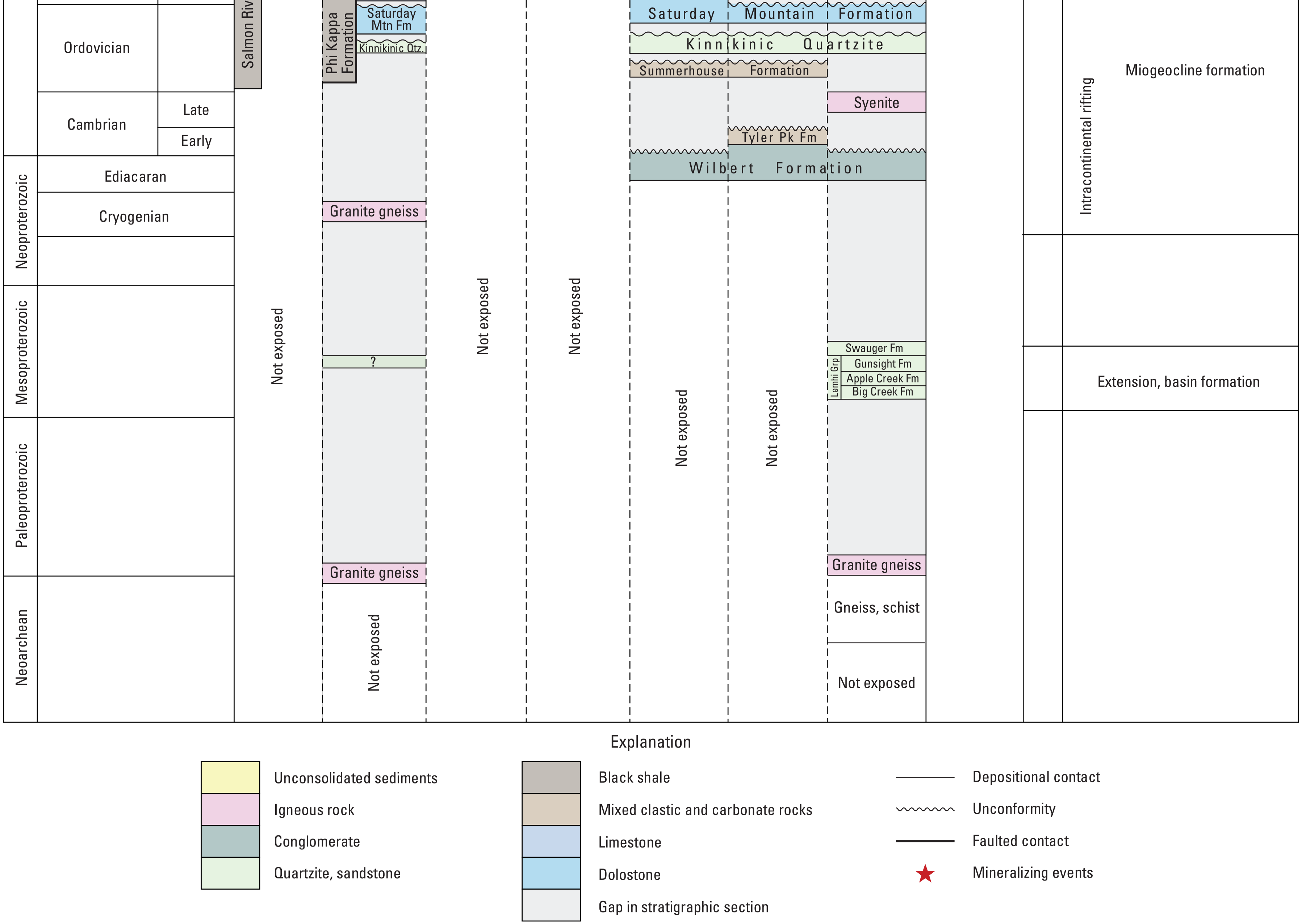


Figure 4. Generalized tectono-stratigraphic diagram of the study area for the North-Central Idaho Sagebrush Focal Area. Compiled and modified from Skipp and others (1979a), Isaacson and others (1983), Mahoney and others (1991), Pierce and Morgan (1992), Link and others (1995), and Lund and others (2003, 2010).

Lower Devonian strata are absent in the Beaverhead Mountains. However, Middle Devonian dolostones are present and are characterized by paleovalley and fluvial karst deposits (fig. 4; Grader and Dehler, 1999). Lower and Middle Devonian rocks in the Lemhi Range formed in restricted shallow and marginal marine deposits (Beartooth Butte Formation and Carey Dolomite). A more complete rock record is preserved in the Lost River Range where dolostone, limestone, and quartzite (Jefferson Formation) were deposited in a shallow marine setting. Across these central and eastern ranges, Lower to middle Upper Devonian strata preserve shallowing upward sequences deposited in peritidal and shallow subtidal environments but also include rocks deposited in channels and as evaporite-solution breccia. Deposition reflected structurally controlled, intermittent subsidence in the restricted basin of the central Idaho trough and also intermittent exposure due to a global glacial event (Grader and Dehler, 1999). Uppermost Devonian rocks in the Beaverhead Mountains to Lost River Range are the finely crystalline limestone, silty limestone, and calcareous siltstone (Three Forks Formation) of a restricted-basin shelf facies (Skipp and Sandberg, 1975; Grader and Dehler, 1999). West of the central Idaho trough in the western White Knob Mountains, uppermost Devonian rocks are quartzose sandstone, dolostone, dolostone conglomerate with pebbles of underlying Devonian rocks, and, towards the top, both dolomitic and calcareous sandstone (Picabo Formation). The clastic rocks are evidence of development of the Antler highland west of the study area.

Farther west, the Middle and Upper Devonian section consists of a lower unit composed mostly of cherty argillite, lesser limestone, and a local quartzite lens, as well as of an upper member composed of argillite, thin quartzite lenses, and lesser chert-pebble conglomerate (Milligen Formation and age-equivalent parts of the Salmon River assemblage). Mafic tuff layers and dikes are present locally throughout the unit. This succession is as much as 1,150 m thick; the Lower to Middle Devonian part was deposited in a deep marine, starved basin setting but the Upper Devonian part was deposited by east-prograding, deep-marine turbidite complexes, both types originating in continental slope and rise environments (Turner and Otto, 1995). Both the chert pebble conglomerates of the upper part and the mafic igneous activity present throughout the unit are interpreted as evidence of syn-depositional extension in a foreland basin related to crustal thickening and development of the Antler highland farther west (Turner and Otto, 1995). Syngenetic Ag-Pb-Zn deposits are characteristic of these western-facies Devonian units (Turner and Otto, 1995; Link and others, 1995).

The Silurian to Late Devonian subsidence occurred in response to mature miogeoclinal development. The basin shoaled against the Lemhi arch on the eastern margin but the shoreline migrated back and forth through time between the western Beaverhead and the Lemhi ranges. The basin deepened west of the major basin-bounding faults, which lay in the area of the present Lemhi-Birch Creek valley and southern Lemhi Range (Grader and Dehler, 1999). The continental-margin deposits, largely composed of reef materials, were coupled with gravity flow deposition into a well-developed deeper basin in areas in, and west of, the White Knob Mountains. In the Middle to Late Devonian, the margin geometry on the eastern side of the area began to change, developing a northwest-striking trough that faced an incipient foreland basin as the Antler highland started forming in the west (McFadden and others, 1988; Grader and Dehler, 1999).

Above a regional Early Mississippian-aged unconformity, thick Mississippian stratigraphic sections were deposited across the study area. In the east, the Beaverhead Mountains were the site of about 400 m of massive limestone deposited as part of a carbonate-bank complex (Scott Peak Formation). It is locally overlain by about 200 m of an Upper Mississippian black carbonaceous shale, calcareous shale, and limestone unit (Railroad Canyon Formation) that formed in a narrow facies belt related to an intra-ramp basin (Skipp and others, 1979b; Batt and others, 2007). From the Lemhi Range to the eastern White Knob Mountains, the Middle to Upper Mississippian rocks include thick shaley limestone, limestone, shale, and quartzite (Middle Canyon, Scott Peak, South Creek, Surrett Canyon, Arco Hills, and (lower beds of) Bluebird Mountain Formations, respectively). This depositional cycle initiated as a forebank complex (Middle Canyon Formation) then transitioned to a deeper water interval of silty limestone (South Creek Formation) that thickened westward and finally transitioned to a carbonate-bank complex (Scott Peak and Surrett Canyon Formations). In the eastern White Knob Mountains, this complex is nearly 1,300 m thick (Skipp and others, 1979b). Overlying shale (Arco Hills Formation) and thin quartzite in the east (Bluebird Mountain Formation) marked a west-directed transport of cratonic platform detritus onto the shelf (Skipp and others, 1979a).

By contrast, the Lower Mississippian strata in the western White Knob Mountains are an approximately 1,200-m-thick succession of dark-colored, fine-grained turbidite, calcareous siltite, and silty limestone (McGowan Creek Formation; Skipp and others, 1979b). They originated as west-derived distal turbidite fans in the lower part that were overlain by starved basin deposits. Upper Mississippian strata in the western White Knob Mountains consist of 1,600 m of limestone and a wedge of west-derived conglomerate (White Knob Limestone), which were deposited on a carbonate platform at the eastern margin of the Antler turbidite basin (Link and others, 1996).

In the Pioneer Mountains, the Mississippian rocks are thick, dark-colored argillite, limestone, and conglomerate (Copper Basin Group). The Lower Mississippian member consists of dark argillite, siltite, and grit turbidites at the base grading upward to predominantly carbonate debris both as turbidites and proximal debris flows. The Lower to Upper Mississippian member consists of mudstones to cobble conglomerates deposited in shallower environments. The basal member represents a prograding submarine fan succession. The overlying carbonate debris was deposited as distal calciclastic turbidite deposits derived from the west that interfingered with proximal carbonate bank debris from the east. The upper member formed as an upward-fining fan delta (Link and others, 1996). The Antler foreland basin section is about 4,000 m thick, much thicker than equivalent rocks south of the Snake River Plain. Lead-silver skarn, replacement, and vein deposits are present, primarily in the calciclastic turbidites in the middle of the succession (Link and others, 1995). Exposures of Mississippian rocks on the far western side of the area are limited to Early Mississippian age, with only about 200 m of section present due to an unconformity at the base and the absence of Upper Mississippian rocks (fig. 4).

The Mississippian stratigraphic model consists of a continental shelf setting on the east side of the area, the Antler highland west of the study area, and the Antler foreland basin between. The Lower Mississippian turbidite deposits in the western and central parts of the area were sourced from the highland, transported eastward across deposits of the pre-Early Devonian continental slope, and deposited into the developing Antler flysch trough. Rapid deposition in the Early Mississippian reflected active syndepositional faulting and subsidence (Skipp and others, 1979b; Link and others, 1996; Batt and others, 2007). On the east, coeval west-directed transport of cratonic platform detritus onto the shelf terminated development of the Mississippian carbonate bank (Skipp and others, 1979a). Uplift of the Antler highland and foreland-basin subsidence slowed during the Late Mississippian (Link and others, 1996).

Pennsylvanian-aged strata in the east are an approximately 1,000-m-thick succession of sandy or silty limestone, calcareous sandstone, and cherty limestone and dolostone (Snaky Canyon Formation) that formed as a shallow-water carbonate bank in water that gradually deepened westward (Skipp and others, 1979a). In the White Knob Mountains in the west-central part of the study area, basal layers include coarse conglomerate containing debris from a source called the Copper Basin highland to the west. The Middle and Upper Pennsylvanian parts of the unit contain more silt and sandstone than carbonate rocks. By contrast, Pennsylvanian rocks in the western part of the study area, in the Wood River drainage, are a 3,000-m-thick mixed succession of fine-grained carbonaceous siltstone, limestone, sandy limestone, sandstone, and conglomerate (Sun Valley Group). The Sun Valley Group formed in braided delta and deep-water shelf environments west of a highland (Copper Basin highland) that formed in the area of the Pioneer Mountains (Mahoney and others, 1991; Link and others, 1995). Two fining-upward cycles and subsidence events are preserved in these rocks. The first cycle received debris from the Copper Basin highland, but the second cycle received carbonate debris transported from the continental shelf farther east after the highland was eroded (Link and others, 1995).

Subsequent to the ancestral Rocky Mountain orogeny of Pennsylvanian and Early Permian time, the Sublette Basin, a tectonically stable semi-enclosed epicontinental basin formed along the western margin of the North American craton; the Phosphoria Formation and equivalent sediments were deposited in the basin. The Sublette Basin (also referred to as the Phosphoria Sea) covered an approximately 400,000-square-kilometer (km^2) area in southern Idaho, southwestern Montana, western Wyoming, northern Utah, and northeastern Nevada (Maughan, 1994). At this time, a deeper expanse of open ocean to the west was barred on the south by the Humboldt highland, a remnant of the Antler orogenic belt in central Nevada (Geslin, 1998) and in central Utah by the Confusion shelf (Maughan, 1994). Inland to the east, an approximately 250-km-wide carbonate platform extended into central Wyoming and separated the Sublette Basin from an evaporitic sabkha system that dominated the sedimentary regime of the Goose Egg Basin further east (Maughan, 1966, 1994). The sedimentary rocks of the epicontinental basin (Phosphoria Formation) contain potential for phosphate as well as by-product U, F, Cd Cr, Ni, Mo, Ag, REE, and black shale V (Oberlindacher and Hovland, 1979).

Idaho Batholith and Challis Igneous Events

Late Cretaceous plutons of the Idaho batholith crop out north of the Snake River Plain in the far western part of the study area (fig. 3). The two older intrusive units (undivided on the state map of Lewis and others, 2012) represent relatively minor phases in the study area. Quartz diorite (Croesus stock) is exposed in a small area south of Hailey, Idaho, and is primarily composed of plagioclase, biotite, and augite. The quartz diorite intruded Devonian shales (Milligen Formation) and its roof and peripheral zone contain associated Ag-Pb-Zn deposits (Worl and Johnson, 1995). The quartz diorite is dated at about 97 Ma (Gaschnig and others, 2010). Exposures of hornblende-biotite granodiorite are present southwest of Hailey and in small areas west of Carey, Idaho (fig. 1). The hornblende-biotite granodiorite phase is characterized by plagioclase, K-feldspar, quartz, biotite, and hornblende. K-feldspar phenocrysts are locally present. Biotite granite-granodiorite, one of the main phases of the Idaho batholith (these are not subdivided on the state map of Lewis and others, 2012), is the most voluminous phase in the study area and is present northeast of Fairfield and along the northern edge of the Bennett Hills (Kiilsgaard and others, 2001). The biotite granite-granodiorite is generally equigranular, but locally contains plagioclase phenocrysts and minor muscovite. The intrusive ages for the undivided granite-granodiorite unit where exposed near the study area (Lewis and others, 2012) are about 91 and 87 Ma (Gaschnig and others, 2010).

Eocene plutonic rocks of the 52- to 45-Ma Challis plutonic-volcanic event are broadly distributed across the study area north of the Snake River Plain (fig. 3; Moye and others, 1988; Fisher and Johnson, 1995; Gaschnig and others, 2010; none of the exposures in the study area have been dated). The largest exposures are stocks in the Pioneer and White Knob Mountains. In addition, there are several smaller apophyses in the three ranges to the east, as well as small exposures in the western Bennett Hills at the west edge of the area. These are characteristically hornblende-biotite granite. The plutons commonly exhibit elevated concentrations of F, Be, Mo, REE, and U, sharing some similarities with anorogenic granites (Kiilsgaard and others, 2001). The granites commonly display chill-zone textures and miarolitic cavities, demonstrating shallow crustal emplacement (Rehn and Lund, 1981). Venting of the magmas resulted in the formation of the Challis Volcanics. The presence of the coeval subvolcanic intrusive bodies is indicated both by mapping and geophysical data. Many of these stocks and apophyses are associated with potential porphyry copper-molybdenum and polymetallic-vein mineralized systems. In many localities, Paleozoic shale and carbonate rocks in roof and peripheral zones of the Eocene plutonic rocks host polymetallic Ag-Pb-Zn±Cu-Au vein systems and skarns.

The Eocene Challis Volcanics are the extrusive expression of the Challis plutons (fig. 3). Conglomerate and sandstone, composed of debris from Cretaceous plutonic rocks and Paleozoic rocks, is widespread above an unconformity at the base of the volcanic rocks where the volcanic rocks overlie older units (McIntyre, 1982; Moye and others, 1988). In the southern Challis volcanic field, which covers the study area, the lower volcanic units are an andesitic suite, including latitic, andesitic, and dacitic tuff breccias and lava flows, possibly erupted from fissures that lie directly north of the study area (Moye and others, 1988). The thickness of the lower units is regionally variable because the flows were controlled by paleovalleys and graben. The upper parts of the volcanic section are most voluminous and include dacite to rhyodacite ash flow tuff, lava, tuff breccia, and domes (Moye and others, 1988). The tuffs were erupted from calderas that lie about 40–50 km north of the study area. In western and eastern exposures, the volcanic group is mostly composed of the lower andesitic units with interlayered lacustrine deposits (Moye and others, 1988). In the central part of the study area, the Pioneer and White Knob Mountains, the volcanic section is mainly composed of the upper ash-flow tuffs (Moye and others, 1988). Although variable, the volcanic package is commonly about 2,000 m thick, and is thickest in the southern Pioneer Mountains. Epithermal precious-metal mineralization is spatially associated with emplacement of the domes of the upper part of the package (Hardyman and Fisher, 1985; Kiilsgaard and Bennett, 1995). Where the basal contact zone of the volcanic rocks with underlying Cretaceous granite-granodiorite includes conglomerate and sandstones, these subvolcanic deposits are the locus of uranium mineralization near the northwest boundary of the study area (Van Gosen and others, 2006).

The Cretaceous and Eocene plutonic rocks are sources for mineral deposits therefore their locations are critical to resource potential assessments. Because they may be associated with different deposit types, it is important to have tools to discriminate these plutons, even where incompletely exposed. Aeromagnetic and radiometric data help identify and differentiate igneous rocks in the study area (Anderson and Ponce, 2016). Aeromagnetic lows are located over exposed Late Cretaceous plutons of the Idaho batholith; this contrasts with highs observed over outcrops of Eocene plutonic rocks. Because of this residual magnetic anomaly, highs in a high-frequency-passed magnetic field anomaly map indicate the presence of buried Eocene plutons. Radiometric anomaly highs are observed over both the Eocene plutonic and volcanic rocks, whereas the Idaho batholith rocks exhibit relative lows in thorium and uranium. Thus, the radiometric data also help identify buried plutonic rocks that may be related to mineral deposit genesis.

Basin and Range Deposits

In the late Eocene, paleovalleys and modern-day basins began to form and fill with syntectonic sediments (fig. 3). Late Eocene to Miocene composite deposits in these basins consist of interlayered sandstone, conglomerate, limestone, shale, and lesser tuffaceous sandstone and siltstone. Limestone lenses formed in fresh-water lakes and hot springs. Angular unconformities and lensoidal bedding are common as evidence of active tectonism (VanDenburg and others, 1998; Janecke and others, 2000). Along active range-front faults, deposits are commonly very coarse grained including cobble and boulder conglomerate whereas, along less tectonically active range boundaries, pebble conglomerate and sandstone are more common. Local, younger Miocene subbasins contain mudstone, siltstone, and sandstone. Poorly sorted Holocene and Pleistocene deposits originated as glacial outwash, alluvial fan, and terrace deposits. The youngest deposits are active stream alluvium. The three largest basins in the study area contain intra-basin bedrock ridges and related subbasins that are buried beneath more recent deposits (Mundorff and others, 1963; Crone and Haller, 1991; Anders and Schlische, 1994; Liberty and others, 2006). The valley fill in the Little Lost River Valley is estimated at as much as 3,000 m thick (Mundorff and others, 1963). The deepest part of the Pahsimeroi Valley contains as much as 2,000 m of Cenozoic basin fill in a pre-Pleistocene depocenter near the middle of the present valley (Liberty and others, 2006). These drainages end in playas at the northern edge of the Snake River Plain (Mundorff and others, 1963).

Structural Setting

Mesoproterozoic Through Paleozoic Structure

Extensional tectonics during the Mesoproterozoic resulted in the development of the large northwest-striking Mesoproterozoic Lemhi Basin. Normal faults, which sedimentary characteristics suggest existed in the eastern part of the area and controlled the geometry and subsidence of the depositional basin (Tysdal and others, 2005), remain cryptic.

Neoproterozoic to early Paleozoic rifting resulted in the paired extensional arch (Lemhi Arch on the east side of the study area) and basin (miogeocline across the study area) geometries. As with the older basin, discrete normal faults, which are required by sedimentologic characteristics to have controlled basin geometry and subsidence events, remain unidentified. However, abrupt changes in thickness and stratigraphic facies in the Paleozoic section provide clues as to the location of those basin-bounding faults. The significant differences in stratigraphic characteristics, especially thickness, among the Beaverhead, Lemhi, and Lost River ranges (fig. 4; Grader and Dehler, 1999) indicate that major down-to-the-west faults of Ordovician to Devonian age were located in the areas of the present Lemhi-Birch, Little Lost River, and Lost River valleys. The facies changes resulting from the basin-bounding structures became reactivation zones in subsequent compressional and extensional events (see following sections).

Regional compressional tectonism related to the Late Devonian-Early Mississippian Antler orogeny affected the study area. The associated crustal thickening, which caused the overlap of continental slope rocks over outer-shelf rocks and the building of a structural highland, was limited to areas west of the study area. The structures related to the Antler orogenic event in Idaho have not been identified, possibly because of Cretaceous reactivation (Dover, 1980; Skipp and Hall, 1980; Link and others, 1988). Relatively minor folds, cleavage, and tilting below the Mississippian unconformity are related to Antler deformation (Burton and Link, 1995; Turner and Otto, 1995). Other evidence for the Antler orogeny is largely stratigraphic, including palinspastic restoration of the Copper Basin Group, which reconstructs the geometry of the foreland basin receiving siliciclastic debris from the structural highlands (Antler and Copper Basin highlands) that were built and eroded on the west side of the basin (described in stratigraphic section). Additionally, the Copper Basin Group was deposited across the abrupt, probably structural, change from deep-water, allochthonous Milligen Formation on the west to the autochthonous (in the Devonian) continental shelf deposits on the east (fig. 4).

Cretaceous Compressional Structure

Rocks of the study area lie in the hinterland of the Cretaceous thrust belt and were caught up in the generally northeast-vergent deformation. The major Cretaceous thrust sheets are large and regionally persistent (Skipp, 1987); however their distribution is only discontinuously mapped to date (fig. 3). The scale of the compressional structures is determined for part of the Lemhi Range (Beutner, 1972; Tysdal, 2002) where the radius of some is demonstrated to be as much as 10,000–12,000 m (Tysdal, 2002). Footwall zones of the large thrust sheets are characterized by imbricate thrust faults and complex fold systems.

On the east edge of the study area, Archean- to Paleoproterozoic-aged basement rocks were involved in Cretaceous contractional deformation. During the Cretaceous deformation, the basement slices were faulted over Paleozoic strata (M'Gonigle, 1994) that had been deposited on the Precambrian rocks of the Lemhi Arch during Paleozoic highstand periods. On the eastern margin of the study area, thrust slivers of distal Mesoproterozoic rocks, with piggy-backed central-facies Paleozoic rocks, were thrust faulted over younger, eastern-facies Paleozoic and Mesoproterozoic strata. Large thrust faults are discontinuously exposed low on the west flanks of the Beaverhead and Lemhi ranges (Beutner, 1972; Ruppel and Lopez, 1988; Wilson and Skipp, 1994; Lund and others, 2003; Skipp and Kuntz, 2009). Large thrust faults have not been mapped in the Lost River Range. The Copper Basin thrust fault in the White Knob Mountains juxtaposed different Mississippian facies of the Copper Basin Group, but is largely concealed beneath Eocene Challis Volcanics (Skipp and Kuntz, 2009). In the western part of the study area, the Pioneer thrust fault juxtaposed western facies Silurian to Devonian strata over Mississippian foreland basin strata (Dover, 1983; Link and others, 1995; Skipp and Kuntz, 2009). The upper plate of the Pioneer thrust fault carries many imbricate faults that affected Pennsylvanian-Permian Sun Valley Group and Paleozoic Salmon River assemblage rocks (Rodgers and others, 1995), and historically complicated stratigraphic studies of the Pennsylvanian-Permian strata (Mahoney and others, 1991; Link and others, 1995).

Large expanses of the mountain ranges in the eastern part of the study area are only mapped at reconnaissance scales (1:250,000); therefore, structural details are not available. A few areas with detailed mapping show large, upright to northeast-overturned folds as much as 10 km long (Skipp and others, 1983, 1989; Skipp, 1985; Skipp and Kuntz, 2009; Tysdal, 2002). These folds are associated with axial planar cleavage in rocks with siliciclastic components, including some zones of phyllite (Skipp, 1985; Lund and others, 2003).

The large Cretaceous-aged thrust faults cut along facies changes in the Paleozoic strata and probably reactivated the Paleozoic and older (rift-related) basin-bounding normal faults. In juxtaposing western distal facies over eastern proximal facies, the faults shortened the miogeocline. Together, the juxtaposition of facies, reactivation of basin-forming normal faults, and footwall deformation at all scales were significant factors in later mineral-forming events.

Tertiary Extensional Structure

Several phases of Tertiary normal faulting (fig. 3) complicate the Cretaceous structural geometries. These faults are related to crustal thinning and extension driven by relaxation after Cretaceous compression and crustal thickening.

The earliest normal faulting initiated prior to Eocene Challis event igneous activity, resulted in northeast striking faults paralleled by Eocene volcanic vent systems and dike swarms, and had significant offset (Moye and others, 1988; Janecke, 1992; Tysdal, 2002). Normal faults of this generation formed graben in which Eocene volcanic rocks were localized and preserved, and in which Eocene through Miocene unconsolidated sediments were deposited.

During the Miocene, extension directions changed and northwest-striking basin-range faulting was initiated (Janecke, 1992; VanDenburg and others, 1998). The study area is located in the northern Basin and Range Province and present topography formed through this event. The best estimates for the amount of displacement on post-Eocene northeast-striking normal faults can be determined using the location of Cretaceous structures that were reduced and obscured during the younger extension. Reconstructions of the large

Cretaceous-age folds in the Lemhi Range provide estimates of more than 5 km of dip-slip movement on normal faults (Tysdal, 2002).

Valleys formed as half graben, with active faults on the west sides and east-tilted ranges (fig. 3; Crone, 1988; Crone and Haller, 1991; Link and Janecke, 1999). Although some valleys formed simply by alluviation of a trench between tilted mountain blocks, in detail the structure of other valleys is more complex. In the Little Lost River valley and the upper Lemhi Valley, bedrock ridges are buried beneath the valley fill or exposed as low-elevation hills (Mundorff and others, 1963; Crone and Haller, 1991; Anders and Schlische, 1994).

Snake River Plain

The eastern Snake River Plain is a northeast-striking low-relief area about 50–100 km wide that characterizes the southeastern part of the study area (fig. 3). The area is primarily underlain by Quaternary basaltic lavas, with local exposures of pyroclastic deposits, loess, sand dunes, and alluvial sediments (Kuntz and others, 1992). The volcanic rocks are a hot-spot related bimodal succession, with the initial rhyolitic ignimbrites followed by basaltic flows. Ignimbrites and pyroclastic deposits (Idavada Volcanics) derived from eruption of the rhyolitic calderas are exposed along the flanks of the Snake River Plain in successions over a kilometer thick that dip from 5–15° toward the axis of the Plain (Embree and others, 1982). Along the axis of the Snake River Plain, a series of large rhyolitic calderas young progressively to the northeast from about 10 million years old near Twin Falls, Idaho, to less than 0.6 million years old on the Yellowstone Plateau at the Idaho-Wyoming border (Pierce and Morgan, 1992). The basaltic succession is 1–2 km thick throughout most of the Snake River Plain, and formed from coalescing shield volcanoes fed primarily by northwest-striking rift vents.

Subsidence of the Snake River Plain relative to the flanking ranges is interpreted to have occurred by flexure resulting from density-driven subsidence and lower crustal flow away from the Plain, rather than by graben faulting (McQuarrie and Rodgers, 1998). Upper Miocene and lower Pliocene lacustrine deposits in the western part of the eastern Snake River Plain were deposited in the subsiding trough as a result of disruptions in the western Snake River Plain drainage system during the ongoing volcanic activity (Kimmel, 1982).

Leasable Minerals

Coal

Geology and Occurrence

According to published geologic reports, there are no coal-bearing strata recognized in the North-Central Idaho Sagebrush study area. Rocks in the study area are a mix of Quaternary alluvial deposits, Quaternary and Tertiary volcanic beds and basalt flows, Cretaceous granodiorite intrusive rocks, Paleozoic carbonate rocks, and Mesoproterozoic metasedimentary rocks (Lewis and others, 2012).

There are three small coal-bearing areas underlain by Tertiary-age lignites northeast of the study area (East, 2013). However, the coal resource potential of these areas (fig. 5) has not been assessed by the U.S. Geological Survey (USGS).

Results of Previous USGS Assessments

The USGS Open-File report of Coal Fields in the Conterminous United States (East, 2013) shows that the North-Central Idaho Sagebrush study area is not in any known coal region (fig. 5). Wood and others (1983) define a coal region as an area containing one or more coal fields. The USGS has not conducted any formal coal resources assessments within this study area; coal resources are defined as, “naturally occurring concentrations or deposits of coal in the Earth’s crust, in such forms and amounts that economic extraction is currently or potentially feasible,” by Wood and others (1983).

Geothermal

Geology and Occurrence

Overview discussions of the geothermal resources and power production potential in Idaho can be found in Dansart and others (1994) and Neely and Galinato (2007). The geothermal resource potential in the study area represents some of the highest reported in the 2008 national assessment of Williams and others (2008). The areas of high geothermal resource potential (figs. 6, 7) span the eastern Snake River Plain and the adjacent Basin and Range Province north of the Plain. This broad region experienced extensional tectonism and voluminous bimodal hot-spot-related volcanism during the Tertiary, and is an area of higher than normal heat flow that continues north (Blackwell, 1989) into western Montana. The area straddles elevated heat-flow regions that are present along the margins of the Plain and extends into the Plain where expected high heat flow is masked by shallow groundwater flow.

Exploration and Development

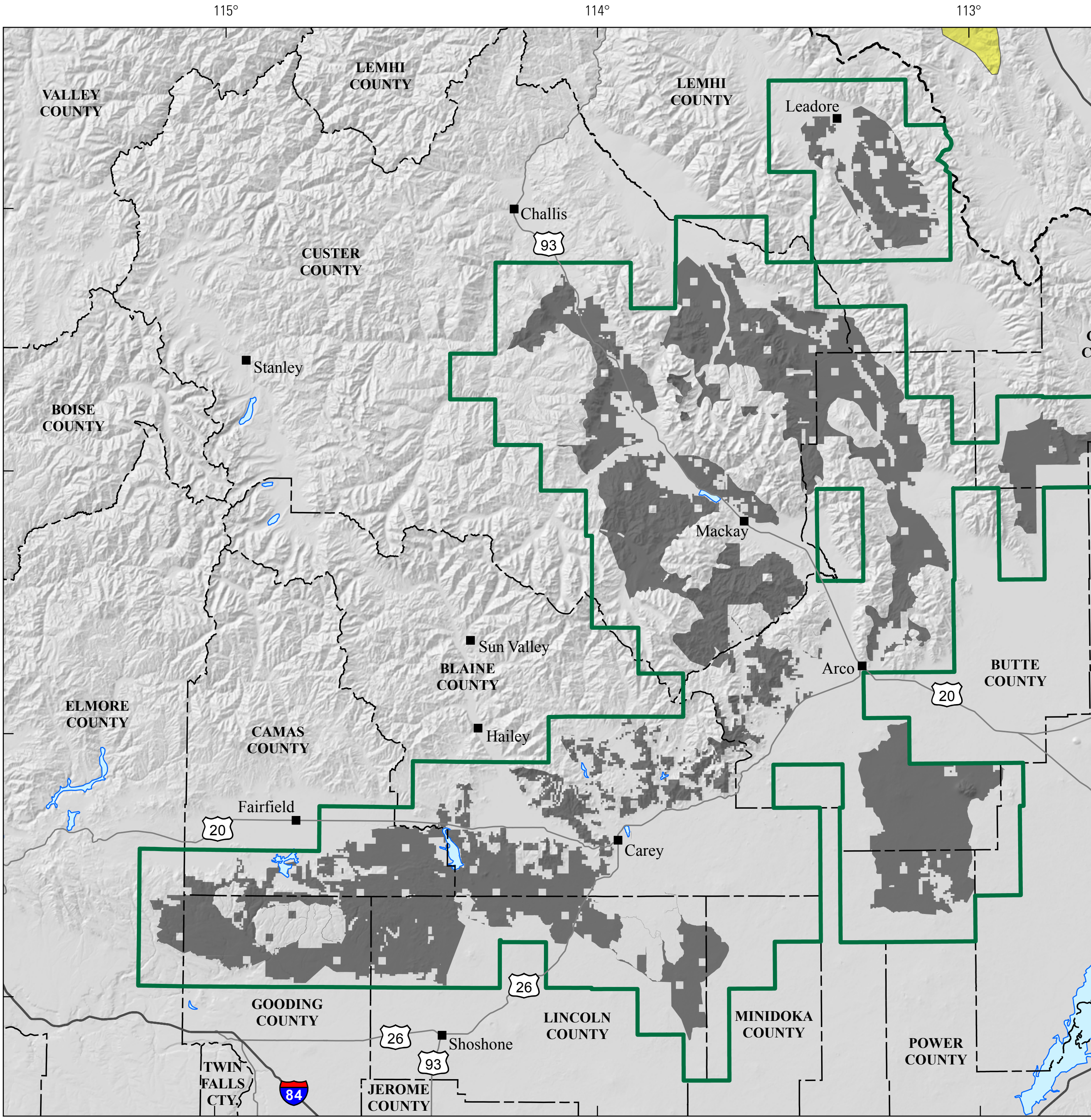
The study area coincides with an overall high geothermal resource potential that includes two moderate-high temperature geothermal systems at the Magic Reservoir area and White Arrow Hot Springs. A third area, Barron’s Hot Springs, is situated directly outside the study area. The area also contains 13 low-temperature geothermal systems (table 2, fig. 6). Geothermal leases exist for areas surrounding the Magic Reservoir system. Less than 10 km from the boundary of the proposed withdrawal area is a deep geothermal exploration well (INEL-1) at the Idaho National Laboratory, which is the site of an ongoing Department of Energy-funded project to study enhanced geothermal system (EGS) resources and technology. Estimated geothermal gradients at this site suggest it is a viable EGS resource.

Table 2. Occurrence of identified geothermal systems in the study area for the North-Central Idaho Sagebrush Focal Area: low temperature systems and moderate-to-high temperature geothermal systems.

[See figure 6 for a plot of the locations of identified geothermal systems. Data based on results from Williams and others (2008). Data sources: U.S. Geological Survey (USGS)—Reed and others, 1983; Geo-Heat Center (GHC)—Boyd, 2002; Lienau and Ross, 1996. Systems for which names were not available are labeled as NA. Abbreviations: °C, degree Celsius; NAD 83, North American Datum of 1983; km^3, cubic kilometer; MWe, megawatt electrical; min, minimum; max, maximum; % prob, percent probability]

Low temperature systems					
Name	Type	Data source	Mean temperature (°C)	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)
L. Roth well	Well	USGS	41	43.54036	–113.503
Barney Warm Springs	Spring	USGS	28.5	44.26868	–113.45
Bradley Pool Warm Spring	Spring	USGS	35	44.35734	–114.15
Little Antelope Flat Warm Spring	Spring	USGS	34	44.38151	–114.088
Big Eightmile Creek Warm Springs	Spring	USGS	33	44.63935	–113.504
Whittaker Warm Springs	Spring	USGS	24	44.61201	–113.364
C. Larkin well	Well	USGS	38	43.33435	–114.082
Condie Hot Springs	Spring	USGS	52	43.33269	–113.917
Milford Sweat Hot Spring	Spring	USGS	44	43.36586	–113.78
Rush Warm Springs	Spring	USGS	22	43.36452	–113.884
D. Archer well	Well	USGS	45	43.02868	–114.999
Hot Sulfur Lake	Well	USGS	27	43.04702	–114.93
J. Shannon well	Well	USGS	47	43.05318	–114.917
near Magic Hot Springs	Well	GHC	37	43.3282	–114.395
Magic Hot Springs Well	Well	GHC	74	43.3289	–114.398
Magic Reservoir Hot Springs	Spring	GHC	20	43.3286	–114.398
UMR-13	Well	GHC	24	43.3248	–114.383
UMR-8	Well	GHC	20	43.2663	–114.353
Champaign	Well	GHC	36	43.5973	–113.566
NA	Well	GHC	41	43.5394	–113.508
UMR-12	Well	GHC	44	43.323	–114.408
UMR-10	Well	GHC	24	43.3042	–114.406
UMR-7	Well	GHC	20	43.2442	–114.388
Tschanne Hot Springs	Spring	GHC	43	43.0384	–114.988
NA	Spring	GHC	21	43.1053	–114.864
NA	Well	GHC	52	43.0536	–114.916
White Arrow Hot Springs	Spring	GHC	54	43.0486	–114.951
UMR-5	Well	GHC	21	43.1915	–114.403

Moderate-to-high temperature geothermal systems											
Name	Latitude	Longitude	Temperature (°C)			Reservoir volume (km^3)			Power potential (MWe)		
	(decimal degrees NAD 83)		Mean	Min	Max	Mean	Min	Max	Mean total	95% prob	5% prob
Magic Reservoir area	43.3283	–114.398	110	105	125	1.5	0.4	9.6	9.1	2.2	20.1
White Arrow Hot Springs	43.0483	–114.953	100	90	110	1.4	0.3	8.3	5	1.2	11.1



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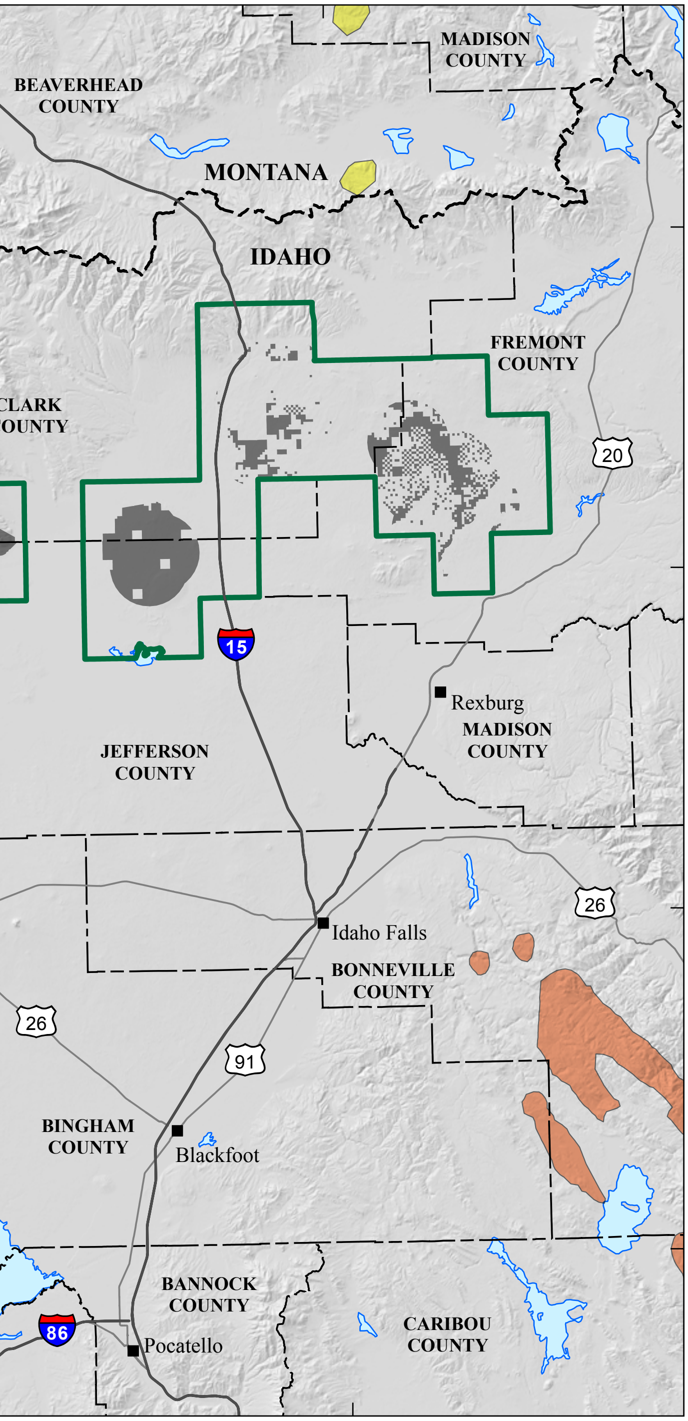
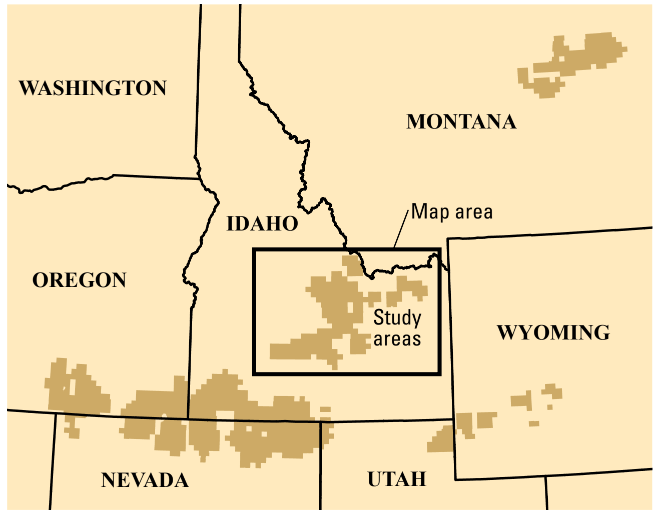
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 5. Map showing coal-bearing areas near the study area for the North-Central Idaho Sagebrush Focal Area (after East, 2013).





EXPLANATION

Hams Fork coal region

Tertiary Lake Beds coal region

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

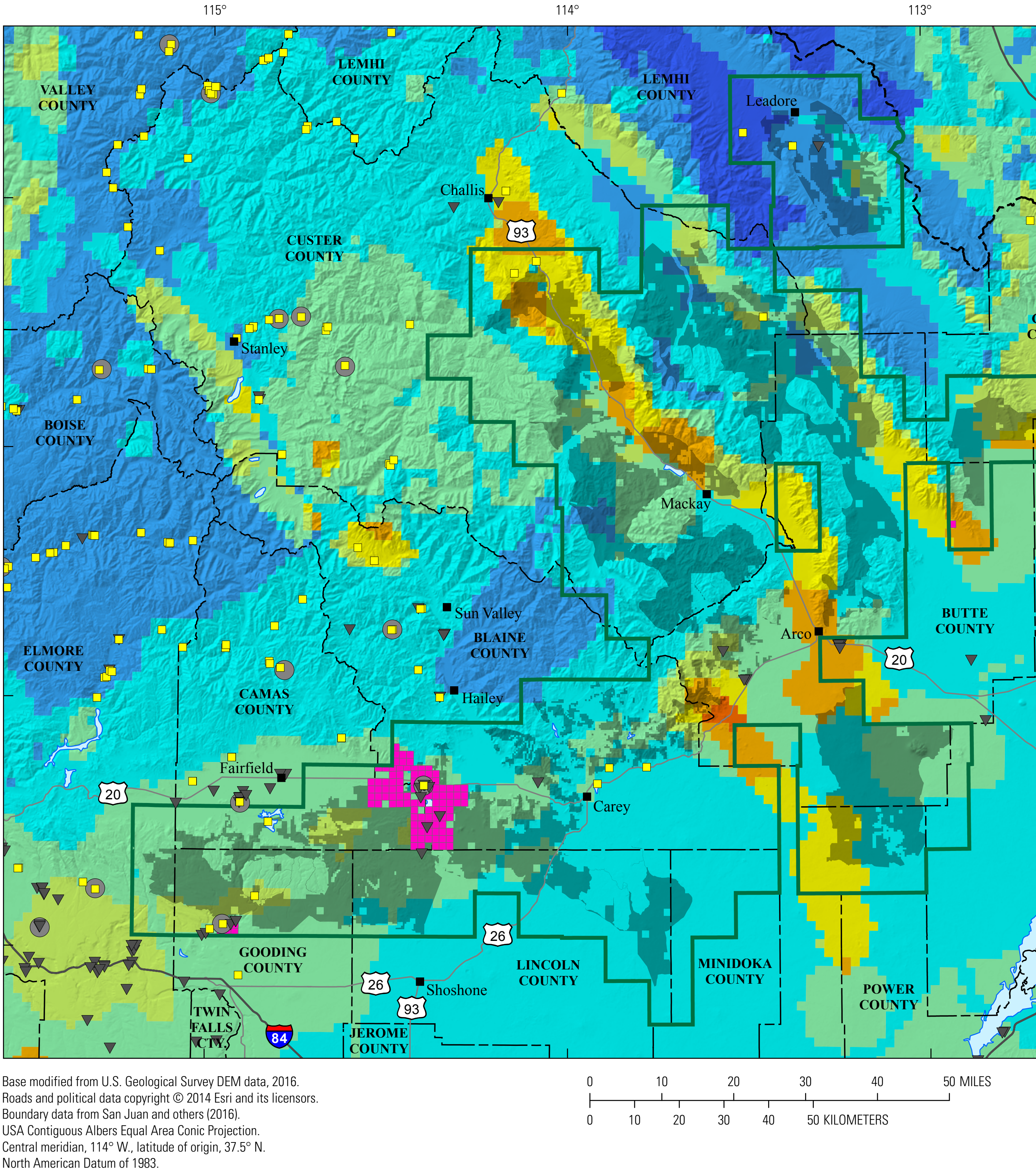
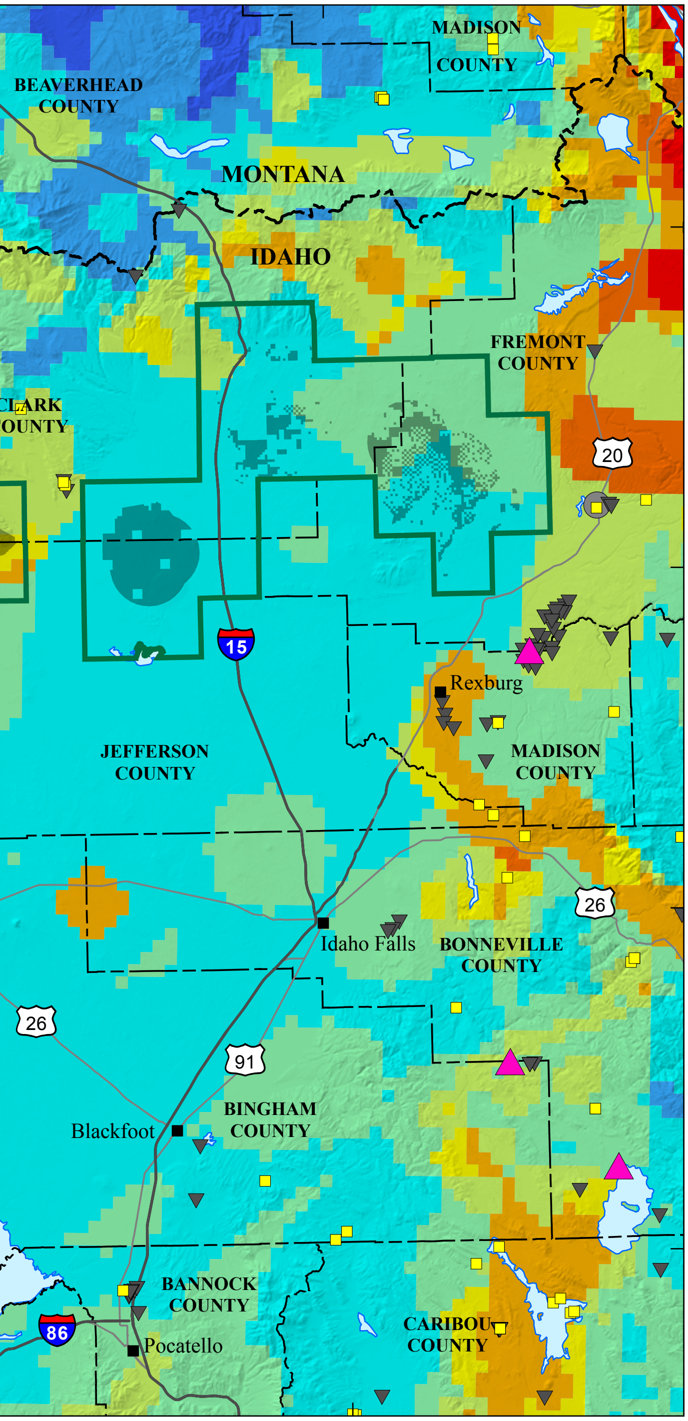
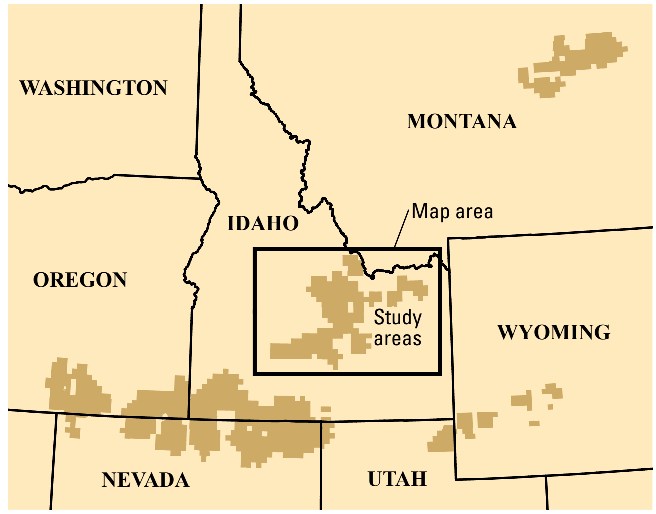


Figure 6. Map of the study area for the North-Central Idaho Sagebrush Focal Area, showing the occurrence of low-temperature and moderate-to-high temperature geothermal systems; operating and developing geothermal power plants; and Federal geothermal leases, overlain on the logistic regression results for hydrothermal favorability (after Williams and others, 2008).

112°





EXPLANATION

Hydrothermal favorability

High

Medium

Low

Geothermal leases

Geothermal developing sites (as of September 2, 2014)

Low-temperature geothermal springs and wells

Spring

Well

Moderate- to high-temperature geothermal systems

Moderate- to high-temperature geothermal systems

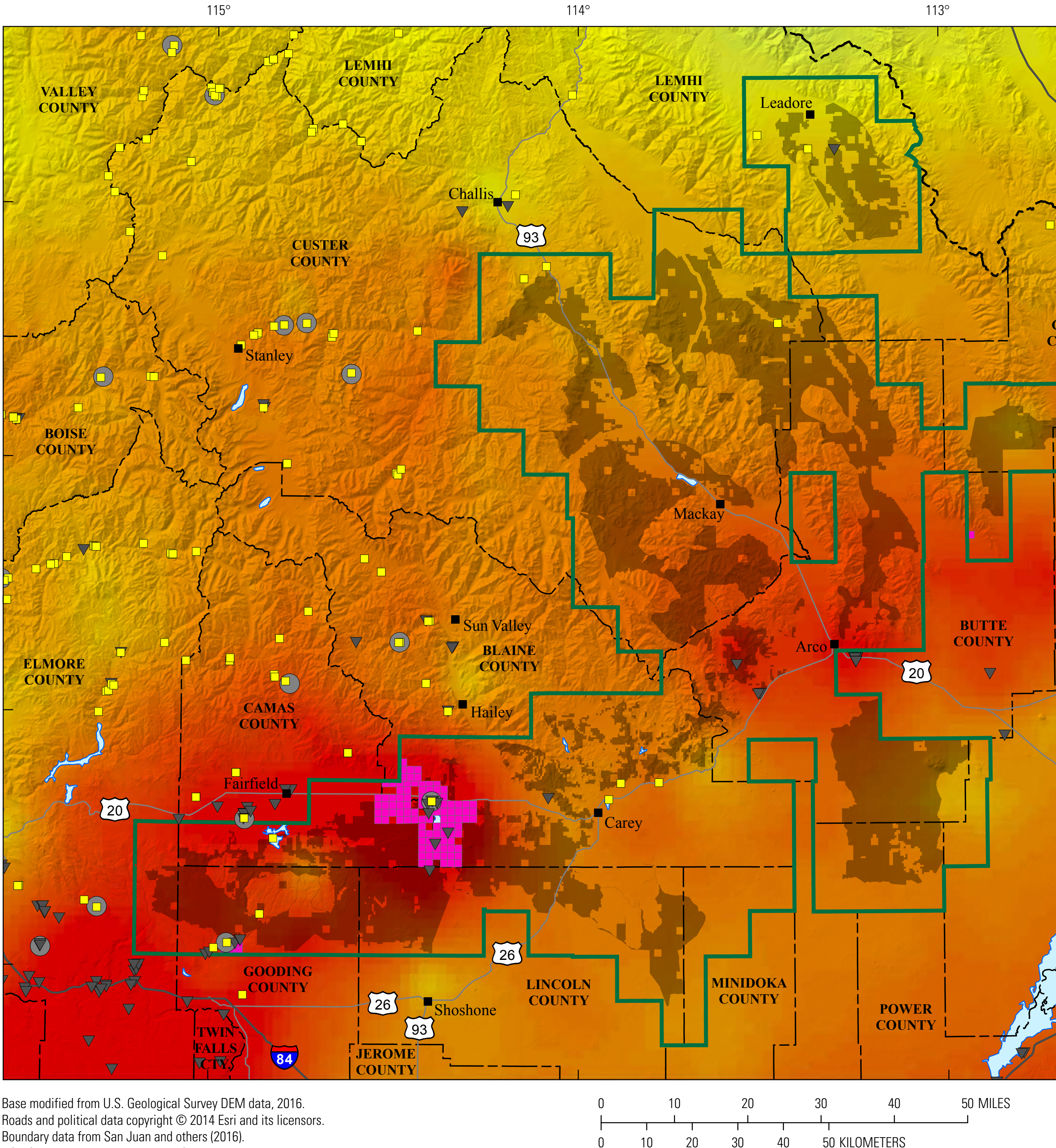
Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries



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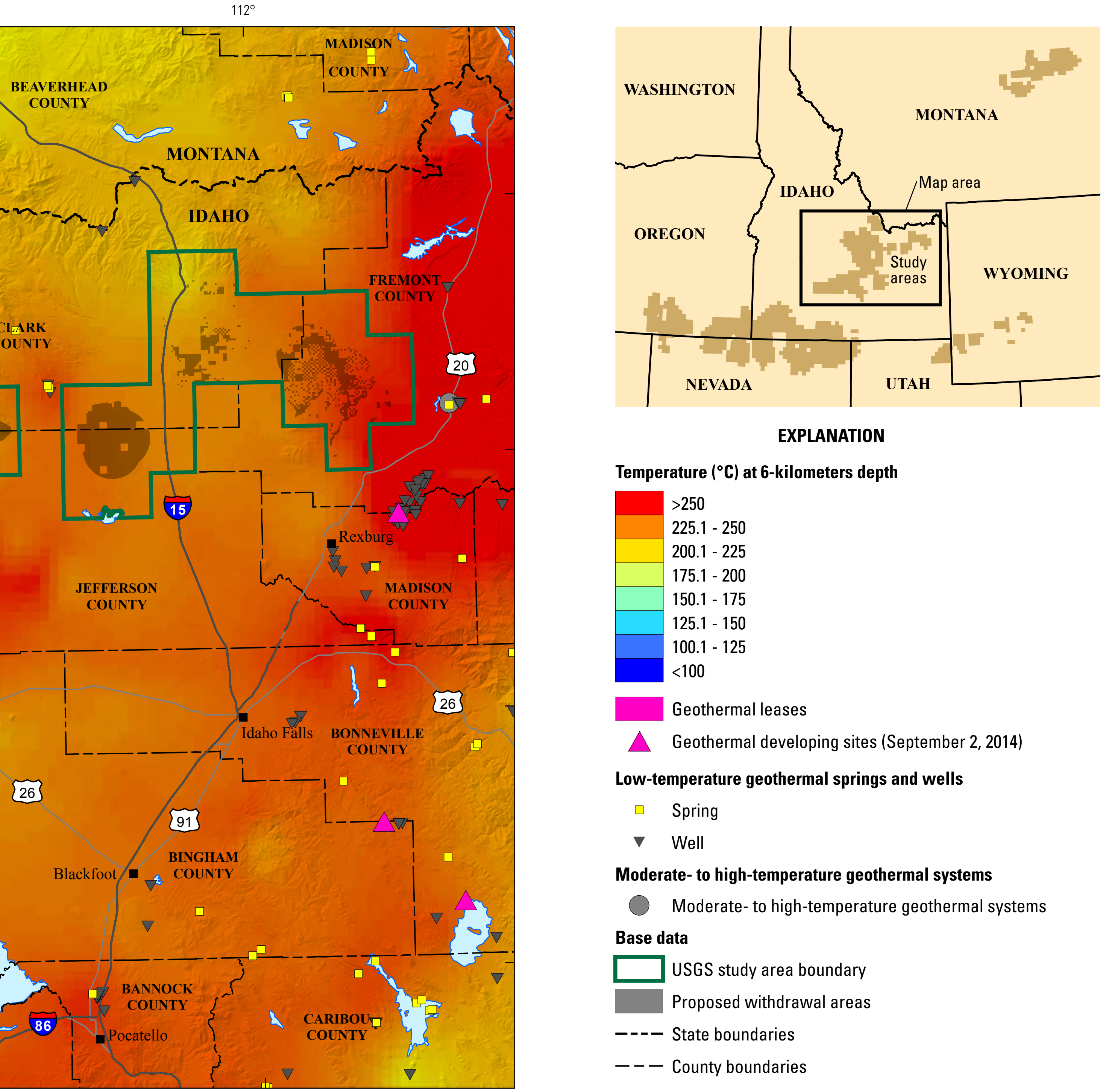
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 7. Map of the study area for the North-Central Idaho Sagebrush Focal Area, showing the occurrence of low-temperature and moderate-to-high temperature geothermal systems; operating and developing geothermal power plants; and Federal geothermal leases; overlain on the temperature at 6-km depth, which provides a proxy for Enhanced Geothermal System (EGS) favorability (after Williams and DeAngelo, 2011).


112°
MADISON
COUNTY
BEAVERHEAD
COUNTY
MONTANA
IDAHO
FREMONT
COUNTY
CLARK
COUNTY
20
15
Rexburg
JEFFERSON
COUNTY
MADISON
COUNTY
26
Idaho Falls
BONNEVILLE
COUNTY
26
91
BINGHAM
COUNTY
Blackfoot
BANNOCK
COUNTY
86
Pocatello
CARIBOU
COUNTY
WASHINGTON
MONTANA
IDAHO
Map area
OREGON
Study
areas
WYOMING
NEVADA
UTAH
EXPLANATION
Temperature (°C) at 6-kilometers depth
>250
225.1 - 250
200.1 - 225
175.1 - 200
150.1 - 175
125.1 - 150
100.1 - 125
<100
Geothermal leases
Geothermal developing sites (September 2, 2014)
Low-temperature geothermal springs and wells
Spring
Well
Moderate- to high-temperature geothermal systems
Moderate- to high-temperature geothermal systems
Base data
USGS study area boundary
Proposed withdrawal areas
State boundaries
County boundaries

Results of Previous USGS Assessments

Geothermal favorability calculations estimate conventional resources based on the results of the 2008 assessment of the nation's moderate- and high-temperature geothermal systems that relies on a logistic regression analysis to identify undiscovered resources (Williams and others, 2008; Williams and DeAngelo, 2011). Geothermal favorability of EGS resources is based on the estimated temperature at 6 km crustal depth (determined from Williams and DeAngelo, 2011). Mean favorability for conventional resources in the study area is roughly two times the average for the entire Western United States (table 3). EGS resource potential across the Sagebrush Focal Areas (fig. 7) also exceeds the average for the entire Western United States (table 3).

For a general discussion of geothermal resources in the Western United States and of the 2008 national resource assessment, see Glen and others (2016). Because the resource favorability results were developed from a database spanning the Western United States (Williams and others, 2008), favorability maps and values pertaining to the study area must be placed in context with respect to the resource potential spanned by the entire assessment dataset. Although viewing the broader context is not strictly necessary for interpreting the temperature at 6 km depth in the crust, which provides a proxy for EGS resource potential, the regional maps (Glen and others, 2016) allow readers to compare the temperatures in the study area with those across the entire Western United States.

Oil and Gas

Geology and Occurrence

The North-Central Idaho Sagebrush study area lies in the Idaho-Snake River Downwarp oil and gas province. According to IHS Enerdeq well data (IHS Energy Group, 2016), there has been no oil or gas production in the study area (fig. 8). Adjacent to the most northern part of the study area is the Montana Thrust Belt oil and gas province (Schenk and others, 2002); however, there are no potential assessed plays adjacent to the North-Central Idaho study area.

The only hydrocarbon production in Idaho near the study area is in Payette County of western Idaho, where there is natural gas and liquid condensate being produced from Miocene lacustrine deposits (Ratchford, 2015). The overall oil and gas potential appears to be low in the North-Central Idaho study area considering the presence of several dry wells in and around the study area). For more details about the geologic assessments of this area, see the USGS oil and gas assessment report by Peterson (1995).

Results of Previous USGS Assessments

Only one quantitative USGS oil and gas play—Miocene Lacustrine (Lake Bruneau)—was identified in the Idaho-Snake River Downwarp assessment (Peterson, 1995). This assessed play occurs within 36 of the 217 townships in the study area (appendix 3). The potential resource was assessed as having a mean of 0.90 million barrels of oil, and more than 11 billion cubic feet of gas in the play (Peterson, 1995).

Phosphate

Resource Description

Phosphate-rich rock is the primary globally mined source for phosphorus (Ruttenberg, 2005). Sedimentary phosphate (phosphorite) of marine origin constitutes the majority of phosphate rock consumed worldwide (Cathcart, 1978). The principal phosphate mineral in phosphorite is carbonate fluorapatite [$Ca_5(PO_4,CO_3OH)_3(F)$, francolite; Filippelli and Delaney, 1992]. Phosphate-rich rock is initially processed into phosphoric acid or converted into elemental phosphorus (P_4; also referred to as white phosphorus). Most phosphate is used in the manufacture of agricultural products such fertilizers, pesticides, and animal feeds (Jasinski and others, 2004; Zhang and others, 2006; Ragheb and Khasawneh, 2010). Phosphate is also used as a food additive and as an ingredient in insecticides, herbicides, flame-retardants, semiconductors, fireworks, matches, and household cleaning products. The phosphorus content in phosphate rock and in fertilizer is expressed as phosphorus pentoxide (P_2O_5) (Kauwenbergh, 2010). Commercially mined phosphate ore typically has (1) a minimum grade of 24 weight

Table 3. Statistics of geothermal favorability based on the 2008 USGS national geothermal assessment logistic regression analysis results (Williams and others, 2008) and temperature at 6-kilometers depth (determined from Williams and DeAngelo, 2011) in the study area for the North-Central Idaho Sagebrush Focal Area, and for the entire Western United States.

[Area: NCI, North-Central Idaho Sagebrush Focal Area; wUS, Western United States; °C, degree Celsius]

Area	Favorability (logistic regression analysis results)				Temperature at 6-kilometer depth (°C)			
	Mean	Minimum	Maximum	Standard deviation	Mean	Minimum	Maximum	Standard deviation
NCI	2.19830236	0.2189936	10.4740095	1.28516988	202.0	147.75	260.25	19.3
wUS	1.21126121	0.01127062	58.6081276	2.04851707	181.8	86.25	290.25	34.6

percent P_2O_5, (2) a minimum bed thickness of 1 m, (3) is laterally extensive, and (4) has minimal overburden (Rogers, 1995). Uranium, vanadium, and REE present in trace amounts in phosphorites are potentially recoverable as byproducts of elemental phosphorus and phosphoric acid production (Altschuler and others, 1967; Goldberg and others, 1992; Maughan, 1994; Ragheb and Khasawneh, 2010). The largest current U.S. domestic phosphate production is from phosphorite of Miocene to Pliocene age in Florida and North Carolina. There is a lesser amount of production from the extensive area of Permian deposits referred to as the Western Phosphate Field that extends across parts of Idaho, Montana, Wyoming, and Utah (Jasinski, 2016).

Geology and Occurrence

The two most phosphate-rich rock units in the Western Phosphate Field are the Meade Peak and Retort Phosphatic Shale Members of the Permian Phosphoria Formation (figs. 3, 4; Mansfield, 1940; Sheldon, 1957; McKelvey and others, 1959; Gulbrandsen and Krier, 1980; Maughan, 1994). Phosphorite deposits of Mississippian age crop out in the region as well, but they have not been commercially developed (Bond and others, 1978; Jewell and others, 2000; Vuke and others, 2007). Phosphate in the Phosphoria Formation occurs as pelletal phosphorite interbedded with organic-matter-enriched mudstone and siltstone, limestone, dolomite, and chert (Piper and Link, 2002). Historic and active phosphate mines and processing facilities of the Western Phosphate Field are concentrated outside of the study area in the southeastern Idaho counties of Caribou, Bear Lake, Bannock, and Bingham (Causey and Moyle, 2001; Moyle and Kayser, 2006); and in Utah at the Little Brush Creek mine and plant north of Vernal, in Uinta County (Rabchevsky, 1995; Jasinski and others, 2004).

Although surface exposures of phosphatic Permian and Mississippian units (figs. 3, 9) crop out in parts of the study area, there is no current production in, or directly adjacent to, the study area. Potential interest in the Permian in the extreme northeast part of the study area occur near closed BLM phosphate prospecting permits near Hawley Creek in Lemhi County, where outcrops of the Retort Phosphatic Shale Member of the Phosphoria Formation are described by Oberlindacher and Hovland (1979).

Exploration and Development

The Hawley Creek exposure of the Retort Member in Lemhi County averages a thickness of 22.3 m and extends a distance of 20.8 km (Oberlindacher and Hovland, 1979). Phosphate of the Hawley Creek exposure is present as oolites, pellets, nodules, and cementing material concentrated in dark-gray laminae. Analyses of samples indicate 2.7 m of medium-grade phosphate rock at 24 to 31 weight percent P_2O_5 and 10.2 m of low-grade phosphate rock at 16 to 24 weight percent P_2O_5 (Oberlindacher and Hovland, 1979). The Retort Member is not being actively explored, but a previous study estimated a resource of 73 million metric tons of medium-grade phosphate rock and 280 million metric tons of low-grade phosphate rock (Oberlindacher and Hovland, 1979). Trace elements having elevated concentrations in the Retort include U, V, F, Cd Cr, Ni, Mo, Ag, and REE. The closed permits in the Hawley Creek area include the Big Bear Creek prospect and Dry Canyon phosphate occurrences in the Phosphoria Formation (fig. 10). The Mississippian strata 50 km southeast of the Hawley Creek deposit along the west edge of the Beaverhead Mountains in Clark County contain one locality, the Blue Dome prospect (U.S. Geological Survey, 2005), which is hosted in a shallow-water carbonate-to-clastic succession (may include the Middle Canyon Formation, McGowan Creek Formation, and White Knob Limestone; see fig. 4; Bond and others, 1978).

Locatable Minerals

Mineral-Resources Potential Introduction and Terminology

The BLM uses legal definitions that group minerals into three categories—(1) locatable minerals (General Mining Act of 1872, 30 U.S.C. 22–42), including most metallic commodities and many high-unit value industrial commodities), (2) leasable minerals (Mineral Leasing Act of 1920, 30 U.S.C. 181 et seq.), including energy and fertilizer minerals), and (3) salable minerals (Mineral Materials Act of 1947, 30 U.S.C. 601 et seq.) which includes common varieties of sand, stone, gravel, pumice, pumicite, cinders and clay). A listing of the mineral commodities and their classification is given in appendix 1 of Day and others (2016).

For the BLM proposed withdrawal areas in the North-Central Idaho Sagebrush Focal Area, the status and numbers of lode claims (table 4, fig. 11) and of surface management permits for locatable minerals (table 5, fig. 12) are tabulated. The surface management permits are provided by commodity on table 6. These data are summarized for the PLSS townships that contain the BLM proposed withdrawal areas.

Table 4. Summary of mining claims for locatable minerals in the proposed withdrawal area of the North-Central Idaho Sagebrush Focal Area.

[For sources, see Dicken and San Juan (2016)]

Lode claims		Placer claims		Millsites	
Active	Closed	Active	Closed	Active	Closed
754	12,195	20	343	7	98

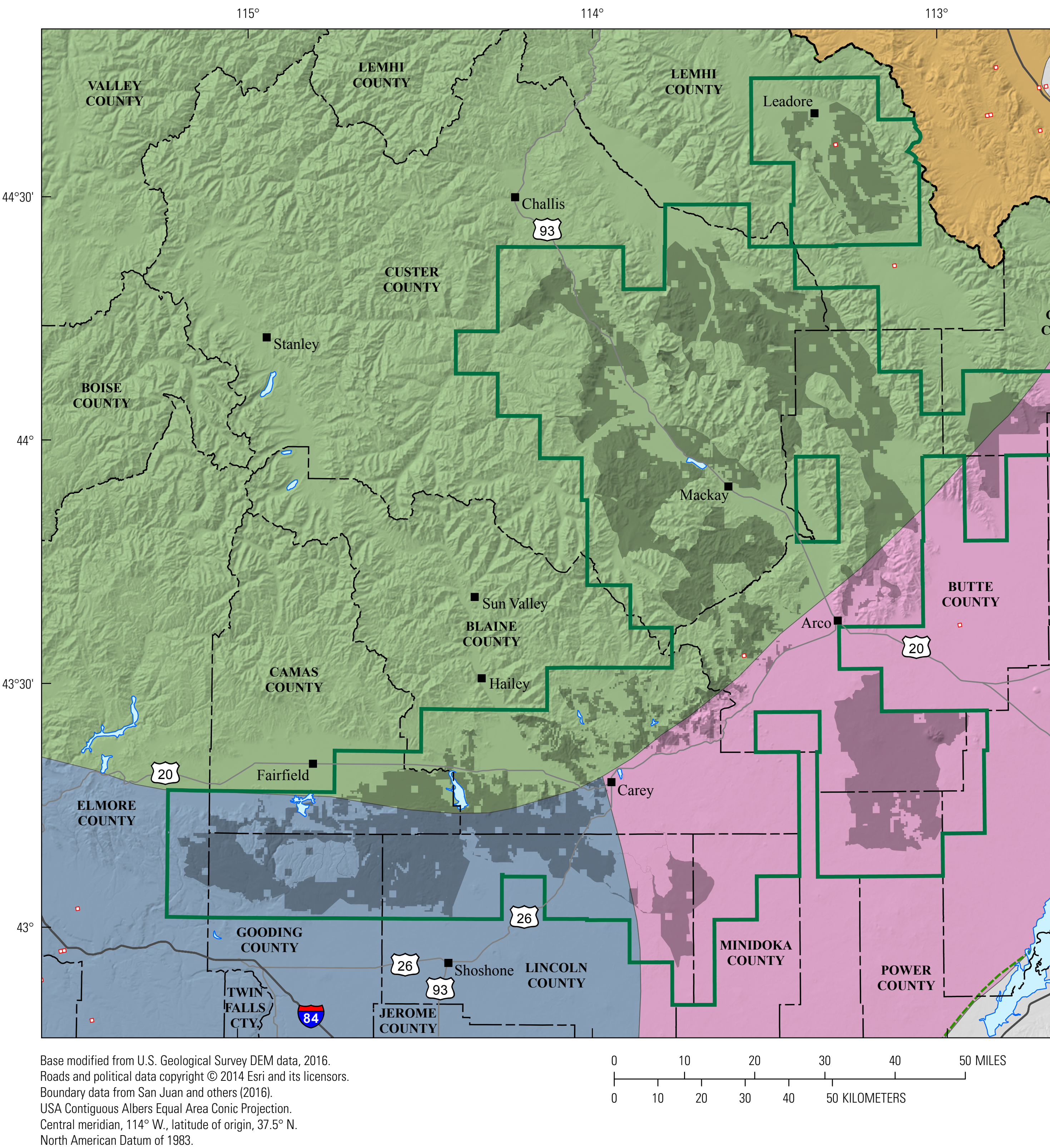
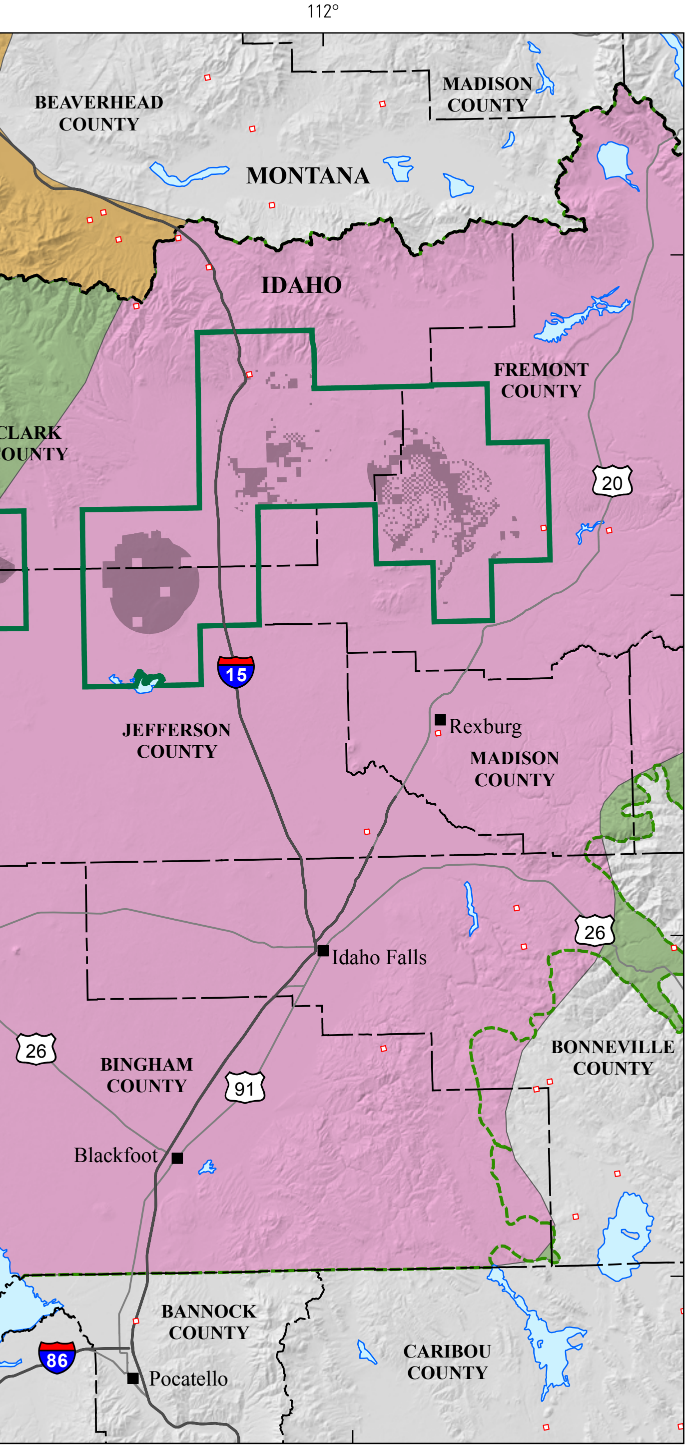
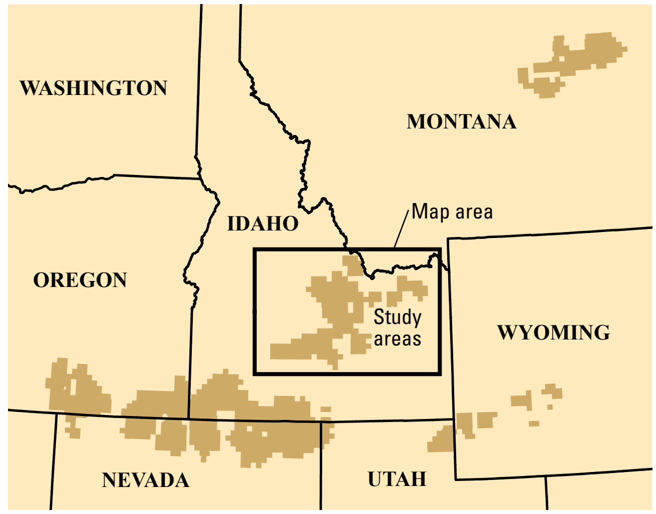


Figure 8. Map of the study area for the North-Central Idaho Sagebrush Focal Area, showing oil and gas exploration and well type (IHS Energy Group, 2016).





EXPLANATION

Oil and gas exploration well status

Number of wells per 1/4-mile square unit (all wells dry)

1 well

Oil and gas plays

Montana thrust belt

Miocene Lacustrine (Lake Bruneau)

Pre-Miocene (Non-quantitative)

Geologic province

Idaho-Snake River downwarp province

Idaho-Snake River downwarp province boundary

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

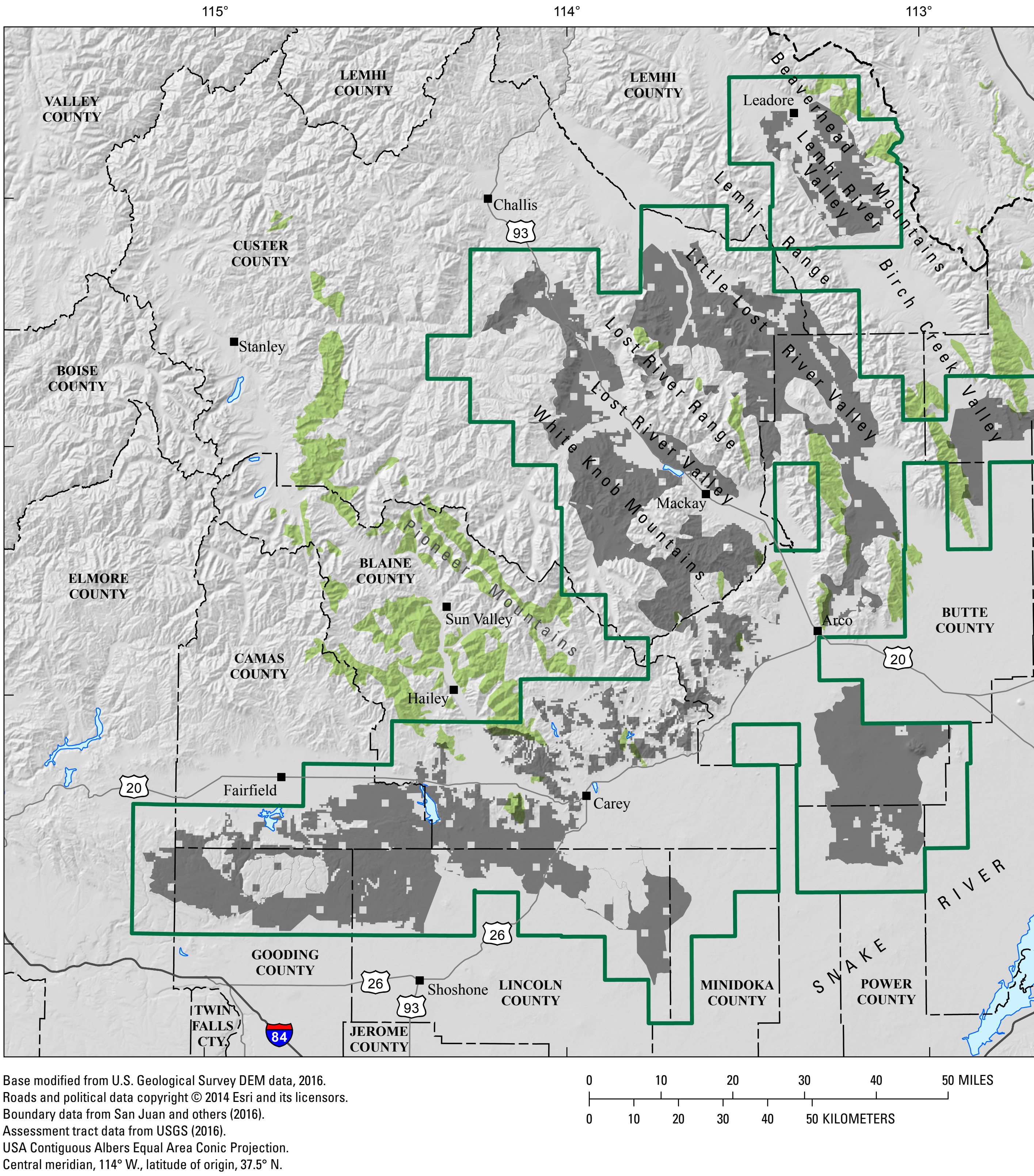
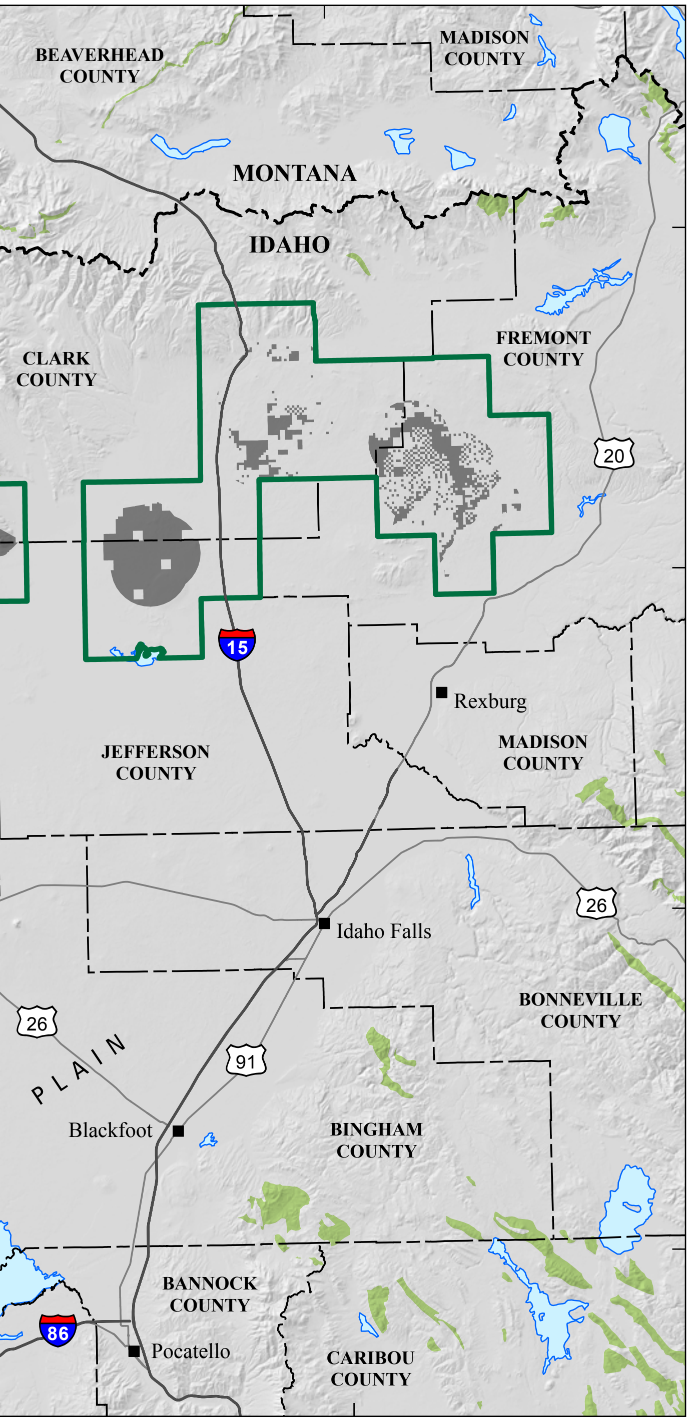
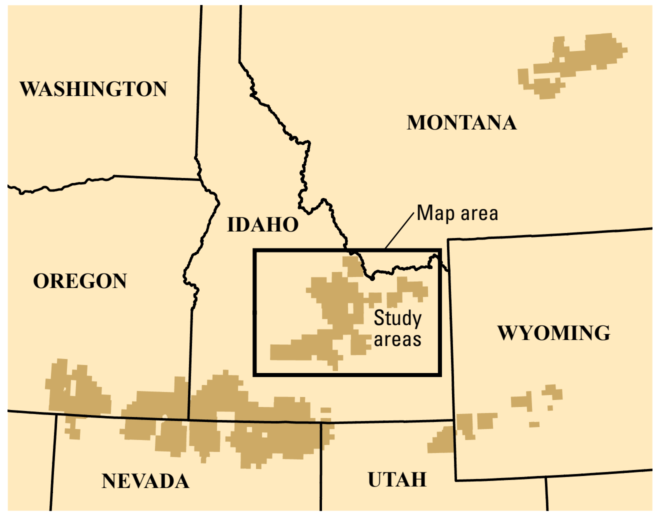


Figure 9. Map showing surface extent of Permian and Mississippian phosphorite and phosphatic shales in the study area for the North-Central Idaho Sagebrush Focal Area (from Bond and others, 1978; Lund and others, 2003; Lewis and others, 2012).





EXPLANATION

Assessment tract type – phosphate

Permissive geology

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

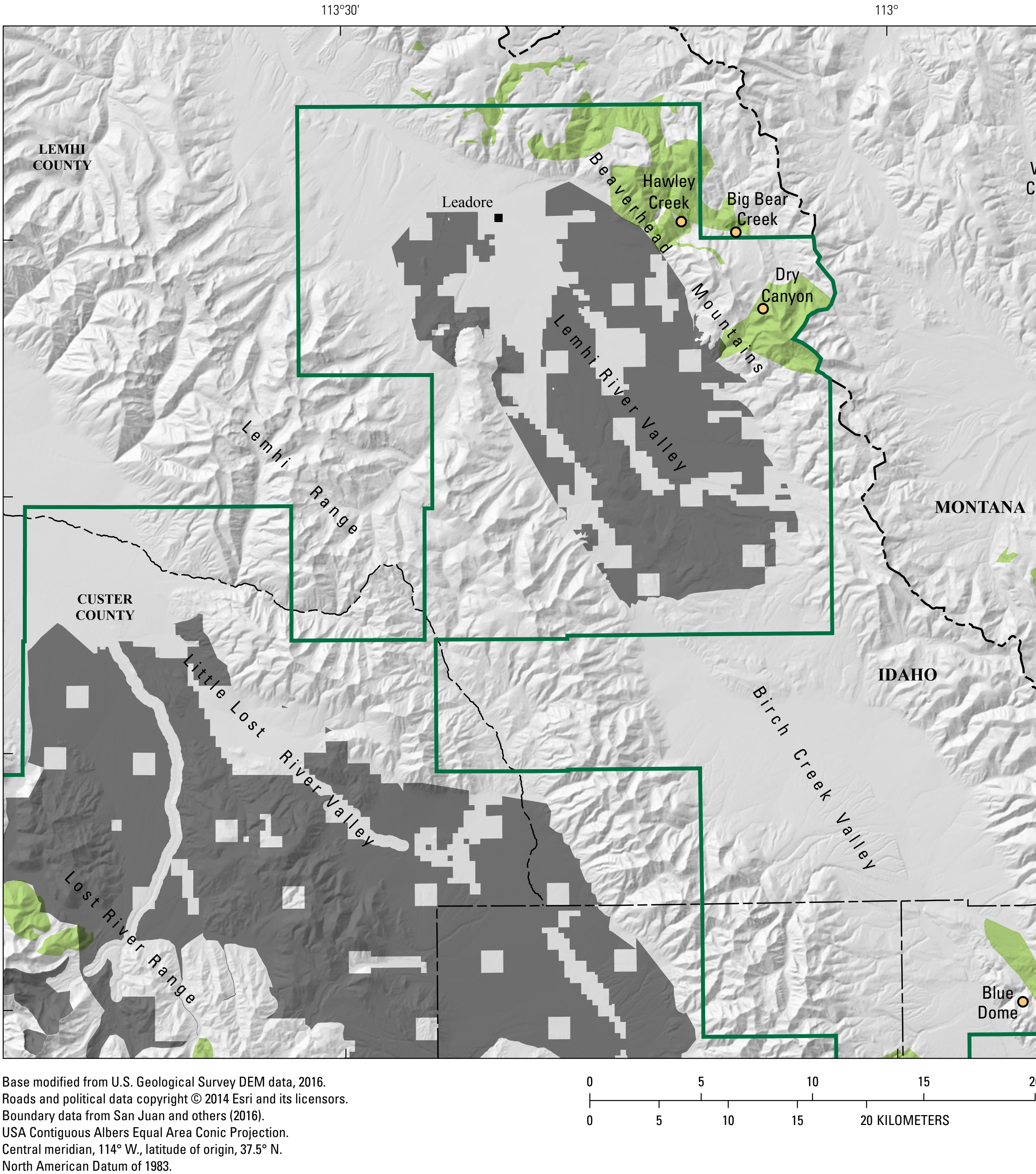
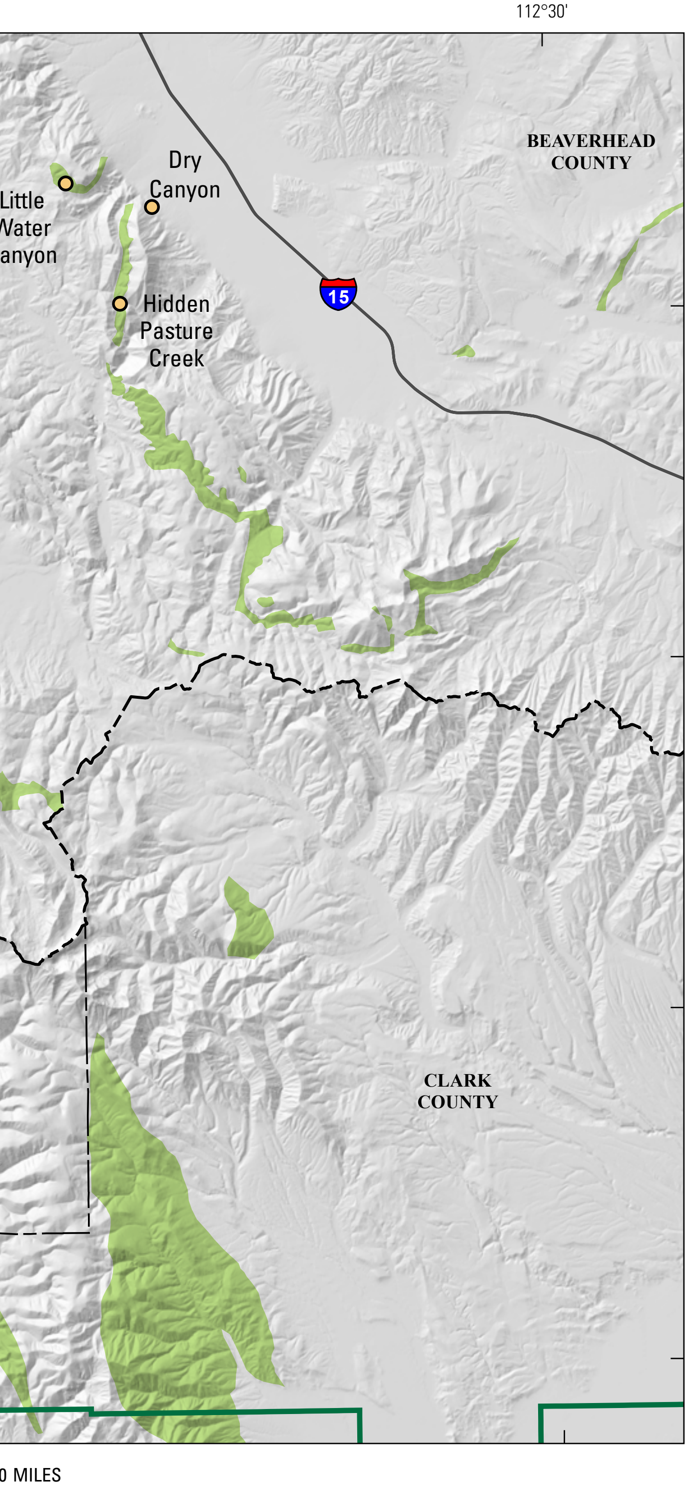
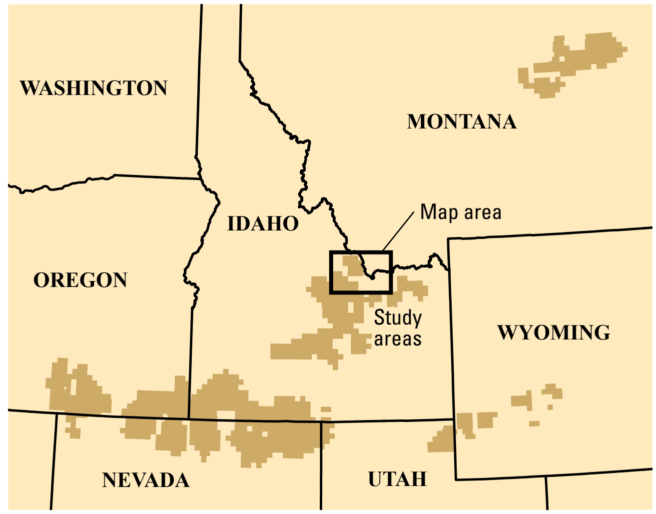


Figure 10. Inset map showing phosphorite, phosphatic shales, and related mineral occurrences in the Phosphoria Formation in the northern part of the study area for the North-Central Idaho Sagebrush Focal Area (Bond and others, 1978; Lund and others, 2003; Lewis and others, 2012).





EXPLANATION

Assessment tract types – phosphate

Permissive geology

Mineral Resource Data System phosphate location

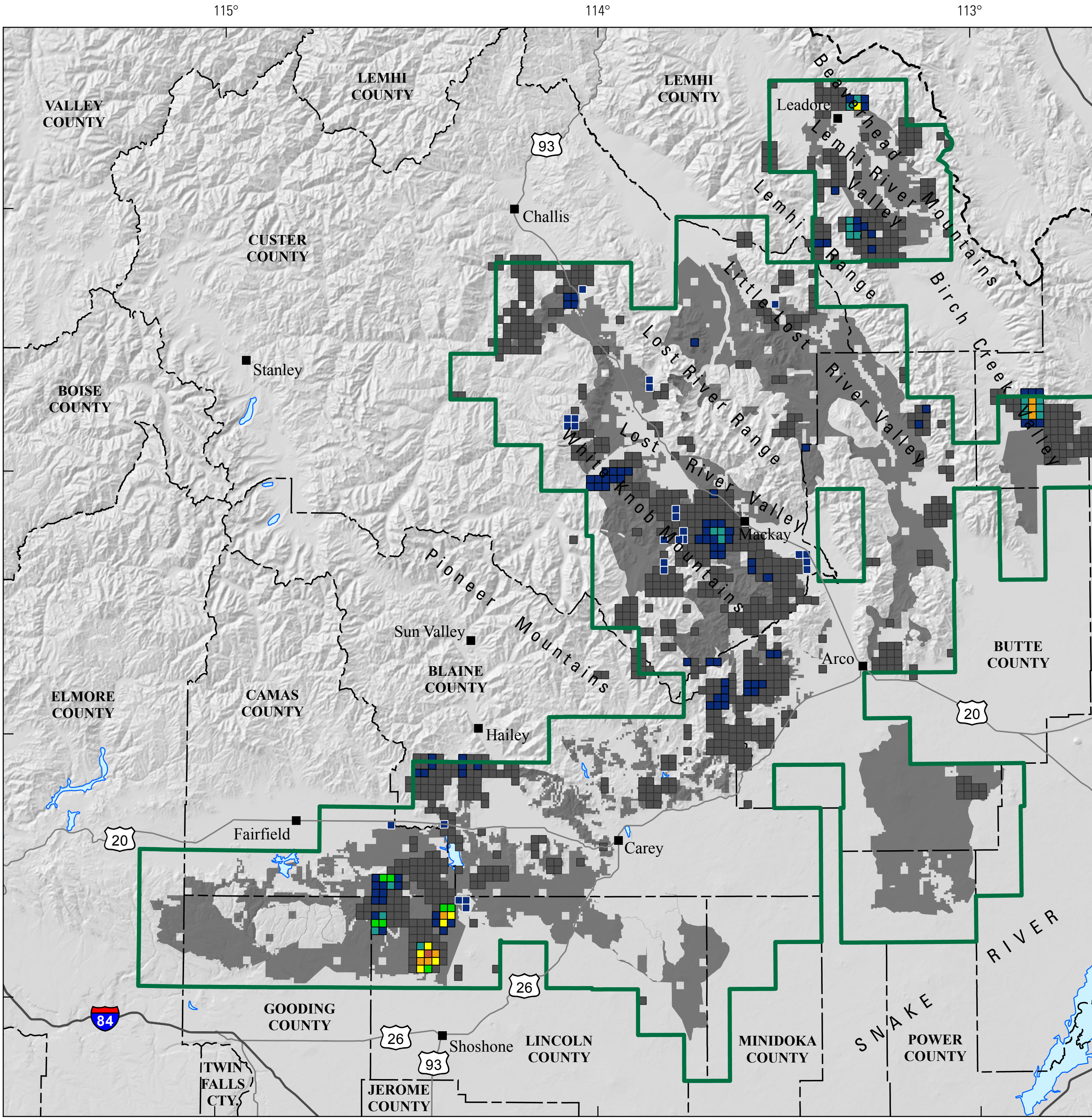
Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries



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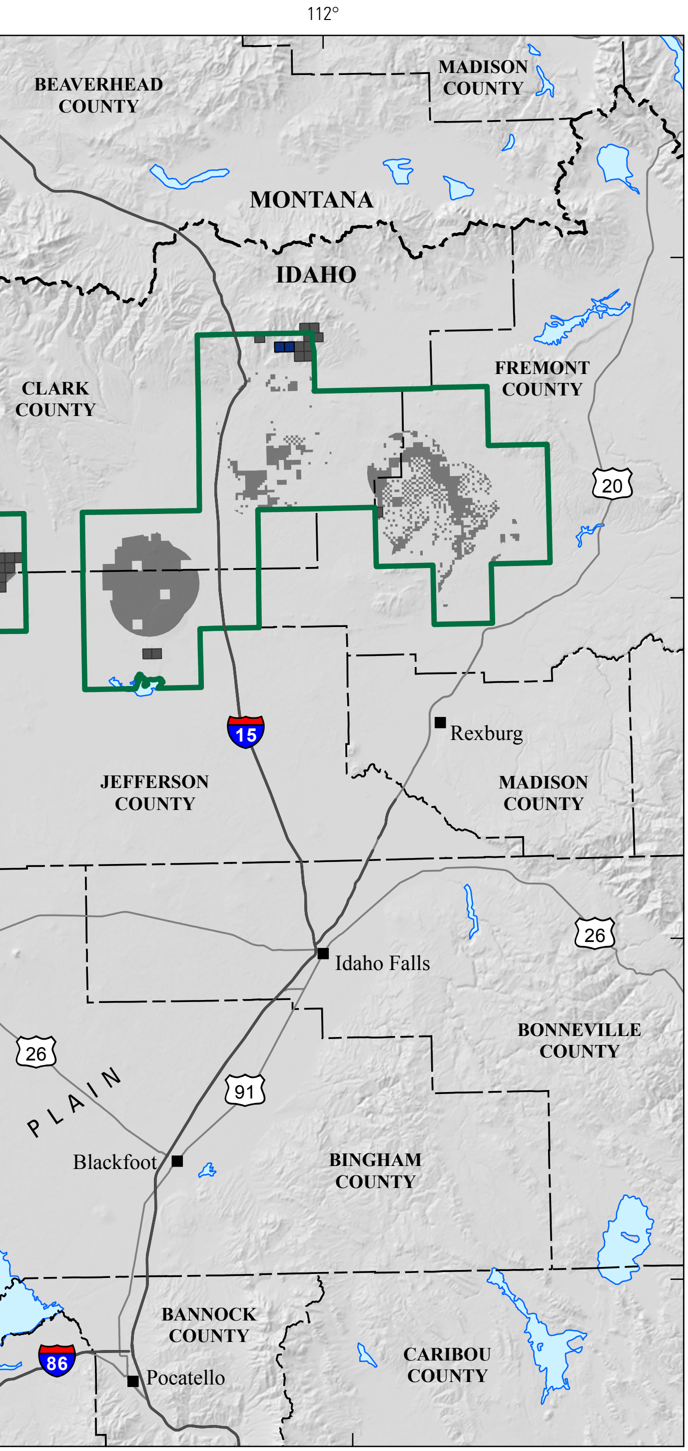
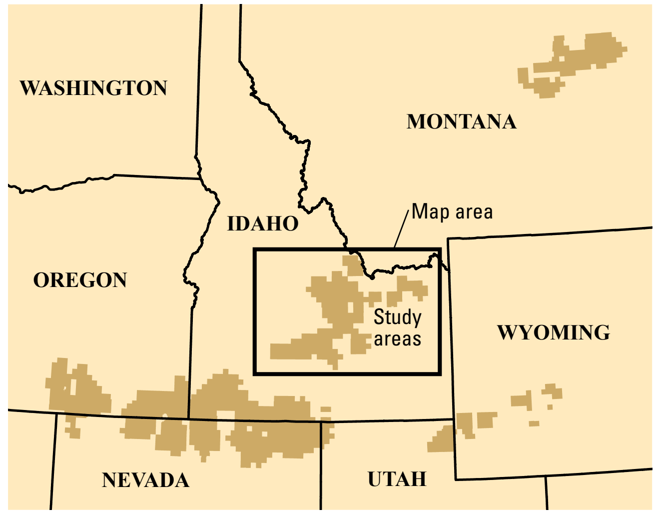
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 11. Map showing active and pending mine claims for locatable commodities in the northern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Active lode and placer mining claims—placers outlined in white

- 1 - 10
- 11 - 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 82
- Closed lode and placer mining claims

Base data

- USGS study area boundary
- Proposed withdrawal areas
- State boundaries
- County boundaries

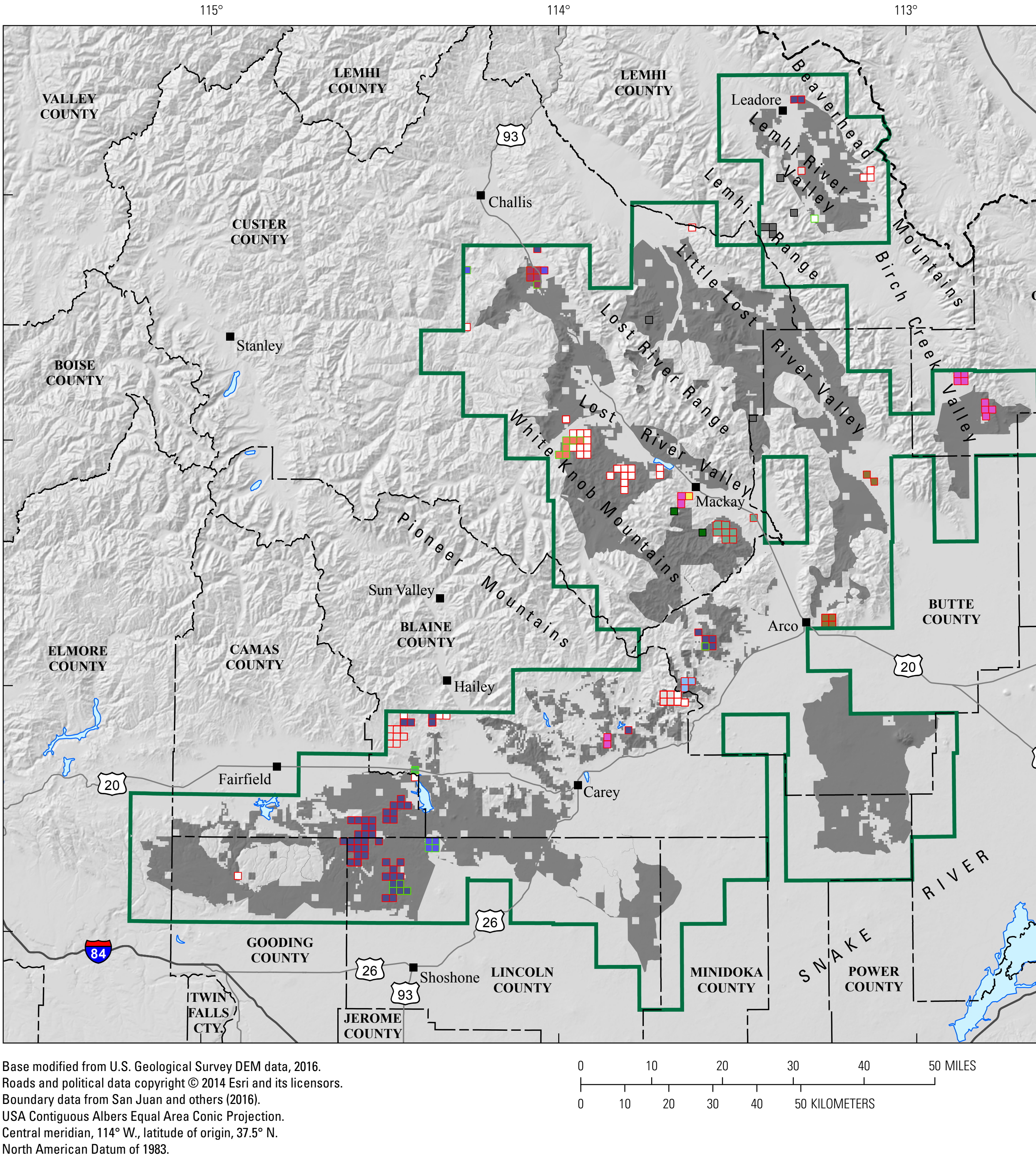
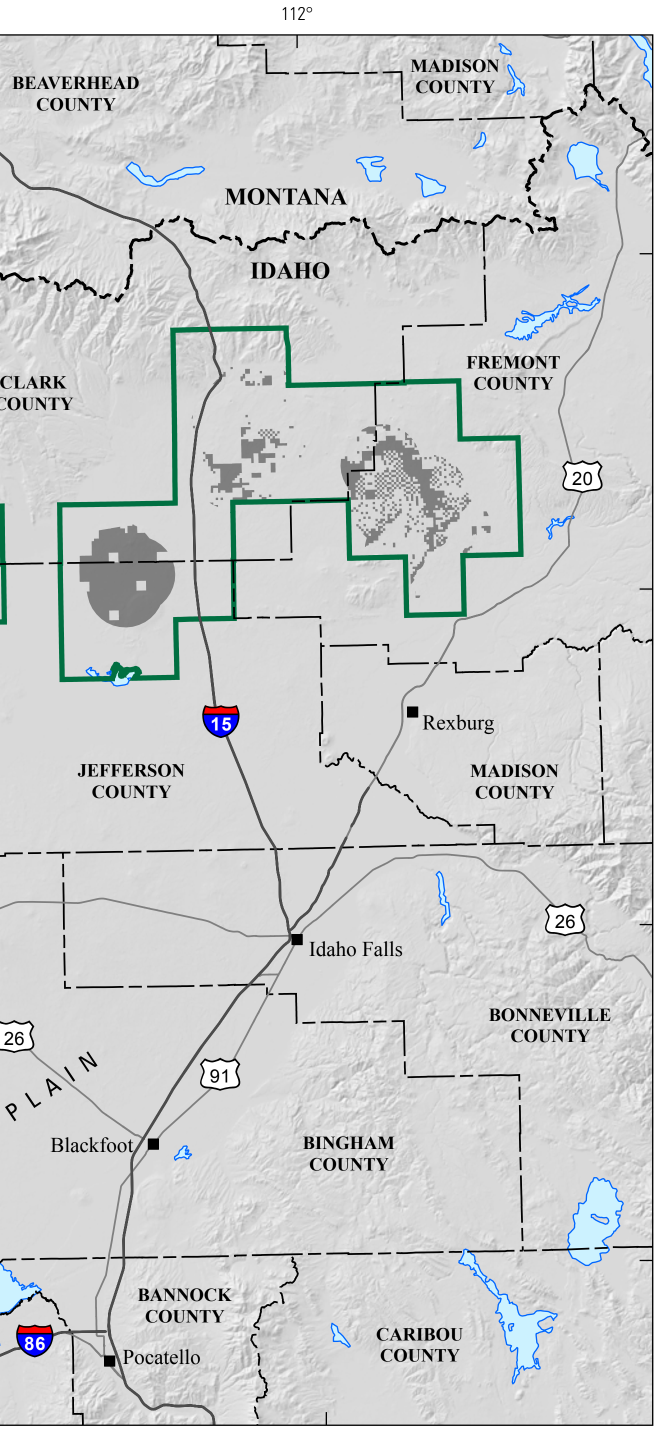
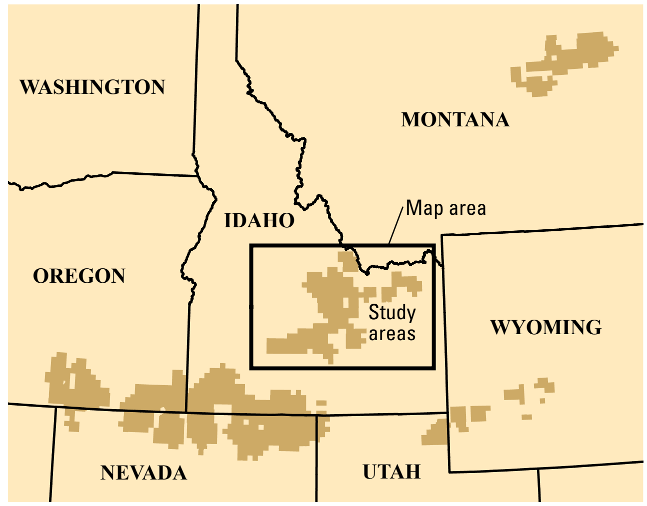


Figure 12. Map showing active and closed or inactive surface management plans in the study area for the North-Central Idaho Sagebrush Focal Area, including 43 Code of Federal Regulations (CFR) 3809 data from the Bureau of Land Management (BLM) (Dicken and San Juan, 2016) and 36 CFR 228 Subpart A plans from the U.S. Forest Service (USFS) (Amanda Kriwox, USFS, written commun., March 10, 2016).



Plan status from U.S. Bureau of Land Management or U.S. Forest Service, 2016
Locatable commodities from Bureau of Land Management, 2016



EXPLANATION

BLM—Plan or notice status

- Authorized or pending
- Closed or expired

BLM—Locatable commodities

- Calcium and limestone
- Base metals
- Gemstone
- Metalliferous minerals
- Precious metals
- Pumice and volcanic cinder
- Silicon and quartzite
- Stone
- Zeolite mineral specimen
- Two or more minerals
- Commodity to be defined
- No commodity specified

U.S. Forest Service—Management plans

- Active
- Inactive, planned inactive, or completed

Base data

- USGS study area boundary
- Proposed withdrawal areas
- State boundaries
- County boundaries

Table 5. Status and number of surface-management plans for locatable minerals in the proposed withdrawal area in the North-Central Idaho Sagebrush Focal Area.

[Source: Dicken and San Juan (2016) for Bureau of Land Management (BLM) 43 Code of Federal Regulations (CFR) 3809 plans; Amanda Kriwox, U.S. Forest Service (USFS), written commun., March 10, 2016, for USFS 36 CFR 228 Subpart A plans. The number of cases is for the complete Public Land Survey System (PLSS) section that includes a proposed withdrawal area. ND, no data]

Permit type	Number of unique cases	Active	Authorized	Pending	Closed	Cancelled	Expired	Rejected	Withdrawn
BLM Plan of operation	10	ND	3	1	6	ND	ND	ND	ND
BLM Notice	55	ND	1	5	47	ND	2	ND	ND
USFS Plan of operation	2	1	2	ND	1	ND	ND	ND	ND
USFS Notice	2	1	ND	ND	1	ND	ND	ND	ND

Table 6. Active surface-management permits summarized by commodity in the proposed withdrawal area in the North-Central Idaho Sagebrush Focal Area.

[Source: Dicken and San Juan (2016) for Bureau of Land Management (BLM) 43 Code of Federal Regulations (CFR) 3809 plans; Amanda Kriwox, U.S. Forest Service (USFS), written commun., March 10, 2016, for USFS 36 CFR 228 Subpart A plans. The number of cases is for the complete Public Land Survey System (PLSS) section that includes a proposed withdrawal area. Gemstones include diamonds, rubies, sapphires, emeralds, jade, opal, and other precious and semi-precious stones]

Commodity	Number of active notices	Number of active plans of operations
Gemstone, semi-precious opal	1	0
Gold	1	0
Gold, lode	2	0
Gold, silver	0	1
None	1	0
Pumice	0	1
Stone, tufa	0	1
To be defined	1	0
Uncommon variety	0	2
Zeolites	0	2

Exploration and Mining Activities

Past Mining Activity

An initial estimate of past mining activity levels was made by summarizing the numbers of mining related features shown on USGS topographic maps of the study area (Fernette and others, 2016b). There are 1,809 mine features shown on USGS 7.5 minute topographic maps of the study area. Of those that can be identified by type, 307 are adits, 82 are mine shafts, 23 are open-pit mines, and 1,105 are prospect pits. These kinds of features (most commonly associated with mining of locatable minerals) give a general indication of the extent of past mining activity in the study area.

A second estimate of past mining activity was made by tabulating mines with a status of “producer” and “past producer” from the USGS Mineral Resource Data System (MRDS) database (U.S. Geological Survey, 2005). The MRDS database contains 185 records in the study area that are reported as “producer” or “past producer.” These records include 129 sites mined for metallic minerals, 5 for industrial minerals, 2 for gemstones, and the remainder for stone, sand, or gravel. The MRDS database contained no production data for these mines, but the records do provide some form of description for the extent and nature of past mining activity.

Recent Mining Activity

Information from mining publications and Idaho Geological Survey annual reports was used to compile locations of active mines in the study area. A total of 124 active mine sites were found in the study area; this includes 1 industrial-minerals operation, 1 metallic-minerals mine, 11 gemstone mines, and 111 sites mining stone, sand, and gravel. The industrial-minerals operation is a zeolite mine and the gemstone mine produces agate and jasper. The metallic-minerals mine is the Champagne Creek gold-silver mine that has an active reclamation permit but is no longer in production.

Mine Production Data

Production data are compiled for the study area and for the BLM proposed withdrawal area. The locations, commodities of interest, mineral deposit type, and activity status for the occurrences with available production data are shown in table 7. The primary source used herein for production data is the Idaho Geological Survey Mines and Prospects database (Mitchell and others, 2015). This database contains production data summarized from Bureau of Mines sources, which were typically confidential. To address the confidentiality issue and make some form of data available, the Idaho Geological Survey dataset (Mitchell and others, 2015) presented value ranges rather than quoted values. For the study area, the data ranges were reduced to single numbers by compiling the lowest value in the data range. This means that the majority of the data in the compilation represents minimum production values. Total production data for the study area and for the BLM proposed withdrawal areas are summarized in table 8.

Table 7. Locations, commodities, deposit types, and activity status for mineral occurrences in the study area for the North-Central Idaho Sagebrush Focal Area for which production data are available.

[Data from Fernette and others (2016a); significant deposits based on definitions in Spanski (2004). NAD 83, North American Datum of 1983]

Site name	Site type	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)	Commodities	Significant deposit	Deposit type	Active within 10 years	Resource data source and production information
Allie Mine	Mine	–113.28	44.45	Au, Ag, Cu, Pb	No	No data	No	Production records
Athaleen	Mine	–113.30	44.48	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Automatic Mine	Mine	–113.13	44.11	Cu	No	Polymetallic veins	No	Production records
Baby Joe	Mine	–113.31	44.70	Au, Ag, Cu, Pb	No	No data	No	Production records
Badger Creek Mine	Mine	–113.12	44.10	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Badger King Mine	Mine	–113.15	44.10	Ag, Pb	No	Polymetallic veins	No	Production records
Bartlett Ridge	Exploration	–113.94	43.99	Agate	No	No data	Yes	No data
Bell Mountain Group	Mine	–113.25	44.23	Au, Ag, Cu, Pb	No	No data	No	Production records
Big John	Mine	–114.36	43.30	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Bighorn Mine	Mine	–113.02	44.01	Au, Ag, Pb	No	Polymetallic replacement	No	Production records
Black Daisy Mine	Mine	–113.70	43.90	Au, Ag, Cu, Zn, Pb	No	No data	No	Production records
Blue Bird Mine	Mine	–113.67	43.89	Au, Ag, Cu, Zn, Pb	No	Zn-Pb skarn	No	Production records
Bowerman Mine	Mine	–115.11	43.24	Au, Ag	No	Polymetallic veins	No	Production records
Brown Bull Mine	Mine	–113.32	44.47	Au, Ag, Cu, Pb	No	No data	No	Production records
Bunting Mine	Mine	–113.14	44.10	Au, Ag, Cu, Pb	No	No data	No	Production records
Butte-Antelope Mine	Mine	–113.66	43.59	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Camas Mine	Mine	–114.47	43.41	Au, Ag, Cu, Pb	Yes	Polymetallic veins	No	Production records
Carrie Cody	Mine	–113.31	44.46	Au, Ag, Cu, Pb	No	No data	No	Production records
Champagne Creek Mine	Mine, exploration	–113.56	43.59	Au, Ag, Cu, Pb, Zn	Yes	No data	Yes	Production records
Champion Group	Mine	–113.67	43.86	Au, Ag, Cu, Pb, Zn	No	Zn-Pb skarn	No	Production records
Cleopatra	Mine	–113.14	44.10	Au, Ag, Cu, Pb	No	No data	No	Production records
Copper Basin Mine	Mine	–113.81	43.80	Au, Ag, Cu, Pb	No	Cu skarn	No	Production records

Table 7. Locations, commodities, deposit types, and activity status for mineral occurrences in the study area for the North-Central Idaho Sagebrush Focal Area for which production data are available.—Continued

[Data from Fernette and others (2016a); significant deposits based on definitions in Spanski (2004). NAD 83, North American Datum of 1983]

Site name	Site type	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)	Commodities	Significant deposit	Deposit type	Active within 10 years	Resource data source and production information
Copper Carbonate	Mine	–113.35	44.74	Ag, Cu	No	No data	No	Production records
Copper Mountain Mine	Mine	–113.03	44.03	Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Copper Queen	Mine	–113.62	43.51	Ag, Cu, Pb	No	No data	No	Production records
Copper Queen Mine	Mine	–113.72	43.88	Au, Ag, Cu, Pb, Zn, W	No	Cu skarn	No	Production records
D. Day	Mine	–114.46	43.46	Au, Ag, Cu, Pb	No	No data	No	Production records
Diamond Prospect	Mine	–113.64	43.50	Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Dirigo	Mine	–113.33	44.71	Ag, Cu, Pb	No	No data	No	Production records
Dorthy Mine	Mine	–113.28	44.45	Au, Ag, Pb	No	Polymetallic replacement	No	Production records
Doughboy Mine	Mine	–113.70	43.91	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
East Fork Road Prospect 1A	Exploration	–114.29	44.22	Gravel, rip rap	Unknown	No data	Yes	No data
Edres Mine	Mine	–114.32	43.44	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Ella Mine	Mine	–113.57	43.60	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Empire Mine (Sultana)	Mine, exploration	–113.67	43.89	Au, Ag, Cu, Pb, Zn	Yes	Cu skarn	Yes	Production records, resource data
Galena	Mine	–113.36	44.72	Ag, Pb	No	No data	No	Production records
Gamebet Claim Group	Mine	–113.93	43.71	Ag, Cu	No	Cu skarn	No	Production records
George Washington Nos. 1–4	Mine	–113.71	43.84	Au, Cu, Pb	No	Zn-Pb skarn	No	Production records
Glengaril	Mine	–114.43	43.44	Au, Ag, Cu, Pb	No	No data	No	Production records
Grand View Canyon	Exploration	–114.04	44.35	Gravel	Unknown	No data	Yes	No data
Groom's Democrat	Mine	–113.31	44.48	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Hard Scrabble	Mine	–113.32	44.47	Au, Ag, Cu, Pb	No	No data	No	Production records
Hidden Treasure	Mine	–114.34	43.43	Au, Pb	No	No data	No	Production records
High Desert Agate	Exploration	–113.92	44.01	Agate	Unknown	No data	Yes	No data

Table 7. Locations, commodities, deposit types, and activity status for mineral occurrences in the study area for the North-Central Idaho Sagebrush Focal Area for which production data are available.—Continued

[Data from Fernette and others (2016a); significant deposits based on definitions in Spanski (2004). NAD 83, North American Datum of 1983]

Site name	Site type	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)	Commodities	Significant deposit	Deposit type	Active within 10 years	Resource data source and production information
Hill Billy	Mine	–114.33	43.44	Au, Pb	No	No data	No	Production records
Hillside Prospect	Mine	–114.28	43.45	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Hilltop Mine	Mine	–113.31	44.48	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Hornsilver Mine	Mine	–113.56	43.59	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Horseshoe Mine	Mine	–113.68	43.89	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Hub Group	Mine	–113.61	43.51	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Jennie R. Mine	Mine	–114.42	43.41	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Jeppeson	Mine	–112.84	44.13	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Jimmy Smith Road Prospect	Exploration	–114.39	44.16	Sand, gravel	Unknown	No data	Yes	No data
Joe Jump Basin	Exploration	–114.29	44.19	Sand, gravel	Unknown	No data	Yes	No data
Jumbo Deposit	Mine	–113.31	44.48	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	No records
Kimmel	Mine	–113.30	44.70	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Lady Franklin	Mine	–113.30	44.45	Au, Ag, Cu, Pb	No	No data	No	Production records
Lark Mine	Mine	–114.27	43.43	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Latest Out Mine	Mine	–113.29	44.45	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Lead Belt Mine	Mine	–113.66	43.60	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Leadville Property	Exploration	–113.30	44.70	Au, Ag	No	No data	Yes	No data
Lee Gulch Prospect	Mine	–114.32	43.45	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Liberty Gem Mine	Mine	–114.43	43.45	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Little Hill Mine	Mine	–113.28	44.47	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Lone Pine Creek Flagstone	Exploration	–114.13	44.34	Decorative rock, building stone, flagstone	Unknown	No data	Yes	No data
Long Valley	Exploration	–112.84	44.12	Cu, Zn, Pb	No	No data	Yes	No data
Lost Cabin	Mine	–113.21	44.30	Au, Ag, Cu, Pb	No	No data	No	Production records

Table 7. Locations, commodities, deposit types, and activity status for mineral occurrences in the study area for the North-Central Idaho Sagebrush Focal Area for which production data are available.—Continued

[Data from Fernette and others (2016a); significant deposits based on definitions in Spanski (2004). NAD 83, North American Datum of 1983]

Site name	Site type	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)	Commodities	Significant deposit	Deposit type	Active within 10 years	Resource data source and production information
Lucky Boy	Mine	–114.41	43.43	Au, Ag, Cu, Pb	No	No data	No	Production records
Martha Mine	Mine	–113.28	44.45	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Martin Property Mine	Mine	–113.59	43.48	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Mattair-Powell Prospect	Mine	–114.39	43.35	Au, Ag, Pb	No	No data	No	Production records
Moonstone	Exploration	–114.44	43.09	Au	Yes	No data	Yes	Resource data
Mountain Boy Mine	Mine	–113.31	44.45	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Murphy	Mine	–113.30	44.45	Ag, Cu, Pb	No	No data	No	Production records
Nipper	Mine	–113.15	44.10	Au, Ag, Pb	No	Polymetallic replacement	No	Production records
Oriental Mine	Mine	–114.42	43.43	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Pandora Prospect	Mine	–113.67	43.51	Au, Ag, Cu, Pb	No	Polymetallic replacement	No	Production records
Paymaster Mine	Mine	–113.66	43.48	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Peacock Mine	Mine	–113.40	44.73	Au, Ag, Cu, Pb	No	No data	No	Production records
Pittsburgh-Idaho Mine	Mine	–113.28	44.45	Au, Ag, Cu, Pb, Zn	Yes	Polymetallic replacement	No	Production records
Portuguese Creek	Exploration	–114.57	43.14	Au, PGE, REE	Unknown	No data	Yes	Resource data
Quick Jump	Exploration	–114.06	44.33	Heulandite; mordenite; calcite; apophyllite; quartz	Unknown	No data	Yes	No data
Red Bird Mine	Mine	–113.13	44.08	Au, Ag, Pb	No	No data	No	Production records
Ridgeway Mine	Mine	–113.31	44.46	Au, Ag, Cu, Pb	No	No data	No	Production records
Rustler Claims Mine	Mine	–114.44	43.42	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Scott Mine	Exploration	–112.78	44.06	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Sentinel Mine	Mine	–113.01	43.98	Au, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Silver And Lead Bell	Mine	–113.67	43.87	Ag, Cu, Pb, Zn	No	No data	No	Production records
Silver Bell Mine	Mine	–113.61	43.50	Au, Ag, Cu, Pb	No	Polymetallic veins	No	Production records
Silver Fissure	Mine	–113.31	44.48	Au, Ag, Cu, Pb	No	No data	No	Production records

Table 7. Locations, commodities, deposit types, and activity status for mineral occurrences in the study area for the North-Central Idaho Sagebrush Focal Area for which production data are available.—Continued

[Data from Fernette and others (2016a); significant deposits based on definitions in Spanski (2004). NAD 83, North American Datum of 1983]

Site name	Site type	Latitude (decimal degrees NAD 83)	Longitude (decimal degrees NAD 83)	Commodities	Significant deposit	Deposit type	Active within 10 years	Resource data source and production information
Silver King Group	Mine	–113.68	43.90	Au, Ag, Cu	No	No data	No	Production records
Silver Moon Mine	Mine	–113.26	44.43	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Snowslide	Mine	–113.32	44.47	Au, Ag, Cu, Pb, Zn	No	No data	No	Production records
Speculator	Mine	–113.67	43.84	Au, Ag, Cu, Pb	No	No data	No	Production records
Spencer Project	Exploration	–112.26	44.39	Au, Ag	No	No data	Yes	No data
St. Louis Mine Property	Exploration	–113.58	43.59	Au, Ag	?	No data	Yes	Resource data
Sunnyside Mine	Mine	–113.25	44.40	Ag, Pb	No	No data	No	Production records
Tiger Group Mine	Mine	–113.68	43.89	Au, Ag, Cu	No	Cu skarn	No	Production records
Treasure Vault Mine	Mine	–114.45	43.43	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Utah-Bellevue Mine	Mine	–114.31	43.44	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Valley View Mine	Mine	–113.14	44.08	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
Warm Creek Prospect	Mine	–113.31	44.30	Au, Ag, Pb, Zn	No	No data	No	Production records
Westlake North Prospect	Mine	–114.35	43.44	Au, Ag, Cu, Pb, Zn	No	Polymetallic veins	No	Production records
White Knob Mine	Mine	–113.68	43.89	Au, Ag, Cu, Pb, Zn	No	Zn-Pb Skarn	No	Production records
Whitebird Mine	Mine	–113.01	44.01	Ag, Pb	No	Polymetallic replacement	No	Production records
Wilbert Mine	Mine	–113.02	43.97	Au, Ag, Cu, Pb, Zn	No	Polymetallic replacement	No	Production records
Yellowstone Mine	Mine	–114.07	43.53	Au, Ag	No	No data	No	Production records

Table 8. Summary of historical metal production from the study area for the North-Central Idaho Sagebrush Focal Area, showing data both for study area and for Bureau of Land Management proposed withdrawal areas, May 6, 2016.

[oz, ounce; lb, pound]

Number of deposits	Short tons ore	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
Study area						
92	8,632,419	194,980	8,409,460	94,739,740	230,328,535	6,340,982
Bureau of Land Management proposed withdrawal areas						
11	3,687,779	61,982	915,034	95,210	2,788,010	3,425,156

There are 110 past-producing mines located in the study area (table 7) that have production records (table 9). For most of these mines, the data were reported as a range of values (Mitchell and others, 2015). In table 9, the lowest values in each range are reported so the data represent the minimum production amounts. Operation of these mines spanned the period from 1885 to 1993, with the majority of production taking place prior to 1950. The mine that operated most recently was the Champagne Creek mine. It produced approximately 48,640 ounces (oz) gold and 471,640 oz silver between 1989 and 1992. Prior to that, the mine produced 2.9 million pounds (lb) zinc and 1.5 million lb lead, in addition to gold, silver, and copper. The mines with the most significant production were the Copper Queen, Empire, Hilltop, Horseshoe, Latest Out, Pittsburgh-Idaho, White Knob, and Wilbert Mines, all of which operated prior to 1981.

Table 9. Production data, including years of operation, commodities, and amounts produced at mines in the study area for the North-Central Idaho Sagebrush Focal Area for which such data are available.

[Data from Fernette and others (2016a). Numbers ending in “1”, “01”, or “ 001” are the lower limit of range breaks. oz, ounce; lb, pound; —, no data]

Name	Production		Commodities	Short tons ore	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
	Started	Ended							
Allie Mine	1911	1953	Au; Ag; Cu; Pb	2,576	2,477	1,668	373	9,482	—
Athaleen	1917	1919	Au; Ag; Zn; Cu; Pb	—	1	1,001	1,001	50,001	51
Automatic Mine	1907	1907	Cu	—	—	—	10,001	—	—
Baby Joe	1923	1923	Au; Cu; Ag; Pb	—	1	1,001	101	50,001	—
Badger Creek Mine	1910	1948	Au; Cu; Ag; Pb	2,502	—	75,232	—	1,851,881	—
Badger King Mine	1917	1947	Ag; Pb	—	—	51	—	501	—
Bell Mountain Group	1932	1933	Au; Ag; Pb; Cu	—	1	1	5,001	101	—
Big John	1940	1940	Au; Cu; Zn; Ag; Pb	—	1	501	51	5,001	101
Bighorn Mine	1911	1913	Au; Ag; Pb	—	1	1,001	—	50,001	—
Black Daisy Mine	1907	1909	Au; Ag; Zn; Cu; Pb	—	1	1,001	1,001	50,001	51
Blue Bird Mine	1918	1939	Au; Ag; Cu; Pb; Zn	1,530	23	16,426	12,595	509,165	3,111
Bowerman Mine	1914	1915	Au; Ag	41	1	1,416	—	—	—
Brown Bull Mine	1916	1949	Au; Cu; Ag; Pb	180	—	14,800	3,570	115,000	—
Bunting Mine	1912	1912	Au; Cu; Ag; Pb		1	101	1	10,001	—
Butte-Antelope Mine	1965	1975	Au; Cu; Ag; Pb; Zn	254	1	9,185	1,389	25,574	4,850
Camas Mine	1886	1943	Au; Ag; Cu; Pb	275,578	90,826	385,005	—	—	—
Carrie Cody	1901	1901	Au; Ag; Cu; Pb	—	1	501	501	1,001	—
Champagne Creek Mine	1886	1993	Au; Ag; Cu; Pb; Zn	3,687,779	61,475	850,974	80,000	1,576,000	2,922,000
Champion Mine	1908	1955	Au; Ag; Cu; Pb; Zn	2,579	23	7,668	20,473	634,216	150,094
Cleopatra	1909	1916	Au; Ag; Cu; Pb	—	1	5,001	51	100,001	—
Copper Basin Mine	1912	1953	Au; Ag; Cu; Pb	6,174	103	17,985	723,404	2,662	—
Copper Carbonate	1929	1929	Ag; Cu	—	—	1	501	—	—
Copper Mountain Mine	1941	1941	Ag; Cu; Pb	—	—	51	10,001	101	—
Copper Queen	1939	1940	Pb; Ag; Cu	—	—	501	5,001	1	—
Copper Queen Mine	1909	1954	Au; Ag; Cu; Pb; Zn	—	101	100,001	100,001	8,000,001	2,000,001
D. Day	1935	1935	Au; Cu; Ag; Pb	—	1	101	51	1,001	—
Diamond Prospect	1945	1945	Ag; Cu; Pb	—	—	51	101	1,001	—
Dirigo	1929	1929	Ag; Cu; Pb	—	—	101	101	10,001	—

Table 9. Production data, including years of operation, commodities, and amounts produced at mines in the study area for the North-Central Idaho Sagebrush Focal Area for which such data are available.—Continued

[Data from Fernette and others (2016a). Numbers ending in “1”, “01”, or “ 001” are the lower limit of range breaks. oz, ounce; lb, pound; —, no data]

Name	Production		Commodities	Short tons ore	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
	Started	Ended							
Dorthy Mine	1910	1910	Au; Ag; Pb	—	1	1	—	501	—
Doughboy Mine	1919	1968	Au; Cu; Zn; Ag; Pb	1,069	8	31,701	1,984	637,135	3,968
Edres Mine	1902	1907	Au; Ag; Cu; Pb; Zn	2,205	1	5,001	501	100,001	10,001
Ella Mine	1906	1906	Au; Cu; Ag; Pb	10,031	0	119,954	0	1,604,963	1,410,957
Empire Mine	1902	1982	Au; Ag; Cu; Pb; Zn	921,077	41,431	1,294,531	61,689,291	24,110	908,078
Galena	1939	1940	Ag; Pb	—	—	101	5,001	—	—
Gamebet Claim Group	1957	1957	Ag; Cu	—	—	80	4,850	—	—
George Washington Nos. 1–4	1949	1949	Ag; Cu; Pb	—	—	1	1	1,001	—
Gilmore	1910	1929	Au; Ag; Pb; Zn	412,148	1	154	—	9,892	23,492
Glengaril	1922	1922	Au; Cu; Ag; Pb	—	1	501	1	501	—
Groom’s Democrat	1901	1901	Au; Ag; Cu; Pb; Zn	—	51	5,001	5,001	100,001	50,001
Hard Scrabble	1910	1910	Au; Ag; Cu; Pb	—	1	101	101	1,001	—
Hidden Treasure	1908	1908	Ag; Pb	—	—	1,001	—	50,001	—
Hill Billy	1956	1956	Ag; Pb	—	—	51	—	1,001	—
Hillside Prospect	1911	1911	Au; Cu; Ag; Pb	—	1	1,001	51	10,001	—
Hilltop Mine	1915	1968	Au; Ag; Cu; Pb; Zn	9,186	1,836	127,109	62,977	2,781,103	86,866
Hornsilver Mine	1937	1946	Au; Ag; Cu; Pb; Zn	15,653	1,964	56,424	66	1,121,056	2,050,927
Horseshoe Mine	1916	1971	Au; Ag; Cu; Pb; Zn	16,810	111	129,686	257,945	3,896,442	1,113,821
Hub Group	1884	1884	Au; Ag; Cu; Pb	551	209	104,490	—	44,092	—
Jennie R. Mine	1883	1908	Au; Cu; Ag; Pb	342	4	325	205	102,515	3,212
Jeppeson	1968	1969	Au; Cu; Ag; Zn; Pb	—	1	1,001	101	100,001	5,001
Jumbo Deposit	1910	1910	Au; Cu; Ag; Pb	220	1	501	101	10,001	—
Kimmel	1917	1929	Au; Cu; Ag; Pb	13,448	—	3,334	—	268,875	—
Lady Franklin	1941	1941	Au; Cu; Ag; Pb	—	1	501	101	10,001	—
Lark Mine	1919	1927	Au; Cu; Ag; Pb	—	1	10,001	501	100,001	—
Latest Out Mine	1908	1953	Au; Ag; Cu; Pb; Zn	90,004	2,257	1,619,656	—	61,200,957	8,994,850
Lead Belt Mine	1908	1941	Au; Cu; Ag; Pb	2,061	48	25,254	3,990	579,815	—
Lee Gulch Prospect	1916	1916	Au; Cu; Ag; Pb	—	1	101	1	1,001	—
Liberty Gem Mine	1931	1940	Au; Ag; Cu; Pb; Zn	—	101	10,001	5,001	100,001	100,001
Little Hill Mine	1905	1905	Au; Ag; Cu; Pb; Zn	—	1	1,001	1,001	100,001	1,001
Lost Cabin	1938	1938	Ag; Cu; Pb	—	—	1	1	1,001	—
Lucky Boy	1884	1884	Au; Cu; Pb; Ag	—	—	1,001	51	101	—
Martha Mine	1913	1949	Au; Ag; Cu; Pb	35,005	8,635	154,338	62,949	7,327,780	—
Martin Property Mine	1922	1927	Au; Cu; Ag; Pb	—	1	1,001	101	5,001	—

Table 9. Production data, including years of operation, commodities, and amounts produced at mines in the study area for the North-Central Idaho Sagebrush Focal Area for which such data are available.—Continued

[Data from Fernette and others (2016a). Numbers ending in “1”, “01”, or “ 001” are the lower limit of range breaks. oz, ounce; lb, pound; —, no data]

Name	Production		Commodities	Short tons ore	Au (oz)	Ag (oz)	Cu (lb)	Pb (lb)	Zn (lb)
	Started	Ended							
Mattair-Powell Prospect	1935	1938	Au; Ag; Pb	—	1	101	—	101	—
Mountain Boy Mine	1916	1962	Au; Ag; Cu; Pb; Zn	1,286	116	9,225	—	685,738	6,500
Murphy	1912	1912	Ag; Cu; Pb	—	—	101	101	5,001	—
Nipper	1934	1934	Au; Ag; Pb	—	—	1	—	101	—
Oriental Mine	1912	1912	Au; Cu; Ag; Pb	22	1	101	—	101	—
Pandora Prospect	1928	1928	Au; Ag; Cu; Pb	—	1	501	1,001	1,001	—
Paymaster Mine	1941	1947	Au; Ag; Cu; Pb; Zn	13,338	—	21,885	32,408	469,584	1,807,778
Peacock Mine	1951	1951	Au; Ag; Pb; Cu	—	—	—	—	—	—
Pittsburgh-Idaho Mine	1902	1981	Au; Ag; Cu; Pb; Zn	203,887	5,628	2,156,744	667,540	92,342,343	824,994
Red Bird Mine	1884	1948	Au; Ag; Pb	—	—	1,800,000	—	33,000,000	—
Ridgeway Mine	1921	1922	Au; Cu; Ag; Pb	—	1	501	—	10,001	—
Rustler Claims Mine	1950	1950	Au; Ag; Cu; Pb; Zn	2,646	1	1,001	5,001	10,001	10,001
Scott Mine	1888	1925	Au; Cu; Zn; Ag; Pb	1,179	—	5,884	—	1,058,218	23,589
Sentinel Mine	1947	1947	Cu; Pb; Au; Zn	—	—	—	—	50,001	50,001
Silver and Lead Bell	1951	1951	Ag; Cu; Pb; Zn	—	—	101	101	1,001	1,001
Silver Bell Mine	1934	1934	Au; Cu; Ag; Pb	—	1	501	101	10,001	—
Silver Fissure	1911	1911	Au; Cu; Ag; Pb	—	1	501	101	5,001	—
Silver King Group	1909	1909	Au; Ag; Cu	—	1	1	101	—	—
Silver Moon Mine	1939	1940	Au; Ag; Cu; Pb; Zn	—	1	50,001	1,001	50,001	1,001
Snowslide	1939	1940	Au; Cu; Ag; Pb; Zn	—	1	501	101	1,001	1,001
Speculator	1918	1918	Au; Ag; Cu; Pb	—	1	1,001	1,001	50,001	—
Sunnyside Mine	1925	1925	Ag; Pb	—	—	101	—	10,001	—
Tiger Group Mine	1911	1911	Au; Ag; Cu	—	1	1	1,001	—	—
Treasure Vault Mine	1934	1943	Au; Ag; Pb; Zn; Cu	2,094	101	1,001	1,001	5,001	101
Utah-Bellevue Mine	1915	1925	Au; Ag; Zn; Cu; Pb	4,740	608	214,284	22,752	849,396	—
Valley View Mine	1947	1952	Au; Ag; Zn; Cu; Pb	—	1	501	1,001	10,001	101
Warm Creek Prospect	1964	1964	Au; Ag; Pb; Zn	—	1	101	—	101	101
Westlake North Prospect	1916	1916	Au; Ag; Cu; Zn; Pb	—	1	1,001	1,001	10,001	1,001
White Knob Mine	1908	1968	Au; Pb; Zn; Ag; Cu	51,501	409	295,308	252,274	9,455,350	3,436,438
Whitebird Mine	1948	1948	Ag; Pb	—	—	51	—	5,001	—
Wilbert Mine	1906	1950	Au; Cu; Ag; Zn; Pb	148,040	—	500,747	—	45,789,957	—
Yellowstone Mine	1941	1941	Au; Ag	—	1	1	—	—	—

Active Exploration Sites

A total of 18 active exploration sites are identified in the study area; 10 of these sites are for metallic minerals and the remainder for stone, sand, and gravel. Information about active exploration sites is compiled from mining publications and Idaho Geological Survey annual summaries of mining and exploration in Idaho (Fernette and others, 2016a).

Four deposits with resource estimates are present in the study area; three of these are active exploration sites, including the Empire, Moonstone, and Portuguese Creek prospects (table 7). Two of these deposits, Moonstone and Portuguese Creek, lie in areas proposed by BLM for withdrawal from mineral entry. The Moonstone deposit is described as a disseminated gold deposit with an estimated resource of 32,663,164 tons (reported as short tons [2,000 pounds or 907.19 kilograms], unless otherwise noted) and an average grade of 0.405 oz per ton gold based on data from 8 drill holes. The estimated resource is reported to represent 20 percent of the total mineralized zone, which is not fully explored. The Portuguese Creek deposit has an estimated resource of 50,000,000 tons containing platinum, gold and REEs based on data from 12 drill holes. The grade of the mineralization has not been made public. The gold is reportedly found as minute films of native metal on silicate minerals in the olivine-bearing Moonstone rhyolite. A fourth deposit with resource estimates is the Hawley Creek phosphate deposit. As a leasable commodity, phosphate is described above (see Leasable Commodities section). The Hawley Creek deposit is in the study area but outside of the BLM proposed withdrawal area. It is not being actively explored, but has an estimated resource of 308.8 million tons with an average grade of 16.8 weight percent P_2O_5.

Locatable Mineral-Resource Potential

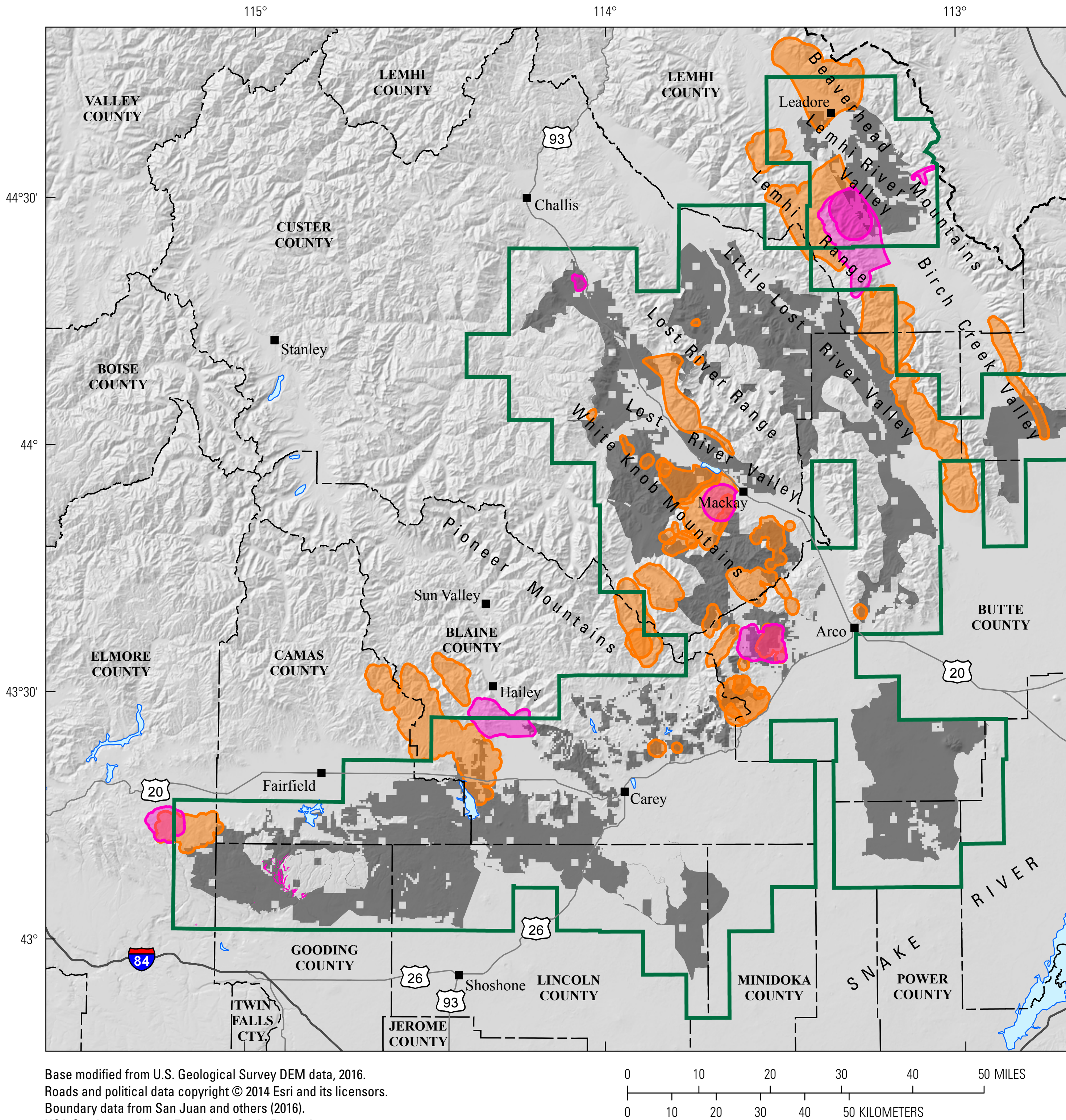
This mineral-resource potential assessment establishes that the study area contains geology permissive for 18 types of mineral deposits. Of these deposit types, available published datasets provide evidence that mineralizing processes or commodity accumulations probably occurred for 12 of the deposit types. Evidence of mineralizing processes (and possibly commodity accumulation) includes anomalous geochemical abundances for certain elements, presence of alteration products from published reports (including Mineral Resources Data System [MRDS] dataset, U.S. Geological Survey, 2005; and United States Mineral Resources [USMIN] dataset, Fernette and others, 2016a) or remote sensing data, evidence of buried plutons from geophysical data, and confirmation of previous exploration or mining activity for appropriate commodities and deposit type (see Day and others [2016] for methodologies). The mineral-resource potential assessment resulted in the designation of 33 geographic tracts having demonstrable, moderate or high potential for locatable mineral resources. When plotted together on the study area map, there is evidence of widespread mineralizing processes active across the northern part of the study area (fig. 13). The mineralizing processes were related to Paleozoic depositional settings as well as to late Paleozoic, Cretaceous, and Eocene orogenic events. Younger mineralizing processes, which are localized in the Snake River Plain (fig. 13), are related to Miocene-Pleistocene volcanism.

Out of the total 18 deposit types for which geology is permissive for their occurrence, evidence of mineralization is not recognized for 6 deposit types. In the absence of evidence for mineralizing processes or commodity accumulations related to these six deposit types, no tracts are drawn. However, the existing evidence for these deposit types is discussed in the text. Multiple digital datasets are used to define the mineral-resource potential assessment tracts as presented by descriptions of each tract in this chapter. The digital datasets, including geologic maps, geochemical data, geophysical (radiometric, aeromagnetic, and gravity) data, remote sensing of alteration minerals, previous assessment tracts, and mineral deposit databases, are integral to the mineral-resource potential assessments. Details about the datasets and their uses in this study are available in San Juan and others (2016) and in appendix 2.

Hydrothermal-Plutonic Mineral System

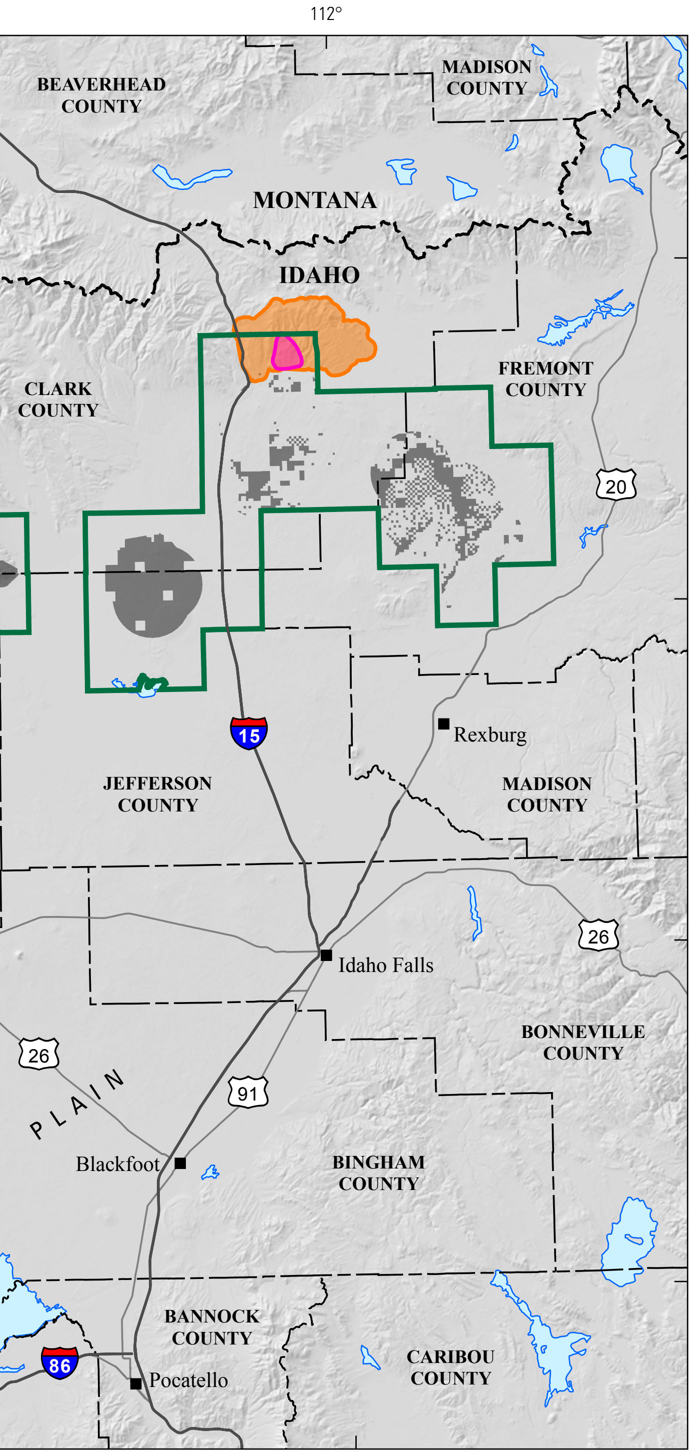
Porphyry-Related Deposit Type

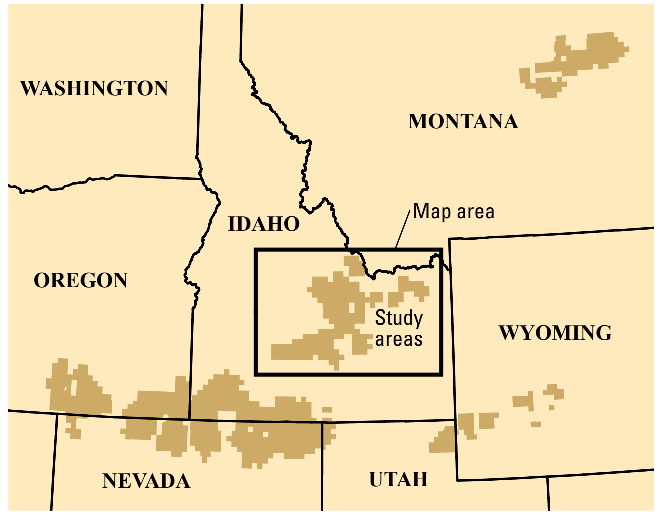
Porphyry copper deposits form in, and are genetically related to, shallowly emplaced, calcalkalic granodioritic to granitic (intermediate to felsic) intrusions. Commodities in this deposit type include copper, molybdenum, gold, and silver. The mineralized porphyry systems form in and around the upper parts of the intrusive systems. Deposits can be zoned with copper- and (or) molybdenum-rich ore zones, featuring barren, low-grade pyritic cores surrounded by pyritic haloes and by peripheral base- and precious-metal bearing veins. Deposits reach about 2 km in size, and metal and alteration haloes extend about 8 km in diameter (John and others, 2010). In general, porphyry copper-molybdenum deposit systems are associated with adjacent skarn and (or) polymetallic-vein deposits of porphyry-related types (John and others, 2010). Where these associated kinds of deposits are probably closely related to or a consequence of porphyry-type mineralization, they are combined. In other cases where the causal relationship is less clear because of distance between occurrences of different forms, lack of data, or lack of a demonstrable porphyry system, other deposit types are more appropriate for vein systems (see polymetallic-vein type, below).



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 13. Map showing the geographic distribution of mineral-resource-potential tracts for all locatable-mineral deposit types ranked moderate or high in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tracts – high and moderate rankings – all deposit types

High potential tract

Moderate potential tract

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

In copper-rich porphyry deposits, copper-bearing minerals are disseminated in host rock as well as in veins and breccia distributed in host rock. The deposits are large but the ore is of relatively low to moderate grade. Host rocks, including the genetically related intrusion and its country rocks, are broadly altered. Copper-rich zones are also commonly Mo-, Au-, and Ag-bearing, possibly with Bi, W, B, and Sr. Peripheral zones are commonly enriched in Pb, Zn, Mn, V, Sb, As, Se, Te, Co, Ba, and Rb. Mercury is present in some deposits. The deposits are also sulfur-rich, with sulfur mainly occurring in the form of pyrite (John and others, 2010).

Low-fluorine stockwork molybdenite deposits are closely related to copper-rich porphyry deposits, form in a similar tectonic setting, and are also large but with low ore grades. These deposits consist of stockwork, molybdenite-bearing quartz veinlets. Molybdenum, Cu, W, and F may be anomalously high in host rocks close to and overlying mineralized zones; anomalously high levels of Pb, Zn, and Ag are in peripheral zones as far as several kilometers distant. Mo, W, F, Cu, Pb, Zn, and Ag may be anomalously high in stream sediments. Molybdenum, tungsten, and lead may be present in heavy mineral concentrates. The deposits are commonly 0.5–3 km in diameter (Taylor and others, 2012).

High-fluorine porphyry molybdenum (Climax-type) deposits related to extension-related rhyolite and granite bodies may also be present near the north edge of the study area (but the names and specific locations are not provided in Ludington and Plumlee, 2009). These deposits are also large, but are relatively high grade for porphyry-type deposits. The deposits are characterized by quartz-molybdenite stockwork veins above and in the top of the intrusive body, and commonly enriched in fluorine, rubidium, nickel, and tantalum (Ludington and Plumlee, 2009).

Permissive Geology and Occurrences in Study Area

A northeast-striking porphyry copper and porphyry molybdenum belt crosses central Idaho into central Montana (Idaho-Montana porphyry belt of Rostad, 1978). In central Idaho, such porphyry deposits are hosted in both the Cretaceous Idaho batholith and the Eocene Challis plutons, showing that mineralizing processes of both Cretaceous and Eocene ages were active (Armstrong and others, 1978; Taylor and others, 2007). The porphyry systems overlie buried Paleoproterozoic juvenile crust in the Great Falls Tectonic Zone (O’Neill and Lopez, 1985) and the mineral endowments may have originated from the basement rocks (Klein and Sims, 2007; Taylor and others, 2007). The porphyry belt extends along the north edge of the study area. Two porphyry deposits included in the belt—the Walton and Blue Jay deposits—are located in in the study area. The porphyry-related resource tracts determined in the present study are related to the Eocene plutons, the predominant age of granites in the study area (fig. 14).

Exploration and Mining History

The tracts defined in the study area have all had exploration, some historic development, and production from deposits identified as porphyry-type mineral occurrences. Many of the occurrences with historic activity were explored or mined for porphyry-related vein or skarn deposits rather than to exploit the occurrences as large-volume, low-grade, porphyry-type mineralized systems.

Resource Assessment Tracts

Blackstone Tract H/D—There is high potential, with certainty level D, for porphyry-related Au-Ag-Cu-Pb-Zn polymetallic-vein deposits in the Blackstone tract (fig. 15), in the upper part of an Eocene pluton. The tract is in the Volcano Mining District, Elmore County, 36 km southwest of Fairfield, Idaho (fig. 1). The tract geometry is based on the location of the Blackstone mine and on exposure of the top of the Eocene granite pluton. The tract is trimmed to extend 1 km into valley fill, accounting for shallow burial of potentially mineralized rock.

The geology of the Blackstone tract is characterized by Cretaceous quartz monzonite and two-mica granite (approximately 90–80 Ma), as well as Eocene granodiorite, quartz monzodiorite, minor diorite, granite, and subvolcanic dacite stocks and dikes (approximately 52–45 Ma). These rocks are partly covered by Miocene rhyolite ignimbrite in the south and by Pliocene-Pleistocene basalt flows in the north. Quaternary-aged unconsolidated alluvium overlies much of the northern part of the tract (Worl and Johnson, 1995).

Mineralization at the Blackstone and Revenue mines (Fernette and others, 2016a; San Juan and others, 2016) in the tract consists of northeast-striking mesothermal silver, telluride, base-metal, and manganese-oxide-bearing veins and stockworks hosted predominantly in Cretaceous granodiorite. However, mineralization is controlled by east-striking down-to-the-north normal faults, and also spatially and temporally associated with east-northeast striking Eocene dikes (Allen, 1952; Bennett, 2001). Alteration includes biotite after hornblende, sericite after plagioclase, and late albite, epidote, magnetite, and specular hematite. Mineralized zones at the Revenue mine contain chalcopyrite, galena, sphalerite, and molybdenite (Bell, 1930).

From 1902 to 1982, the Blackstone mine had intermittent production. A more intense mining effort took place between 1982 and 1988 (Bennett, 2001). Blackstone currently has proven high-grade ore reserves of 35,500 tons of ore with grades of 0.106 oz Au, 23.58 oz Ag, 4.94 weight percent Cu, 1.5 weight percent Mn, and 8.5 weight percent Zn per ton; low leach-grade ore reserves of 700,000 tons of ore with grades of 0.078 oz Au, 2.11 oz Ag, 0.2 weight percent Cu, 2 weight percent Mn, 0.25 weight percent Pb, and 0.5 weight percent Zn per ton (Kucera and Egan, 2015). There are active lode claims adjacent to the study area; however, none are in the study area.

There are no analyzed rock or heavy mineral concentrate samples in the geochemical databases for the Blackstone tract. Only one sediment sample is weakly anomalous for zinc and may be related to mineralization. Five sediment or soil samples in this tract are anomalous or weakly anomalous for uranium or thorium but these elements are probably not associated with porphyry mineralization (Smith and others, 2016).

Advanced Spaceborne Thermal Emission Reflection Radiometer (ASTER, Rockwell, 2016) satellite imagery shows small, local areas of ferric iron and sericite/smectite in the tract. Argillic minerals are exposed at the Blackstone open pit and the Ajax mine. A short-wave infrared (SWIR) scratch-error region passes through tract (Rockwell, 2016), so some data are unreliable.

Radiometric mapping over the felsic volcanic and intrusive rocks does not image a Late Cretaceous pluton. A magnetic anomaly is suggestive of a concealed Eocene pluton, mostly north and east of the tract. Mineral occurrences in a magnetic low could indicate the presence of a concealed Late Cretaceous pluton or of hydrothermal alteration (Anderson and Ponce, 2016).

This Blackstone tract is in the area of a previous USGS mineral-resource potential assessment (Parks and others, 2016) and ranked as permissive for porphyry, Comstock, and hot-spring deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998).

Empire Tract H/D—There is high potential, with certainty level D, for porphyry-related Cu-Zn ± Pb-Ag-Au skarn deposits in the Empire tract (fig. 16) of the Alder Creek Mining District in Custer County, 6 km west of Mackay, Idaho (fig. 1). The tract encompasses an area of many porphyry and porphyry-related occurrences in the roof zone of an Eocene plutonic system. The Empire tract includes Mississippian carbonate roof rocks, particularly on the northeast side (top) of the northeast-tilted pluton. In all, the tract size approximates the average geometry of porphyry deposits (John and others, 2010; Taylor and others, 2012). The tract is trimmed 1 km into hanging-wall rocks along normal faults bounding both the northwest and southeast sides. The Empire tract lies in a larger tract (Mackay tract, see below) that has polymetallic/replacement/skarn potential.

The geology of the Empire tract is characterized by intensely folded Mississippian White Knob Limestone that was intruded by the Eocene Mackay Granite and numerous syn- and post-mineral dikes (Skipp and Kuntz, 2009). The Mackay Granite is exposed in a horst bounded by east-northeast striking normal faults (Skipp and Kuntz, 2009). From both regional geologic maps and from mine maps (Chang and Meinert, 2008; Skipp and Kuntz, 2009), it can be determined that this block was also tilted to the northeast.

There are a total of 87 active lode claims present in 17 sections near the Empire mine, in the Empire porphyry tract. Porphyry-related skarns are located around the northern and northeastern margins of the Mackay Granite. In the eastern part of the tract the deposits are associated with granite porphyry, the chilled upper margin of the pluton. Garnet, pyroxene, wollastonite, and amphibole endo- and exo-skarns are developed in the roof zone of the pluton (Chang and Meinert, 2008). The Copper Queen, Easlie, Hanni, Horseshoe, Phoenix, Tiger Group, Vaught, and White Knob historic mines, several unnamed prospects, and the Empire deposit represent porphyry-related occurrences (Umpleby, 1917; Ross, 1956; Fernette and others, 2016a).

Production initiated at the Empire mine in 1884; it operated continuously from 1902 to 1930, and sporadically thereafter into the 1980s (Chang and Meinert, 2008; Nelson and Ross, 1968). In 1997, the Empire deposit had combined production and estimated resources of 17,832,000 metric tons at 0.5 grams per ton (g/t) Au, 15 g/t Ag, 0.6 weight percent Cu, and minor Pb and Zn credits (tables 7, 9). Active exploration is currently underway and a prefeasibility/scoping study reports a reserve base of 1,823,000 metric tons at 0.48 g/t Au, 13.5 g/t Ag, 0.49 weight percent Cu, and 0.19 weight percent Zn. Tungsten and molybdenum are also present at the Empire mine (Hatch, 2006).

There are no analyzed samples of heavy mineral concentrates in the USGS geochemical databases for the Empire tract. Rock samples collected in this tract contain anomalously high concentrations of Ag, As, B, Ba, Bi, Cd, Cu, Mo, Pb, Sb, Sn, W, and Zn. Sediment or soil samples are anomalous for copper and weakly anomalous for zinc. See Smith and others (2016) on how the data were processed.

ASTER satellite imagery shows intense argillic, ferric iron, and (or) phyllic alteration 1 km northwest of the Drummond copper mine. Sericite/smectite surrounds zones of argillic and (or) phyllic alteration. Weak advanced argillic alteration is located 1.5 km west of the Drummond mine. Extensive sericite is mapped along ridgelines, most likely related to specific lithologies in Mississippian sedimentary rocks. The tract also contains small, local expressions of argillic alteration ± ferric iron. See Rockwell (2016) for how these data are processed.

Radiometric mapping distinguishes both Challis igneous and older sedimentary rocks. The aeromagnetic maps (see Anderson and Ponce, 2016) image the exposed Eocene Mackay pluton and suggest that it extends beneath the cover of older rocks 5 km south and west of the tract.

Previous USGS mineral-resource-potential assessments (Parks and others, 2016) rank this area as permissive for copper, zinc-lead, gold skarn deposits, porphyry deposits, and polymetallic-replacement deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998) and moderately to highly favorable for polymetallic skarn and vein deposits (Worl and others, 1989; rendered in digital form in Carlson and others, 2007).

Latest Out Tract H/D—There is high potential, with certainty level D, for porphyry-related Ag-Pb-Zn ± Cu polymetallic-replacement and vein deposits in the Latest Out tract (fig. 17) in the Texas and Spring Mountain Mining Districts located near the town of Gilmore in Lemhi County,

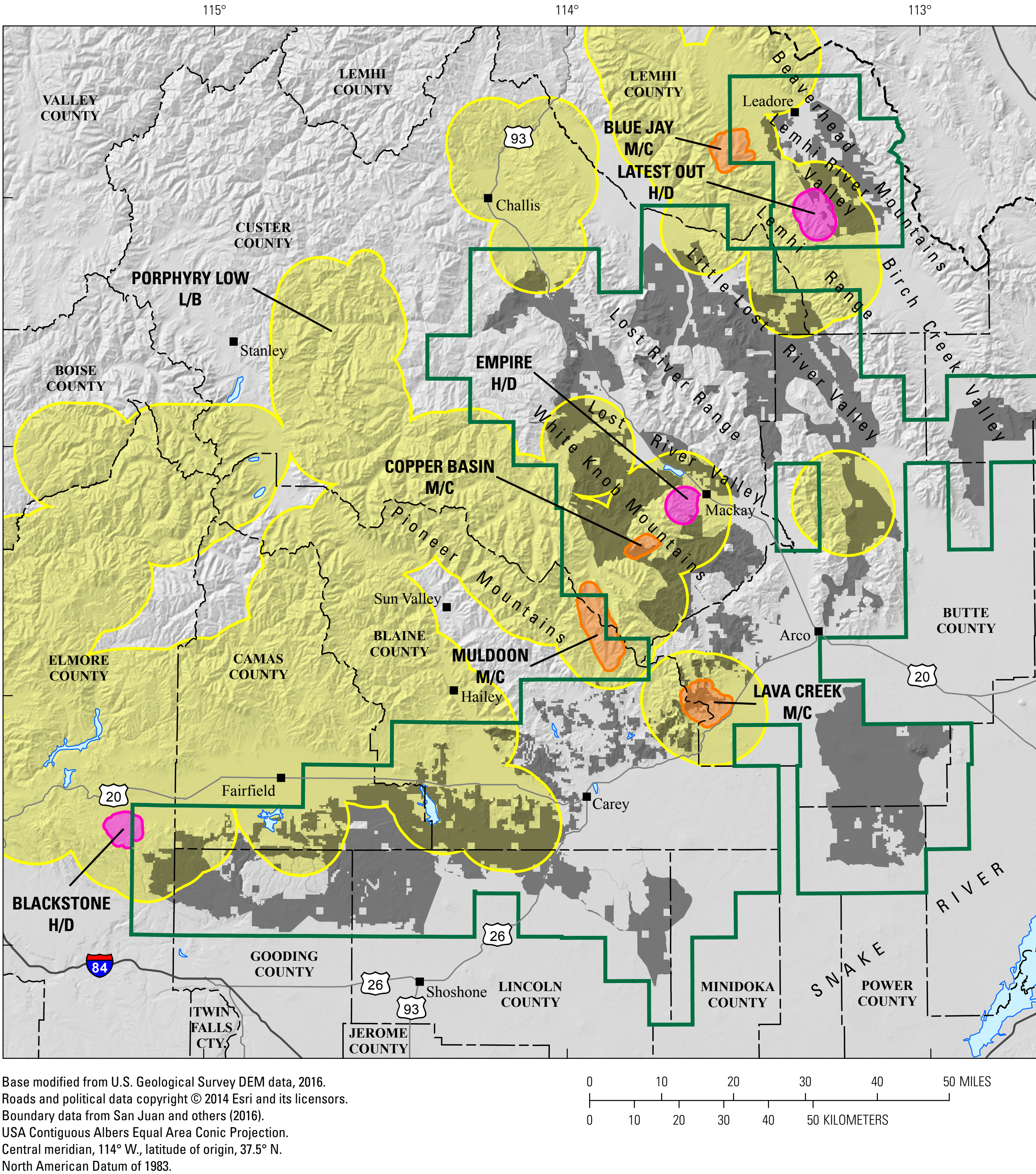
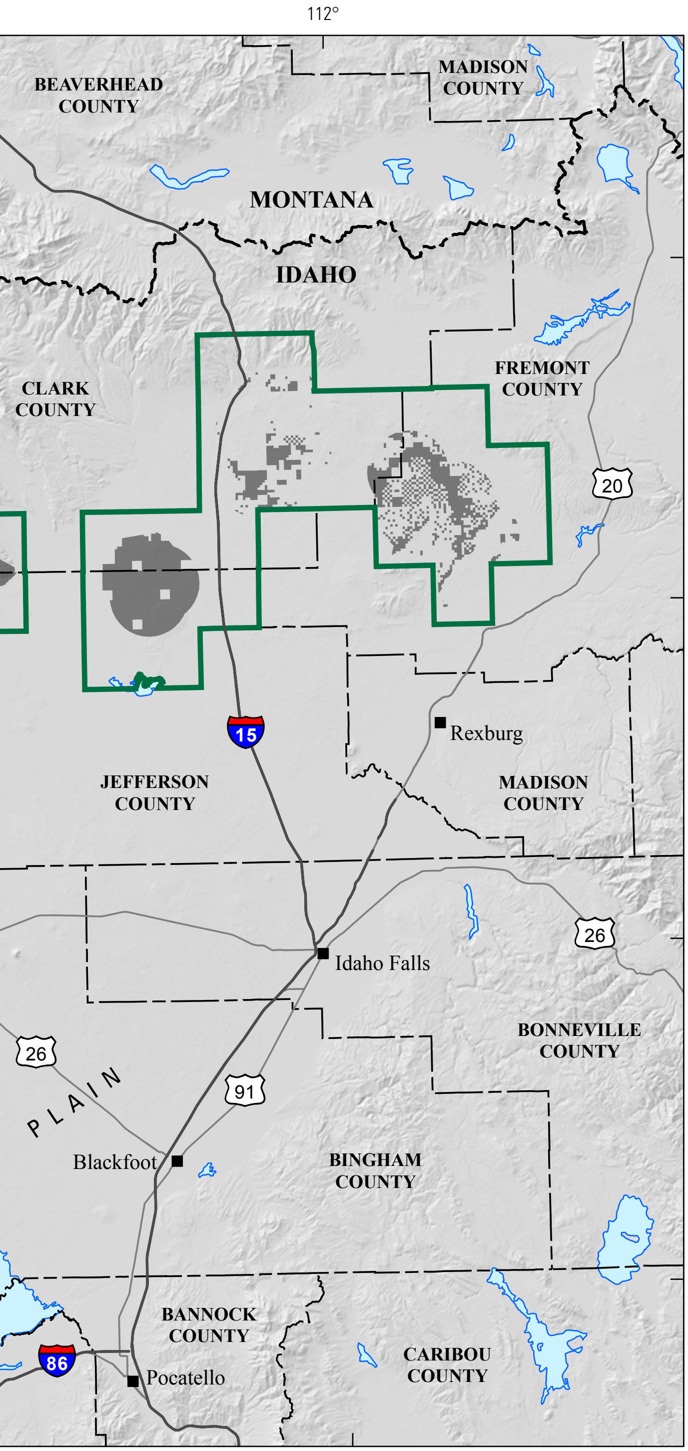
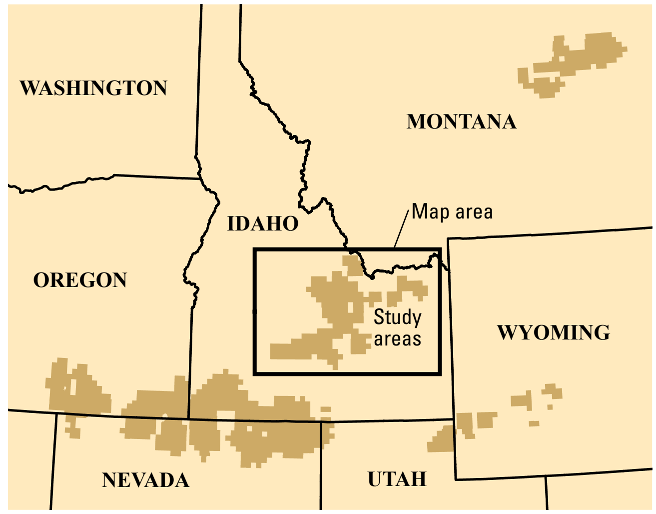


Figure 14. Map showing tracts for porphyry-type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – porphyry/skarn

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) certainty

Low-potential (L) tract with low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

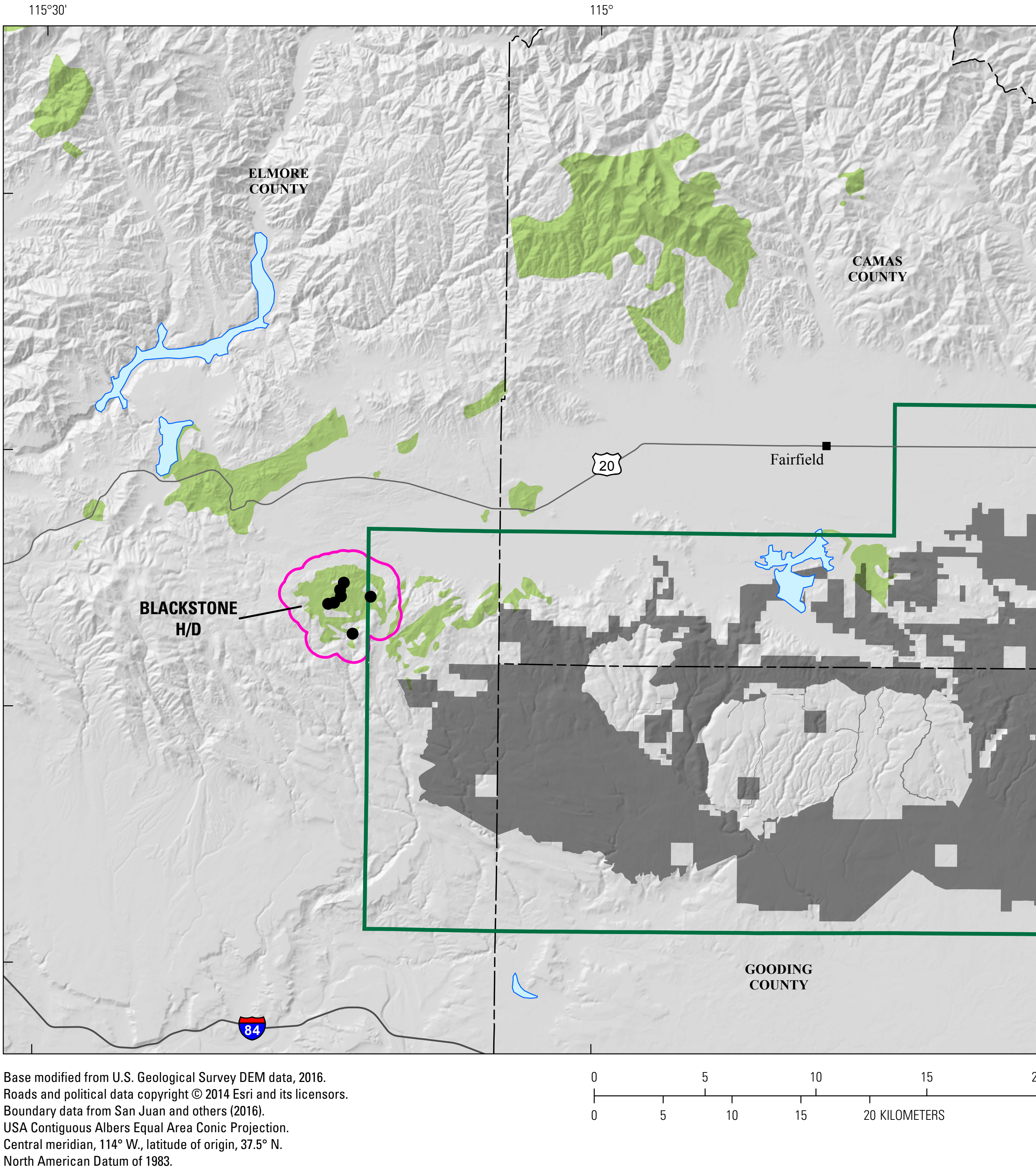
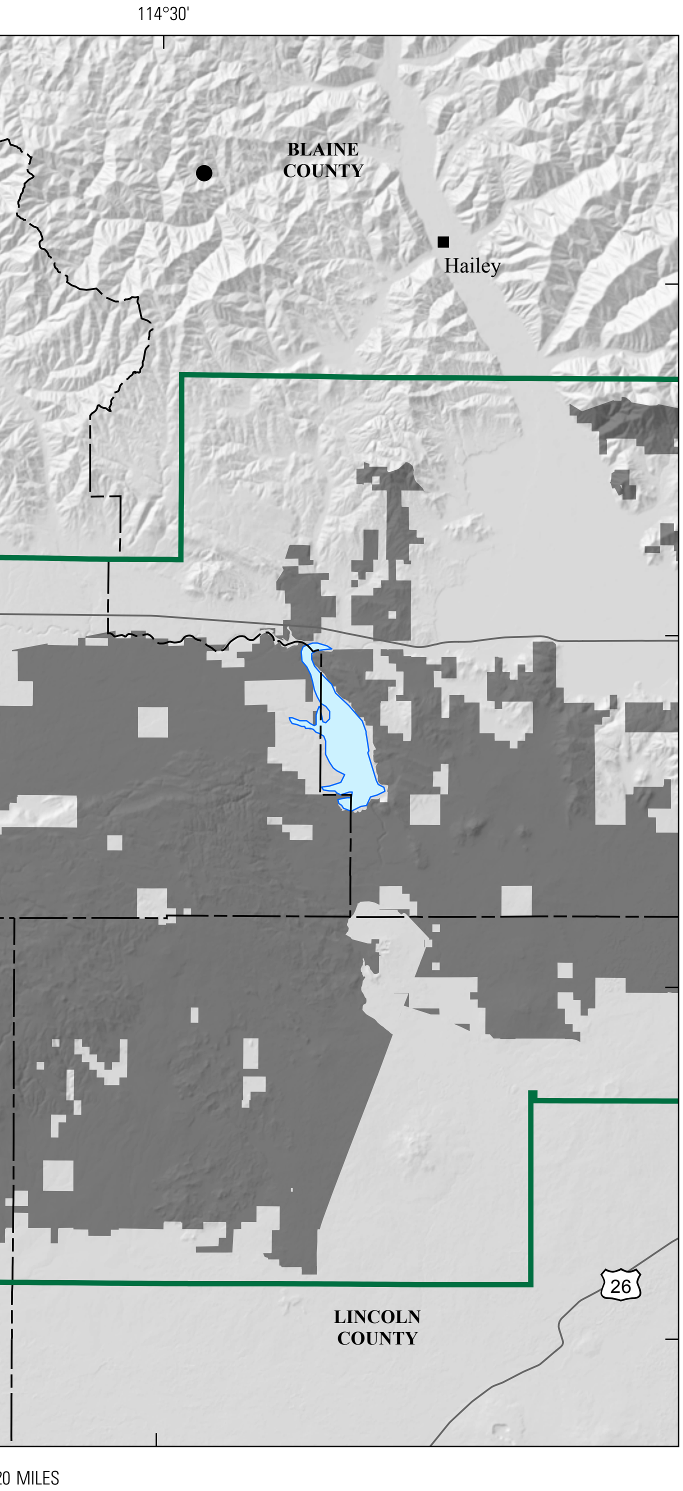
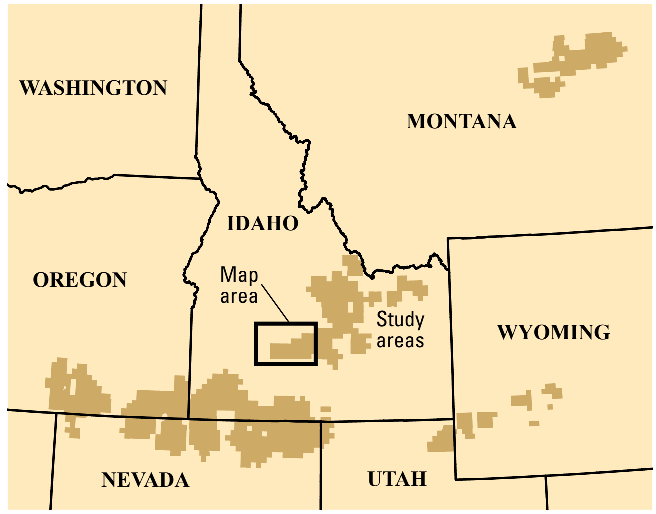


Figure 15. Inset map showing mineral-resource-potential tracts for porphyry-type and porphyry-related type deposits in context of permissive geology and porphyry-deposit occurrences in the western part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – porphyry

High-potential (H) tract with high (D) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

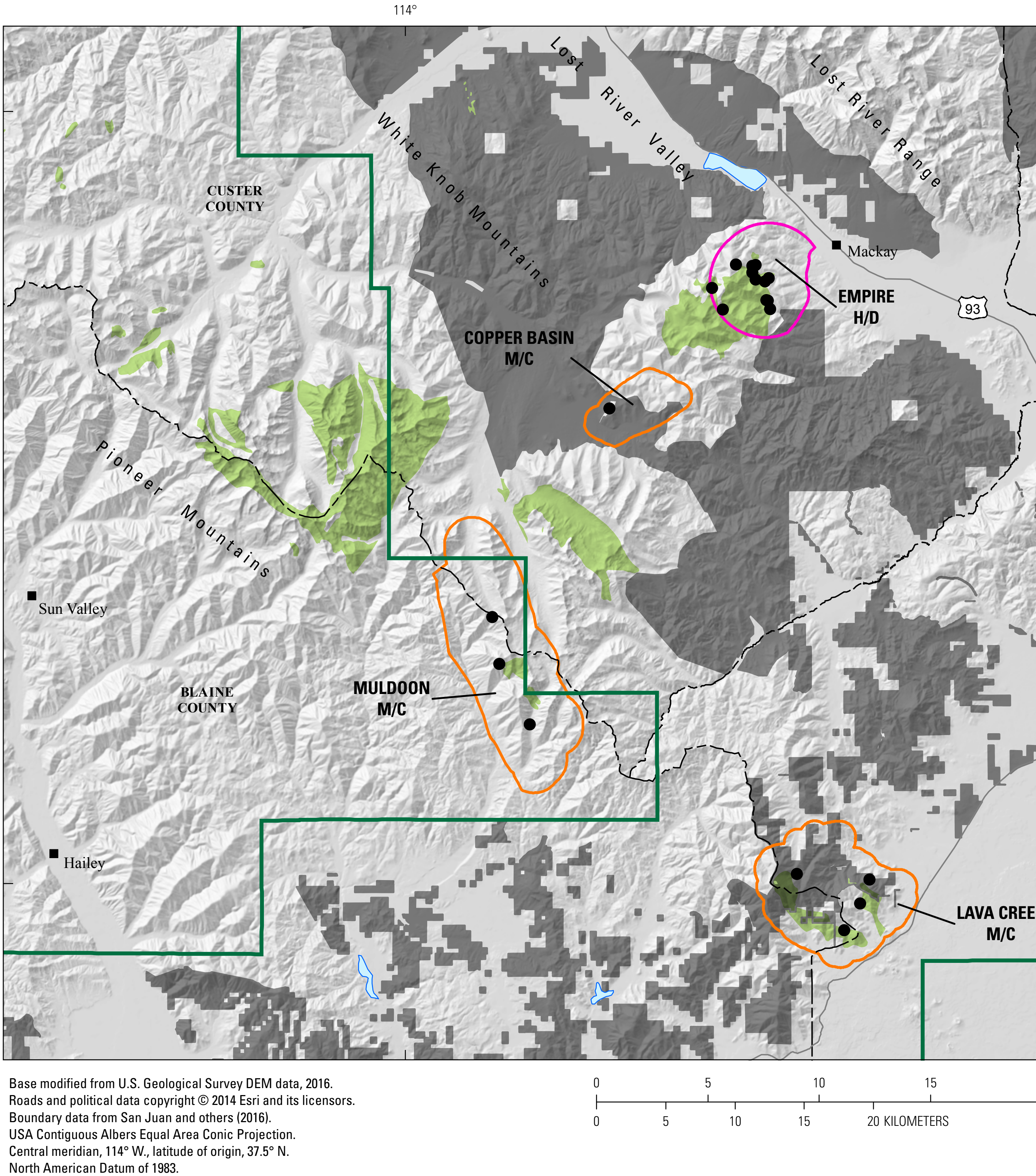
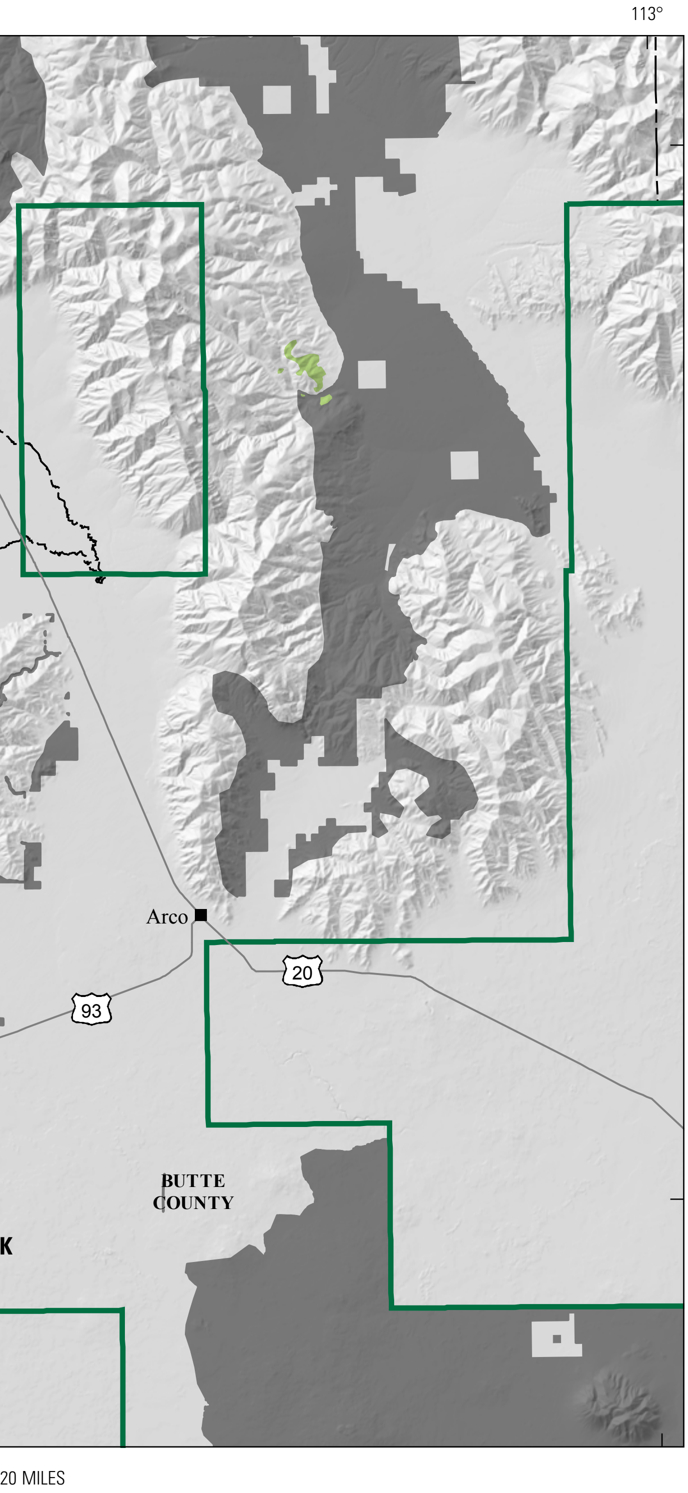
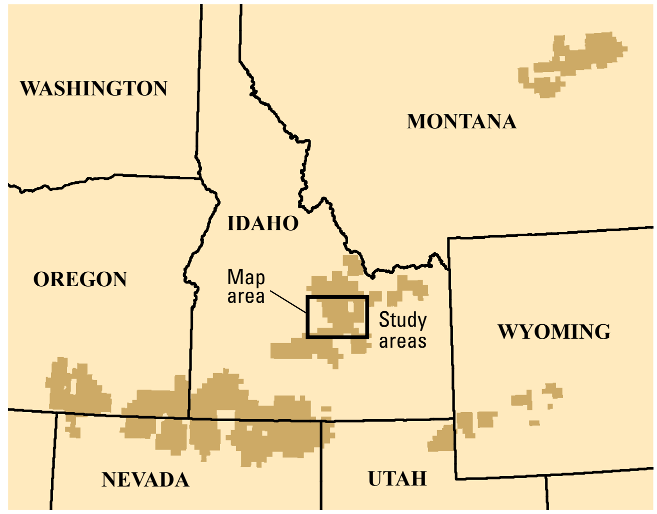


Figure 16. Inset map showing mineral-resource-potential tracts for porphyry-type and porphyry-related type deposits in context of permissive geology and porphyry-deposit occurrences in the central part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – porphyry/skarn

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

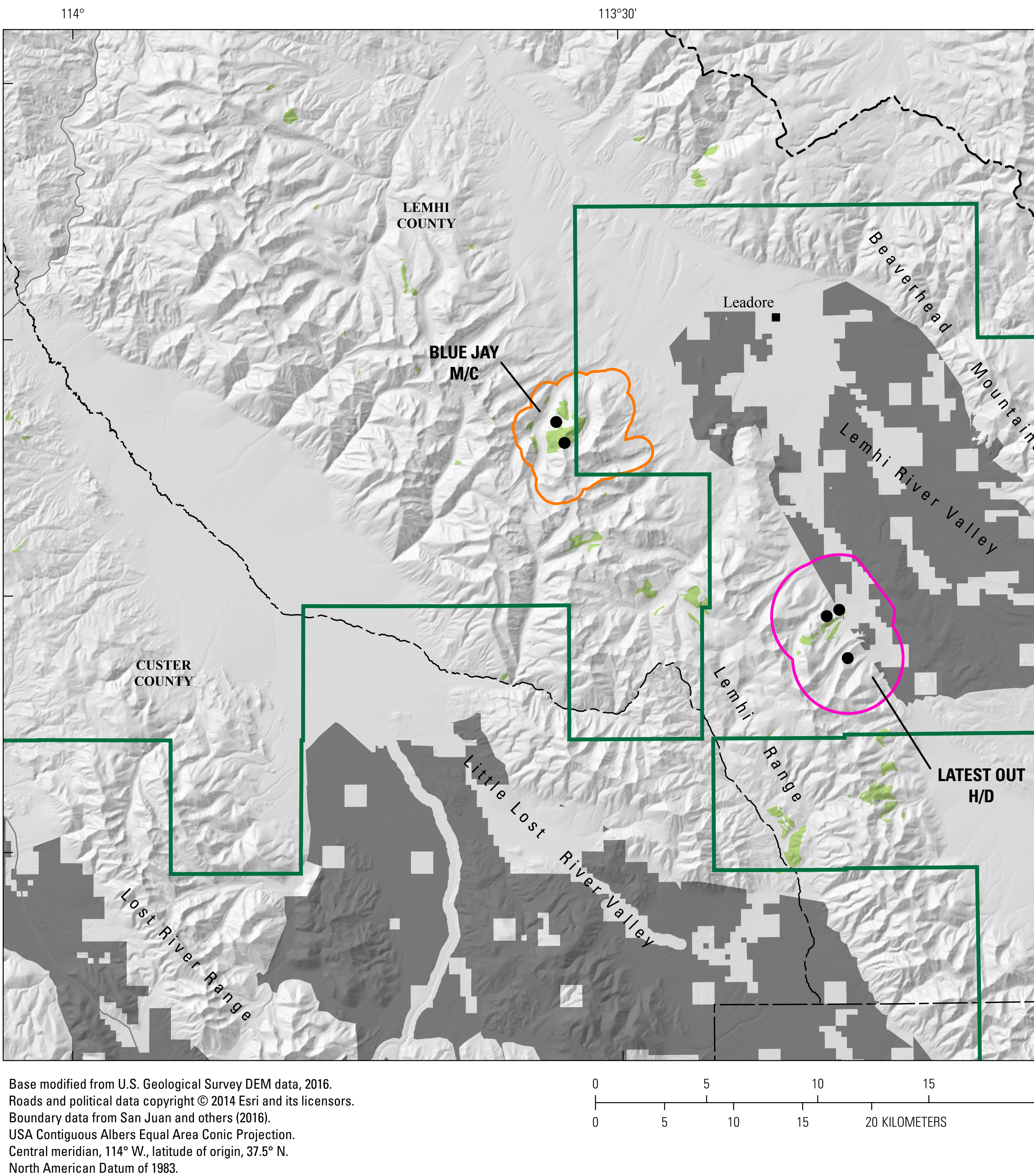
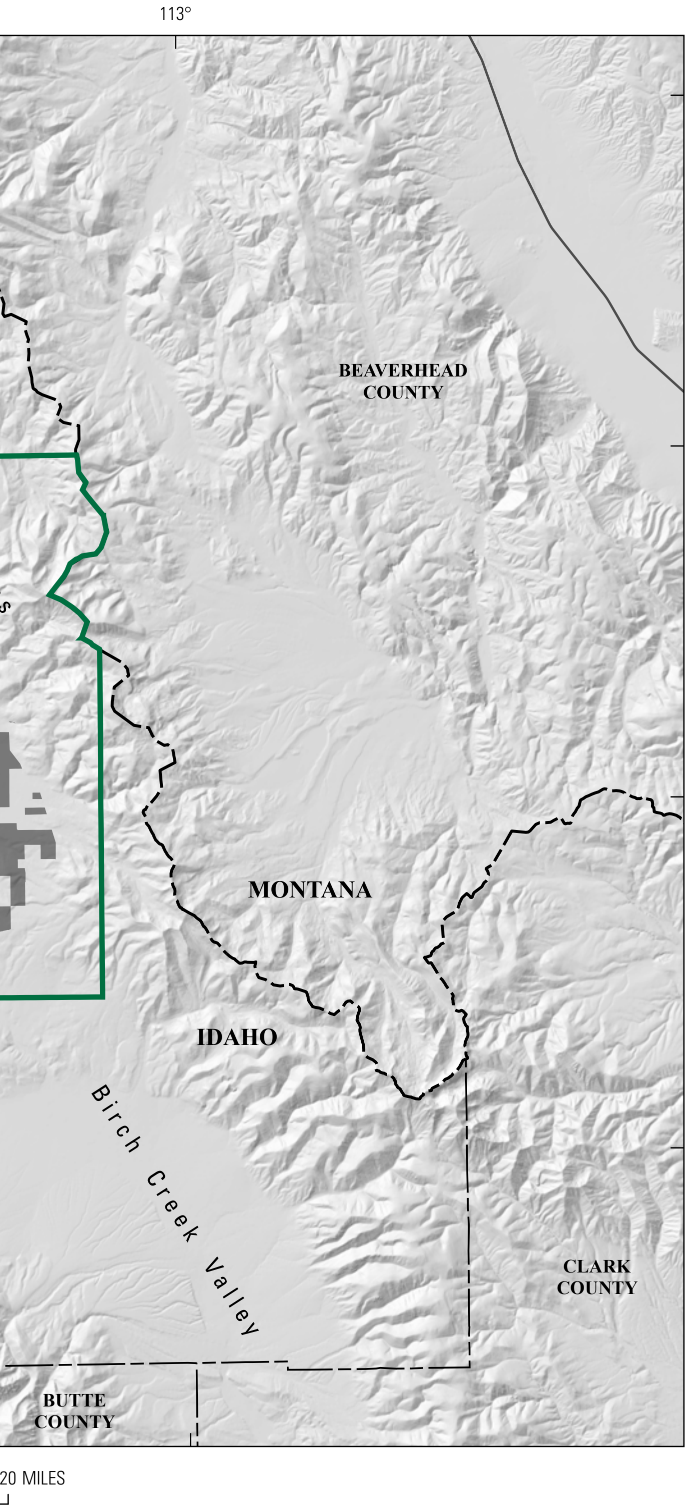
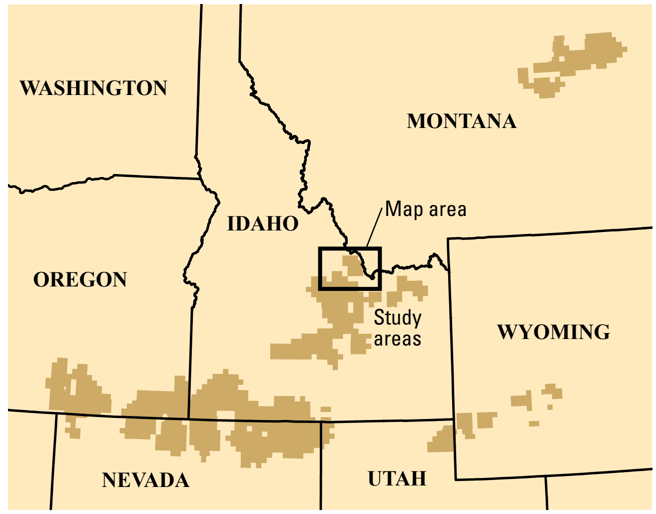


Figure 17. Inset map showing mineral-resource-potential tracts for porphyry-type and porphyry-related type deposits in context of permissive geology and porphyry-deposit occurrences in the northern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – porphyry

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

Idaho (fig. 1). The tract encompasses an area of porphyry-related mineral occurrences in the roof zone of an Eocene granite pluton that is partly exposed at the surface and partly in underground workings; the geographic extent of the pluton is also interpreted from geophysical data. The size of the tract is approximated to the average (8-km diameter) size of this deposit type (John and others, 2010; Taylor and others, 2012), and is trimmed to 1 km depth to bedrock beneath valley fill based on interpretation of drill-hole data and geophysical interpretation. The Latest Out porphyry tract is in the larger Gilmore tract (see below) that has polymetallic/replacement/skarn deposit type resource potential.

The geology of the Latest Out tract is characterized by a normal fault-bounded, east-dipping, tilt block of Proterozoic metamorphic and Ordovician to Mississippian strata (Lund and others, 2003). These rocks were intruded by isolated Eocene granodiorite, quartz monzodiorite, and granite stocks (the Gilmore stock, approximately 49 Ma; Bennett, 1980). Older rocks are partly covered by Quaternary glacial, colluvial, and alluvial deposits (Lund and others, 2003).

Porphyry-related mineralization in the area is associated with Eocene quartz diorite porphyry dikes (Umpleby, 1913). These dikes are spatially related to Ag-Pb-Zn±Cu vein and replacement deposits at the Grooms Democrat mine (Groom Creek porphyry) and Latest Out mine in the Texas District in the northern part of the tract. Another likely porphyry-related prospect is the Idaho Au ± Ag-Mo vein occurrence (Fernette and others, 2016a).

The Latest Out replacement deposit was located in 1880 and is reported to have produced ore from 1889 to 1952 (tables 7, 9). The millsite at the Latest Out mine is closed. The Grooms Democrat claim was also staked in 1880 and was the earliest prospect located in the district (Umpleby, 1913). There are active lode claims over the Grooms Democrat mine and the Idaho occurrence.

Analyzed rock samples from the Latest Out tract have anomalous concentrations of Ag, As, Au, B, Ba, Bi, Cd, Cu, Hg, Mn, Pb, Sb, Se, and Zn. Sediment and soil samples are anomalous for As, Cd, Cu, Hg, Pb, Sb, and Zn, and weakly anomalous for silver and selenium. One heavy-mineral concentrate sample collected in this tract was split into a magnetic fraction (C1), a weakly magnetic fraction (C2), and a nonmagnetic fraction (C3). All three fractions were analyzed for this one site. The C1 fraction was anomalous for As, Cu, Pb, and Zn. The C2 fraction was anomalous for As, Cu, Mo, Pb, and Zn. The C3 fraction, which commonly contains sulfide and oxide ore minerals, was anomalous for Ag, B, Cu, Mo, Pb (more than 50,000 parts per million [ppm]), Sb, V (15,000 ppm), and Zn (Smith and others, 2016).

ASTER satellite imagery shows two large and well-developed advanced argillic, argillic, and argillic-ferric Fe anomalies in Paleozoic quartzite west of the Grooms Democrat and Latest Out mines and in the Idaho porphyry-related occurrence.

The mines and prospects of the Latest Out tract are located at the margins of two magnetic highs that likely indicate Eocene intrusions at shallow depths. These mineral occurrences also lie on a moderate-intensity northwest-striking Bouguer gravity ridge. The Th/K ratio map shows a prominent positive anomaly probably indicating the presence of an Eocene pluton at depth. See Anderson and Ponce (2016) for a discussion on how the geophysical data were processed and interpreted for this study.

Previous U.S. Geological Survey mineral-resource potential assessments mark the tract as permissive for porphyry copper (U.S. Geological Survey National Mineral Resource Assessment Team, 1998). The southern part of the tract is highly favorable for polymetallic-vein and moderately favorable for polymetallic skarn deposits (Worl and others, 1989; rendered in digital form in Carlson and others, 2007; Parks and others, 2016).

Blue Jay Tract M/C—There is moderate potential, with certainty level C, for Mo-W and Cu-Mo-W±Ag-Pb-Zn porphyry deposits in the Blue Jay tract (fig. 17) of the Junction District in Lemhi County, 17 km southwest of Leadore, Idaho (fig. 1). The tract was delineated to encompass exposures of Eocene Big Eightmile granite and Mesoproterozoic and Ordovician roof rocks. The tract includes areas of surface alteration from ASTER, historic prospects, geochemical anomalies, mineral occurrences, and prospects having a recent history of exploration. The tract was trimmed to 1 km into valley fill over buried bedrock, as interpreted from geophysical data.

The geology of the Blue Jay tract is characterized by Mesoproterozoic Big Creek Formation calcareous arkosic metasandstone, Gunsight Formation arkosic metasandstone, Swauger Formation and Ordovician Kinnikinic Quartzite roof and country rocks (figs. 3, 4; Lund and others, 2003). These rocks were intruded by approximately 51 Ma Eocene granite, monzonite, and subordinate diorite stocks (Livingston, 1919; Bennett, 1980). Eocene Challis Volcanics crop out 5 km northwest and southeast. Pleistocene and Quaternary glacial, colluvial, and alluvial deposits cover large parts of the area (Lund and others, 2003).

Porphyry mineralization is present at the Blue Jay (New Departure) Cu-Mo-W porphyry, Mulkey (West Eightmile Creek) Mo-W granite-hosted pegmatite, and the Silver Queen and Ray Lode Pb-Au-Ag porphyry-related vein prospects (Bennett, 1980; Johnson and others, 1998; Worthington, 2007). Mineralization in the Blue Jay area exhibits a similar character to the better-known mineralization at the IMA Mo-W-Ag-Cu-Pb-Zn porphyry-related polymetallic-vein deposit 14 km southeast (Anderson, 1948b; Bardswich, 2010). The deposit there is rooted in an approximately 48 Ma stock with molybdenite stockworks (0.054 weight percent Mo; Worthington, 2007).

Molybdenum and tungsten ore were processed in a 50-ton mill at the Blue Jay mine and Mulkey adit in the early 1900s (Umpleby, 1913; Johnson and others, 1998; Worthington, 2007). The Blue Jay deposit, adjacent to the study area boundary, is the site of active lode claims, and exploration is active in the IMA mine area 10 km west (Anderson, 1948b; Johnson and others, 1998; Causey, 2007; Dicken and San Juan, 2016).

There are no analyzed samples of heavy mineral concentrates in the USGS geochemical databases for this tract. Rock samples are anomalous for Ag, As, Au, B, Cd, Ce, Co, Cu, Mn, Mo, Pb, Se, Te, and U; they are weakly anomalous for Ba, Hg, La, Sn, and Zn. Chemical symbols are explained in the front of this report. Sediment or soil samples are anomalous for As, Au, Cu, and Mo, and weakly anomalous for Se and Zn. See Smith and others (2016) for a discussion on how the geochemical data were processed to support this study.

ASTER imagery indicates intense argillic alteration as well as ferric iron and possible phyllic alteration east and southeast of the Blue Jay mine. On the south side of the Blue Jay mine area, jarosite is mapped in a zone containing argillic alteration and a ferric iron signature. See Rockwell (2016) for a discussion on how the remotely sensed data were processed to support this study.

Radiometric data mostly image sedimentary rocks. Although small granite exposures are mapped in the area (Lund and others, 2003), radiometric data do not convincingly support the presence of an underlying Eocene pluton. Magnetic data do identify an Eocene pluton and suggest that the intrusive body extends 4 km west and 2 km east of mapped exposures. See Anderson and Ponce (2016) for a discussion on how the geophysical data were processed to support this study.

Previous USGS mineral-resource potential assessments mark this area as permissive for porphyry copper deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998).

Copper Basin Tract M/C—There is moderate potential, with certainty level C, for porphyry-related Cu ± Au-Ag-Pb skarns in the Copper Basin tract (fig. 16) of Custer County, 20 km southwest of Mackay, Idaho (fig. 1). The tract centers on the Copper Basin mine and three prospects that are located in both Challis Volcanics and Mississippian carbonate rocks. The mineral occurrences are spatially related to the normal faults bounding a graben underlain by Eocene Challis Volcanics that is juxtaposed against footwall Mississippian White Knob Limestone (Skipp and Kuntz, 2009). The Copper Basin tract encompasses the volcanic graben and is trimmed to 1 km into the footwall rocks on west, north, and east and also trimmed to 1 km into valley fill on the south.

The geology of the Copper Basin tract is characterized by the folded limestone and interbedded shale and sandstone units of the Mississippian Copper Basin Group. These are overlain by the Eocene Challis Volcanics. Both were intruded by northeast-striking granite porphyry and aplite dikes (Ross, 1956; Mitchell, 1999; Skipp and Kuntz, 2009). The Challis Volcanics are preserved in a northeast-striking graben (Skipp and Kuntz, 2009).

Known skarn mineralization exists at the Copper Basin (Reed and Davidson) mine, and the nearby Anderson and Rosenkranze prospects (Mitchell, 1999; Klein, 2004; U.S. Geological Survey, 2005). At the Copper Basin mine, copper oxide and carbonate minerals after chalcopyrite are hosted by a magnetite-bearing garnet-diopside skarn that developed along granite porphyry and rhyolite dikes, as well as locally along bedding planes (Umpleby, 1917).

The Copper Basin mine is reported to have been intermittently active between 1888 and 1919 (Ross, 1956). Further development and exploration work was conducted between 1938 and 1940, and the property was drilled in 1981 and 1988 (Mitchell, 1999). The Copper Basin mine is closed (Fernette and others, 2016a), and no sections in the tract have active lode claims. However, two sections located north of the Copper Basin mine contain active placer claims.

One rock sample with anomalous silver, bismuth, and copper was collected in this tract. Although four sediment or soil samples were collected in this tract, no elements were found in anomalous concentrations. There are no analyzed samples of heavy mineral concentrates in the geochemical databases for this tract.

Based on ASTER data, minor sericite and argillic alteration is present in the vicinity of the Copper Basin mine along a bounding normal fault. Ferric iron and sericite/smectite alteration is present in Challis Volcanics north of the mine.

Radiometric and magnetic data suggest the presence of an Eocene pluton about 3 km northeast of the tract, and indicates the west edge of the same source as imaged in the Empire tract. Radiometric maps show U/Th and U/K highs that correspond with the location of the Copper Basin mine.

Previous USGS mineral-resource potential assessments rank this area as permissive for porphyry copper deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998) and as moderately favorable for polymetallic skarn deposits (Worl and others, 1989; rendered digital in Carlson and others, 2007).

Lava Creek Porphyry Tract M/C—There is moderate potential, with certainty level C, for Ag-Pb-Zn-Cu-Sb-W) porphyry-related deposits in the Lava Creek porphyry tract (fig. 16), located in the southeastern part of the Lava Creek District in Butte and Blaine Counties, 30 km southwest of Arco, Idaho (fig. 1). The tract surrounds four porphyry-related occurrences in Eocene Challis Volcanics located in the roof zone of a subvolcanic intrusion. The pluton intruded complexly folded Mississippian carbonate rocks. The Lava Creek tract is trimmed to 1 km out from bedrock into valley fill to account for shallow burial of potentially mineralized rocks. Because of the geology of the locality and the general 4-km radii sizes of porphyry-type deposits (see John and others, 2010; Taylor and others, 2012), the Lava Creek porphyry tract is coincident with the Lava Creek polymetallic tract (see below).

The geology of the Lava Creek tract is characterized by Mississippian McGowan Creek Formation and Copper Basin Group overlain by Challis Volcanics (figs. 3, 4). The Mississippian rocks were intruded and contact metamorphosed by Eocene granite, granite porphyry, and syenite stocks and dikes (Anderson, 1929) that combined to form a sheet-like plutonic suite beneath the volcanic rocks (Kuntz and others, 2007; Skipp and Kuntz, 2009). The east and southeast edges of the tract are covered by Pliocene-Pleistocene and Quaternary basaltic and sedimentary units of the Snake River Plain (Kuntz and others, 2007; Skipp and Kuntz, 2009).

Rocks of the Eocene Challis Volcanics are mineralized in the Lava Creek tract. The Diamond Ag-Pb-Cu, Golden Chariot Ag-Pb±Cu, Lucky Strike (Copper King) Zn, and Martin Ag-Au-Pb-Zn-Cu veins and disseminations are spatially associated with porphyry dikes (Anderson, 1929; Cook, 1956; Winkler and others, 1989; Worl and Johnson, 1989, 1995). Vein alteration envelopes are zoned outwards from chlorite after biotite and hornblende, to widespread quartz sericite-pyrite, sericite, and kaolin. Compared to other veins in the district, chalcopyrite, specularite, and epidote are relatively abundant at the Golden Chariot mine, but a mineralized pipe in granite porphyry characterizes the Martin mine. Intrusion-related Zn-Pb ± W and W skarns are reported from the Sam and Tom and the Wolframite mines, but the mineralizing processes in these occurrences are unclear.

The district had mining activity prior to 1900, and between 1923 and 1948 (U.S. Geological Survey and U.S. Bureau of Mines, 1981). Past production is reported from the Diamond and Martin mines (Mitchell and others, 2015; Fernette and others, 2016a). The Martin mine was discovered and first worked in 1922, but operations were hindered because of mine flooding (Anderson, 1929). All mines are closed at present and there are no active claims (Fernette and others, 2016a).

Rock samples collected in the tract are anomalous for Ag, As, Au, B, Ba, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Te, and Zn. Sediment or soil samples are anomalous for Ag, Hg, Nb, P, Pb, Te, and Zn. Heavy-mineral-concentrate samples contain anomalous Ag, As, Au, B, Ba, Bi, Cu, Ga, La, Mo, Nb, P, Pb, Sb, Sn, W, and Zn.

ASTER imagery has a SWIR scratch-error region that passes through the tract (Rockwell, 2016). Argillic alteration is imaged in Challis Volcanics rocks and 750 m northeast of the Silver Bell mine. Landsat 7 images reveal small occurrences of ferric iron and clay-sulfate-mica (CSM) minerals, including in Challis Volcanics and 750 m northeast of the Silver Bell mine.

Radiometric data delineate Challis igneous and older sedimentary rocks. Magnetic data indicate the existence of the subvolcanic pluton, but it is difficult to differentiate the pluton signature from that of the nearly coincident north-northwest-striking Snake River Plain rift zone that crosses this tract.

Previous USGS mineral-resource potential assessments rank the area that overlaps the Lava Creek tract as permissive for a variety of different deposit types, including Cu, Zn-Pb, Au skarn, porphyry, polymetallic replacement, Comstock, epithermal, and hot-spring deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998).

Muldoon Porphyry Tract M/C—There is moderate potential, with certainty level C, for porphyry-related polymetallic Cu-Zn-Pb skarn and Ag-Pb-Zn±Cu replacement and vein deposits in the Muldoon tract (Muldoon/Little Wood River District) of Custer and Blaine Counties, 35 km northeast of Hailey, Idaho (fig. 16). The tract centers on three porphyry deposit occurrences in the roof of an Eocene Challis granite pluton where the pluton intruded an elongated zone of mineralized Mississippian carbonate country rocks located in the footwall of the Cretaceous Pioneer thrust fault. On the east, the tract includes the mineralized carbonate roof rocks in the lower part of the Mississippian Copper Basin Group. An area of minor alteration identified from ASTER remote-sensing data along strike north of the exposed plutonic rocks helps define the extent of the tract. On the west, the tract is trimmed to 1 km into the hanging wall of a down-to-west normal fault. The Muldoon porphyry tract overlaps the Muldoon polymetallic-vein tract.

The Muldoon porphyry tract is characterized by tightly folded Mississippian Copper Basin Group carbonate roof rocks that lie in the footwall of the Cretaceous Pioneer thrust fault. These rocks were intruded by the Eocene Muldoon and Garfield porphyritic biotite-pyroxene quartz monzonite stocks and dikes (approximately 49 Ma; Winkler and others, 1989) and are cut by northwest- and northeast-striking rhyolite dikes (Skipp and Kuntz, 2009). The upper plate of the thrust fault was dropped down to the west by an Eocene normal fault that bounds mineralization to the west.

Porphyry-related skarn and nearby replacement deposits in the Muldoon porphyry tract are mainly controlled by the intersection of bedding-parallel faults with east-northeast striking faults in limestone of the Copper Basin Group. The Muldoon replacement and Eaglebird (Garfield) skarn deposits are proximal to the Eocene stocks and exhibit crude zoning of sulfide minerals, including pyrite, pyrrhotite, arsenopyrite, and chalcopyrite that become more common closer to the intrusion (Kunkel, 1989). Mining began at the Muldoon and Eaglebird mines before 1910 and continued into the 1940s. Tungsten and antimony production were reported at the Eaglebird Mine. However, no production amounts are in the records and all mines are closed at present (Fernette and others, 2016a). There are no active lode claims in the Muldoon tract.

There are no analyzed samples of heavy mineral concentrates in the geochemical databases for the Muldoon tract. Rock samples collected in the tract are anomalous for Ag, As, Au, B, Ba, Bi, Cd, Cu, Mn, Mo, P, Pb, Sn, and Zn; they are also weakly anomalous for Cr. Although rarely analyzed for, a number of rocks in the Muldoon track were analyzed for platinum group elements (PGEs) and a few samples have elevated values of Ir, Rh, and Ru. Sediment or soil samples have anomalous concentrations of As, Cd, Cu, Mo, Ni, Pb, V, and Zn, along with weakly anomalous Ag, B, and Co. Anomalies of Ag, B, Cu, Mo, Ni, Pb, V, and Zn continue west and northwest outside of the tract and may indicate additional mineralization or possibly lithologic associations outside of the study area.

ASTER satellite imagery shows intense argillic, ferric iron, and (or) phyllic alteration 1 km northwest of the Drummond Copper mine (Cu, Au, Pb, and Ag). Sericite/smectite surrounds zones of argillic and (or) phyllic alteration. Possible advanced argillic alteration is present 1.5 km west of Drummond mine. Extensive sericite is mapped along ridgelines, most likely related to lithologies in Mississippian sedimentary rocks.

Radiometric data document the location of Challis igneous and older sedimentary rocks. Magnetic mapping shows the presence of an Eocene pluton beneath Paleozoic sedimentary and Eocene Challis Volcanics rocks. The pluton may extend 3.5 km north and south of the tract.

Previous USGS mineral-resource-potential assessments (Parks and others, 2016) mark the northern sector of the tract as permissive for porphyry copper and zinc-lead skarn deposits, and moderately favorable for both polymetallic skarn over the entire tract and stockwork molybdenum deposits over the northern part of the tract (Worl and others, 1989; rendered in digital form in Carlson and others, 2007).

Porphyry Low Tract L/B—There is low potential, with certainty B, for porphyry deposits across a broad part of the study area (fig. 14). This tract is based on the presence of permissive geology in the form of both Cretaceous Idaho batholith and Eocene Challis granitic plutons. The tract is based on exposures of these plutons from geologic maps and extended into country rocks using a 10-km buffer to account for the generalized mapping and shallow burial beneath older roof/wall rocks or younger cover.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in three tracts (Blackstone, Empire, and Latest Out) and moderate mineral-resource potential in four tracts (Blue Jay, Copper Basin, Lava Creek, and Muldoon) for porphyry-type deposits. This type of deposits is characterized by enrichment in copper, molybdenum, gold, and silver. For economic analysis of these commodities, see Bleiwas (2016).

Polymetallic Replacement, Veins, and Skarns

Deposit Type Description

Polymetallic-vein, replacement, and skarn deposits are an assemblage of deposits that are found in felsic plutons or adjacent to them in their sedimentary (commonly carbonate), metamorphic, and volcanic country rocks (Lefebure and Church, 1996). Polymetallic-vein type deposits include both those that are associated with the porphyry mineral deposit type and those for which data are insufficient to relate them with porphyry-related type deposits (see above).

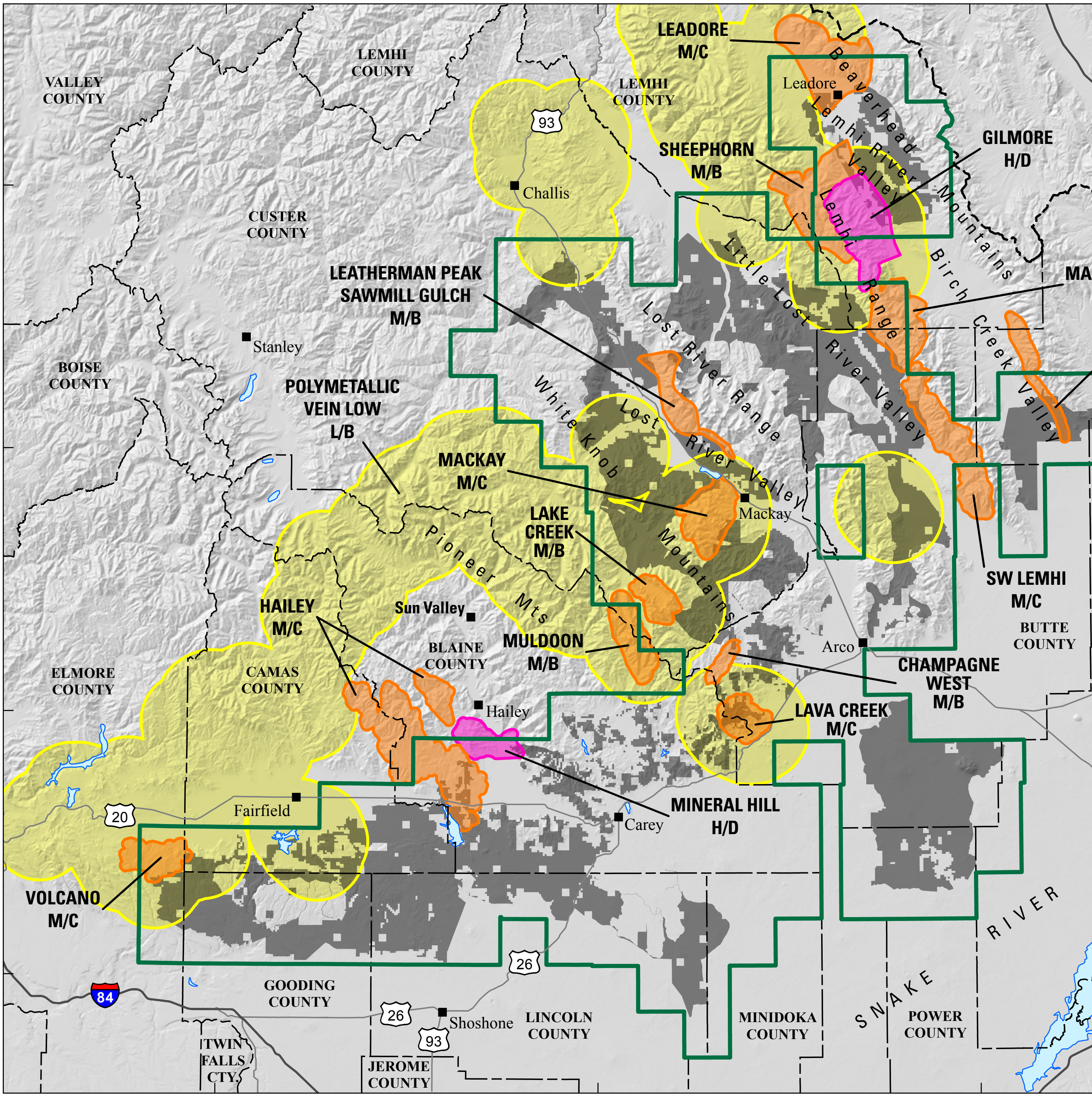
Polymetallic-replacement (manto) deposits can form either proximal or distal to small, high-level felsic plutons. The deposits are generally irregularly shaped and conformable to layering in host rocks. Replacement deposits form as massive lenses or as pipes in limestone, dolostone, or other soluble rock near intrusions. They are possibly distal to porphyry and skarn deposits. The replacement deposits contain silver, lead, zinc, and copper minerals, including sphalerite, galena, pyrite and other sulphides and sulphosalts. On a district-wide basis, polymetallic-replacement deposits commonly are zoned outward from a copper-rich central area through a wide lead-silver intermediate zone, to a zinc- and manganese-rich fringe. Geochemical anomalies in gold, arsenic, antimony, and bismuth are commonly related to the deposits.

Polymetallic-vein deposits form in volcanic and plutonic rocks, and also in sedimentary and metamorphic country rocks, particularly carbonate rocks. In igneous rocks, veins are commonly in fracture sets. The deposits hosted in sedimentary or metamorphic rocks may form proximal or distal relative to hypabyssal felsic plutons. In sedimentary and metamorphic rocks, veins commonly fill fractures and (or) cleavages developed in folds. Veins are generally narrow, tabular, or splayed sets of parallel, intersecting, and offset veins. Individual veins vary from centimeters to more than 3-m wide and can be followed from a few hundred to more than 1,000 m in length and depth; they can widen to tens of meters in stockwork zones. Veins are composed of quartz-carbonate gangue and are sulfide rich, containing sphalerite, galena, silver, and sulphosalt minerals. The primary commodities are Au, Ag, Cu, Pb, Zn, and Fe. Anomalous geochemical signatures include Zn, Cu, Pb, As, Au, Ag, Mn, and Ba. Anomalous metals are commonly zoned outward from Cu-Au to Zn-Pb-Ag to peripheral Mn (Lefebure and Church, 1996).

Copper skarn deposits form in thermally metamorphosed zones in calcic- and (or) magnesium-rich carbonate rocks near felsic intrusive rocks. These skarns are commonly copper dominant, generally containing chalcopyrite-predominant sulfide mineralogy. Rock geochemical results may show zoning from Cu-Au-Ag-rich inner zones grading outward through gold-silver zones with high gold:silver ratios to an outer Pb-Zn-Ag zone. There are Co-As-Sb-Bi-Mo-W geochemical anomalies present in the more reduced copper skarn deposits. Commodities are Cu, Au, Ag, Mo, W, and magnetite (Lefebure and Church, 1996).

Permissive Geology and Occurrences in Study Area

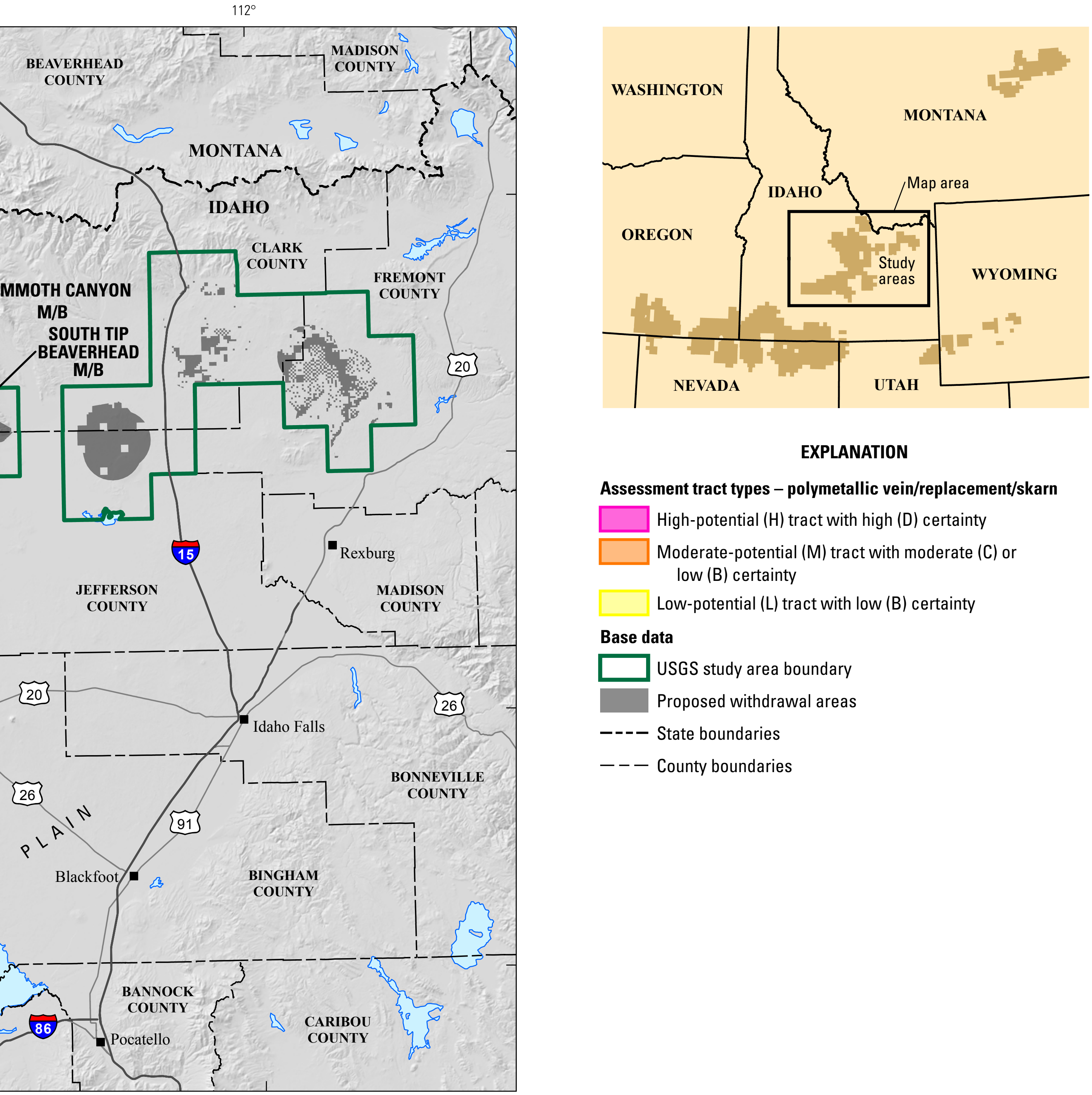
Most of the polymetallic-replacement, vein, and skarn tracts (fig. 18) are proximal to Eocene Challis granite plutons. Some replacement and vein tracts are distal to known Eocene plutons or to such plutons inferred from aeromagnetic data to exist at depth. Polymetallic-replacement, vein, and skarn deposits in the central parts of the study area are commonly hosted by the Mississippian limestone units that were deposits in the foreland basin setting. Many of the tracts in this study area, particularly those in the southeastern part of the area, contain polymetallic veins in areas that are distal to plutons; some are located tens of kilometers from the nearest known pluton. In these, the primary commodities are silver, lead, and zinc with lesser copper and iron. The polymetallic- replacement and vein deposits in the eastern parts of the study area are primarily hosted by Ordovician to Devonian dolostone units that were deposited in a continental shelf setting. For many of the polymetallic-replacement and vein tracts in the eastern part of the study area, there is evident structural preparation, including (1) Cretaceous thrust faults and folds, and (2) post-Cretaceous steep- to shallow-dipping normal



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 18. Map showing mineral-resource potential for polymetallic-vein/replacement/skarn type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.


112°
BEAVERHEAD COUNTY
MADISON COUNTY
MONTANA
IDAHO
CLARK COUNTY
FREMONT COUNTY
MMOTH CANYON M/B
SOUTH TIP BEAVERHEAD M/B
20
15
Rexburg
JEFFERSON COUNTY
MADISON COUNTY
20
26
Idaho Falls
26
BONNEVILLE COUNTY
PLAIN
91
Blackfoot
BINGHAM COUNTY
BANNOCK COUNTY
CARIBOU COUNTY
86
Pocatello
WASHINGTON
MONTANA
IDAHO
Map area
OREGON
Study areas
WYOMING
NEVADA
UTAH
EXPLANATION
Assessment tract types – polymetallic vein/replacement/skarn
High-potential (H) tract with high (D) certainty
Moderate-potential (M) tract with moderate (C) or low (B) certainty
Low-potential (L) tract with low (B) certainty
Base data
USGS study area boundary
Proposed withdrawal areas
State boundaries
County boundaries

faults. Because there are no modern studies of ore genesis for deposits in these tracts, the importance of the structural preparation is inferred from the available evidence.

Exploration and Mining History

There are many mining districts in the study area where polymetallic-vein deposits were exploited historically (see individual tract descriptions). A large number of mines, deposits, and prospects of this type are found in each mountain range except for the Lost River Range, where there is very little history of mining activity or evidence of mineralization (possibly a consequence of its original position in the Paleozoic miogeocline). In the ranges with known deposits, most production was for silver-lead-zinc; however, copper and gold were also common commodities. Many of the deposits have recorded production (tables 7, 9); however most of these polymetallic-vein, replacement, and skarn type deposits are not actively being explored or mined (table 7).

Resource Assessment Tracts

Gilmore Polymetallic-Vein Tract H/D—There is high potential, with certainty level D, for intrusion-related Pb-Ag±Au and Ag-Pb-Zn±Cu polymetallic-replacement and vein deposits in the Gilmore tract of the Texas and Spring Mountain Mining Districts in the eastern Lemhi Range (fig. 19). The tract is based on the location of a large group of mines and prospects, and the exposure of folded Ordovician to Devonian dolostone units in the footwall of a discontinuously mapped thrust fault. The presence of an Eocene pluton larger than surface exposures is interpreted from magnetic data and used as a factor in defining the tract boundaries. The western tract boundary extends 1 km into an intra-range valley and the southern boundary extends 1 km into the footwall of a normal fault that down-dropped the thrust fault system into the Little Lost River valley. The tract is trimmed on the southeast side to 1 km depth of valley fill based on geophysical interpretation where bedrock dips beneath cover.

The geology of the Gilmore tract is characterized by a thrust fault that juxtaposed Mesoproterozoic strata eastward over folded Ordovician to Mississippian siliciclastic and carbonate strata. The deformed country rock was intruded by isolated exposures of Eocene granite (including the approximately 49 Ma Gilmore stock; Bennett, 1980) that is probably largely unexposed. The older rocks and structures were complexly dismembered by normal faults (Lund and others, 2003). The bedrock is covered by relatively thin, Quaternary glacial, colluvial, and alluvial deposits along the eastern range margin (Anderson and Ponce, 2016).

Vein and replacement mineralization in the Gilmore tract is associated with Eocene syn- and post-mineral quartz-diorite porphyry and quartz diorite dikes (Umpleby, 1913). Quartz diorite dikes are present with lead-silver veins at the Lemhi Union and Silver Moon mines, Pb-Ag-Zn-Au veins and replacements at the Gilmore or Pittsburgh-Idaho mine and Pb-Ag-Zn replacements at the Jumbo mine. However, higher temperature Pb-Ag±Cu bearing magnesian skarn is also reported along a quartz diorite dike at the Colorado Group mine (Umpleby, 1913).

From 1910 to 1929, significant production came from the Gilmore mine (374,000 metric tons at 2.1 g/t gold, 374 g/t silver, 2.4 weight percent lead, and 5.7 weight percent zinc). Reported production from Lehmi Union and other mines was less significant (U.S. Geological Survey, 2005; Mitchell and others, 2015). Mining activity in the district ceased in 1929 because of the Great Depression. In the study area, 84 active lode claims are in the sections that contain the Jumbo, Grooms Democrat, Portland, Ridgeway, Little Hill, Carrie Cody, Mountain Boy, and Silver Moon mines, as well as the Old Nicholas Smelter (Fernette and others, 2016a), a part of the Pittsbrugh-Idaho Mine.

Geochemistry (Smith and others, 2016) for the Gilmore tract includes rock samples that are anomalous for Ag, As, Au, B, Ba, Bi, Cd, Cu, Mo, Pb, Sb, and Zn; and weakly anomalous for V. Sediment and soil samples from this tract are anomalous for lead and zinc; samples are weakly anomalous for copper and mercury. There are no analyzed samples of heavy-mineral concentrates in the geochemical databases for this tract.

ASTER data (Rockwell, 2016) delineate intense phyllic and argillic alteration along high ridgelines in the central part of tract. Jarosite is identified locally. Intense argillic alteration, together with possible advanced argillic alteration, is recognized in the eastern part of the tract. A SWIR scratch-error region passes through the central part of the tract.

Radiometric data (Anderson and Ponce, 2016) indicate the presence of the sedimentary and carbonate strata, but provide no indication of an Eocene Challis intrusion. Magnetic data indicate that the Eocene granite exposures are part of a larger pluton that may extend 3 km eastward in the shallow subsurface beneath the Quaternary unconsolidated deposits.

Previous USGS mineral-resource potential assessment studies mark the tract as permissive for porphyry copper deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998). The southern part of the tract was found to have high potential for polymetallic-vein deposits and to be moderately favorable for polymetallic skarn deposits (Worl and others, 1989; rendered in digital form in Carlson and others, 2007).

Mineral Hill Polymetallic-Vein Tract H/D—There is high potential, with certainty level D, for intrusion-related Ag-Pb-Cu-Zn-Au polymetallic-replacement and vein deposits in the Mineral Hill tract (fig. 20) of Blaine County, 7 km south of Hailey, Idaho (fig. 1). The tract encompasses 23 mines and prospects, and the Cretaceous Croesus quartz diorite stock. The Paleozoic argillaceous rocks of the Salmon River assemblage (Worl and Johnson, 1995) in the roof zone of the pluton are also mineralized. The mineral occurrences are characterized as both polymetallic veins with sericite-pyrite, sericite, chlorite, and calcite alteration, and polymetallic deposits containing siderite after hornfels and limy argillite. The tract boundaries reflect the estimated extent of the Croesus stock to about 1 km depth under unconsolidated Quaternary deposits on the south; the tract also includes a small mineralized area in a down-dropped fault block of roof rocks on the east side of the Wood River.

The geology of the area is characterized by Ordovician to Devonian carbonaceous argillite of the Salmon River assemblage and siliciclastic and carbonaceous Pennsylvanian to Permian Sun Valley Group that were intruded by the Late Cretaceous (about 97 Ma) quartz diorite Croesus stock (Gaschnig and others, 2010). Northeast-striking aplitic and pegmatitic dikes are widely distributed throughout the area. The Croesus stock is in fault contact with Eocene Challis Volcanics and the Ordovician-Devonian argillaceous and siliceous rocks of the Salmon River assemblage. It is covered by Pliocene-Pleistocene unconsolidated sedimentary rocks in the south (Worl and Johnson, 1995).

Polymetallic veins in the Mineral Hill tract are hosted by the Late Cretaceous (approximately 84 Ma) Croesus quartz diorite stock, and contact-metamorphosed Ordovician to Devonian carbonaceous rocks. Mineralization occurred at approximately 80 Ma (Worl and Lewis, 2001). Polymetallic veins are represented by two types: a rare Au-Ag-Cu and a common Ag-Pb-Zn-Cu-Au type. Gold-silver-copper veins contain pyrite, pyrrhotite, arsenopyrite, chalcopyrite, and locally galena, sphalerite, siderite, molybdenite, and uraninite (Anderson and others, 1950; Hall and Czamanske, 1972). Localities include the Heine, Colorado Gulch (Magdalena), McCoy, and Utah Belleview mines, and the Eclipse and Sunrise prospects. Ag-Pb-Zn-Cu-Au veins contain pyrite, arsenopyrite, sphalerite, galena, tetrahedrite, native silver, and chalcopyrite. Approximately 60 prospects are located in this vein type, but production is reported to have come only from the Chicago, Comet, Croesus, Edres, Heine, Keystone, Lark, McCoy, Overland, Star, and Utah-Belleview mines. In addition, a W-Ag-Cu-Pb vein occurrence is located in the southern part of the Croesus stock near the Lark mine (Anderson and others, 1950; Worl and Lewis, 2001; U.S. Geological Survey, 2005; Fernette and others, 2016a).

Ag-Pb-Zn-Cu-Au veins are typically associated with replacement and skarn systems along the eastern margin of the pluton. The Relief Ag-Pb-Cu-Sb-Au and Silver Star (Queen of the Hills) skarns developed around quartz diorite sills near the Minnie Moore replacement and vein deposit. Other replacement systems include the Snoose Ag-Pb-Zn-Au-Cu mine, and the Commodore Zn-Ag-Pb-Au, Oswego Ag-Pb, Peterlin Ag-Pb, Sunrise Au, and Telluride Pb-Zn prospects. More distal, polymetallic-replacement type prospects are present at Galena Gulch Mn-Fe and Marjory Pb-Ag ± Fe occurrences (Umpleby and others, 1930; Anderson and others, 1950; Fernette and others, 2016a,b).

Deposits include the Minnie Moore Ag-Pb-Zn-Cu-Au polymetallic-replacement and vein (historic resource of 136,000 metric tons at 171 g/t silver and 5 weight percent lead), and the Colorado Gulch Au-Ag-Cu vein (250 million metric tons [Mt] at 0.25 g/t gold; Long and others, 1998). The Minnie Moore mine was an exploration project in the 1980s (Link and Worl, 2001), and the Colorado Gulch (Magdalena) mine was in operation between 1985 and 1987 (Worl and Lewis, 2001). Both deposits lie outside of the study area.

In the tract, one active lode claim each is located at the Utah-Belleview and Pioneer mines, and five active lode claims are in the section that contains the vein system at the Westlake mine.

Rock samples were collected for geochemistry (Smith and others, 2016) only from the western half of the Mineral Hill tract. One or more of these rocks are anomalous for Ag, As, Au, B, Ba, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Sn, W, and Zn. Sediment or soil samples have anomalous As, Cd, Cr, Mo, Ni, Pb, V, and Zn, as well as weakly anomalous Cu. There are only two heavy-mineral concentrate samples from the northwest part of the tract and these are anomalous for Ag, Bi, Mo, Pb, and W.

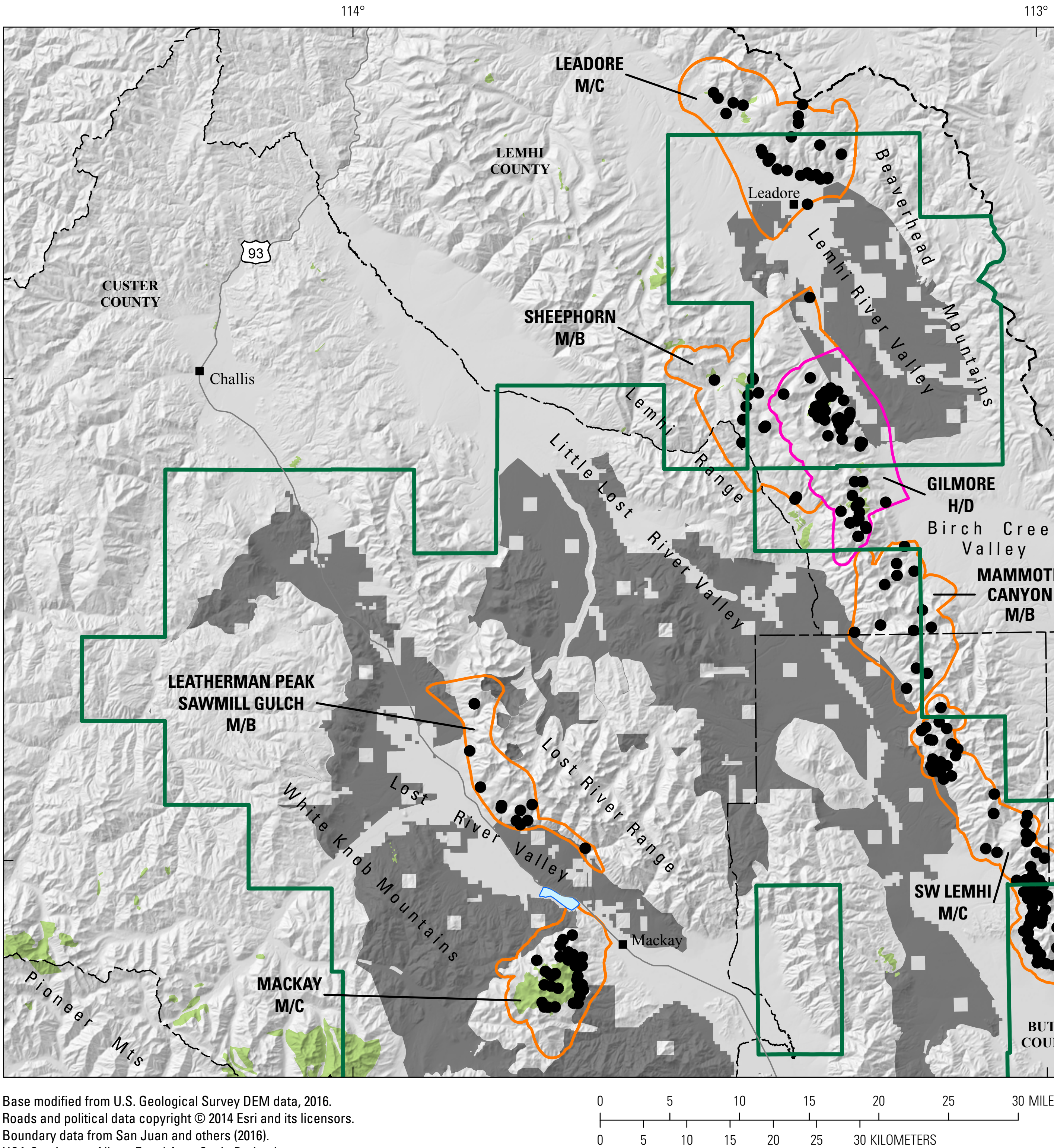
Landsat 7 remote sensing data (Rockwell, 2016) indicate ferric iron alteration in the Cretaceous intrusive rocks. The ASTER data contain an SWIR scratch-error region through tract. Ferric iron is identified locally in the Cretaceous Croesus stock. Sericite/smectite and possibly ferric iron are imaged in the Challis Volcanics rocks in northwestern and southwestern parts of the tract, and in Devonian to Ordovician sedimentary rocks in the northeast.

The Croesus stock is not well imaged in the reduced-to-pole residual magnetic intensity or Bouguer gravity maps. However, radiometric potassium and thorium maps show a northwest-striking high that coincides with the location of the Croesus stock. Radiometric and aeromagnetic signatures provide signatures suggestive of only Cretaceous plutons (not Eocene plutons) in this tract (Anderson and Ponce, 2016).

A previous USGS mineral-resource assessment marks this area as permissive for porphyry copper deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998).

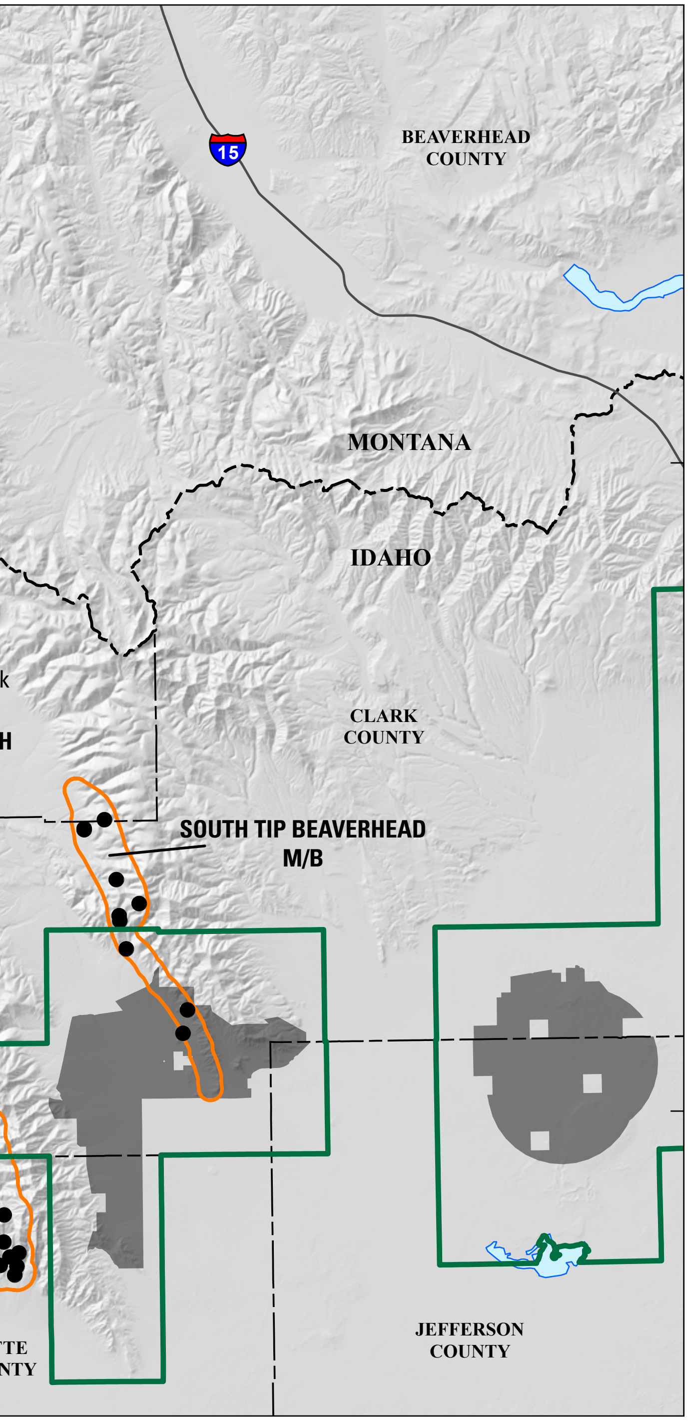
Hailey Polymetallic-Vein Tract M/C—There is moderate potential, with certainty level C, for intrusion-related Ag-Pb-Cu-Zn-Au polymetallic-replacement and vein, and Au-Ag-Cu mesothermal vein deposits in the Hailey tract (fig. 20) southwest of Hailey, Idaho (fig. 1). The tract is composed of two polygons. The Hailey tract is centered on 77 mines and more than 100 other mineral occurrences in, and related to, the Cretaceous Hailey granodiorite. The tract is drawn based on a 1-km buffer around the Cretaceous pluton and its roof zone in Ordovician to Devonian Salmon River assemblage and Pennsylvanian and Permian Sun Valley Group carbonaceous shale units. Besides encompassing the area of the numerous historic mines in the main part of the Hailey Mining District, the tract is extended east and south to include scattered mineral occurrences in roof rocks.

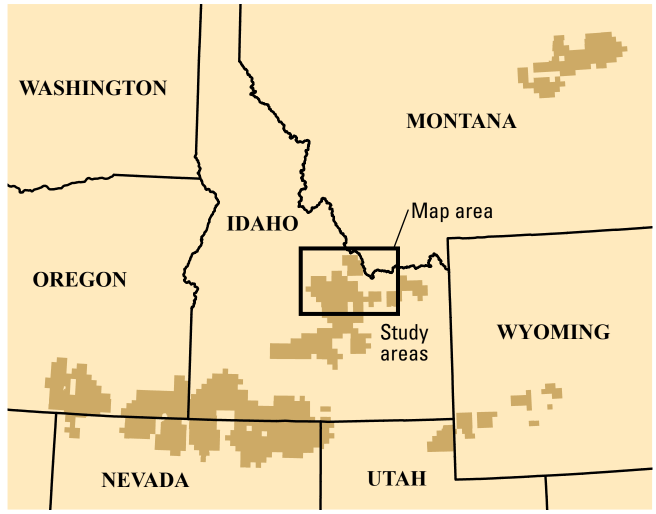
The geology of the Hailey tract is characterized by Ordovician to Devonian argillaceous and siliceous rocks of the Salmon River assemblage and Permian carbonaceous shale, carbonate, and conglomeratic rocks of the Sun Valley Group (Worl and Johnson, 1995) that were intruded by the Late Cretaceous Deer Creek stock and Hailey pluton



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 19. Inset map showing mineral-resource-potential tracts for polymetallic-vein/replacement/skarn type deposits in context of permissive geology and occurrences in the eastern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – polymetallic vein/replacement/skarn

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) or low (B) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

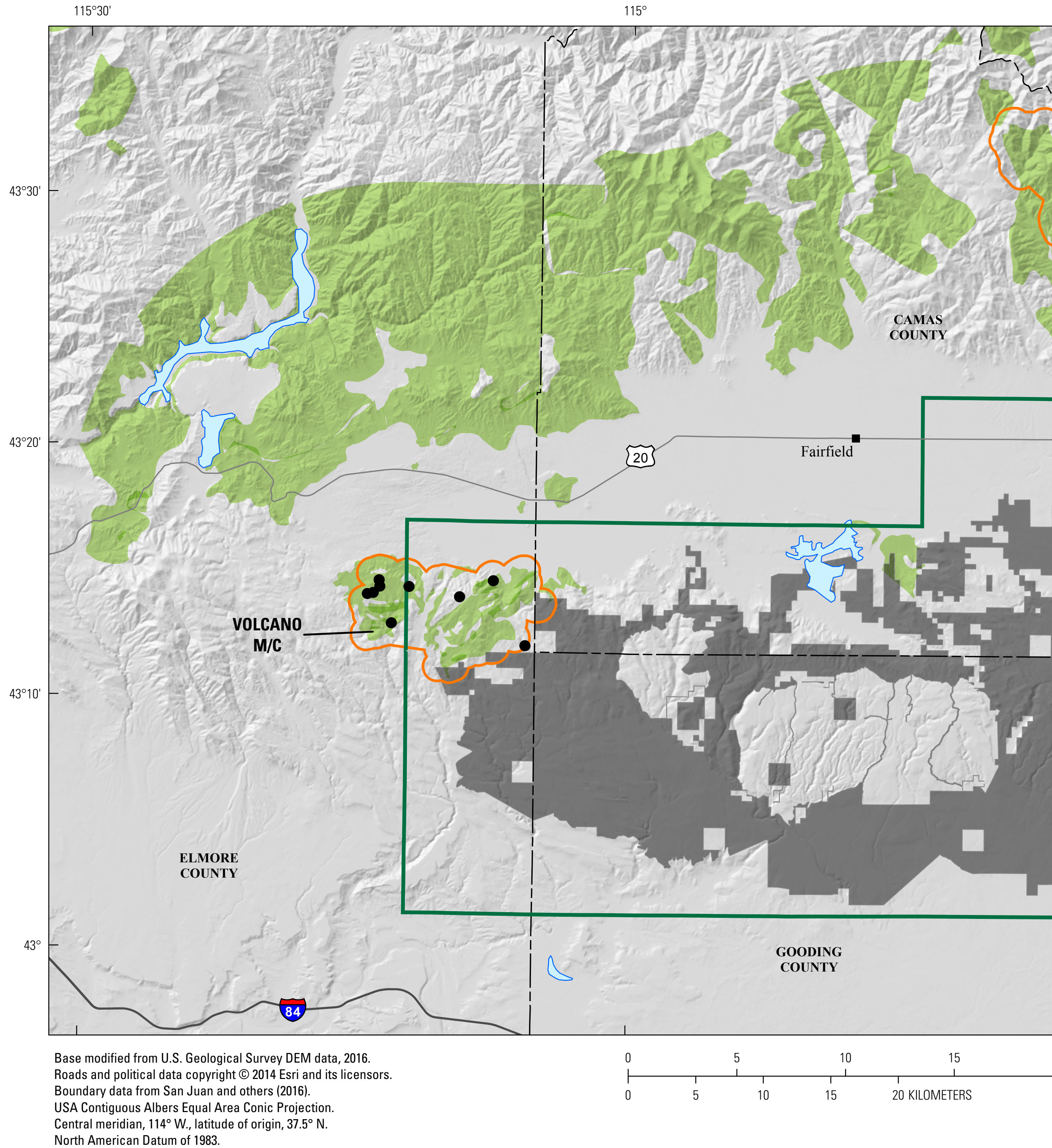
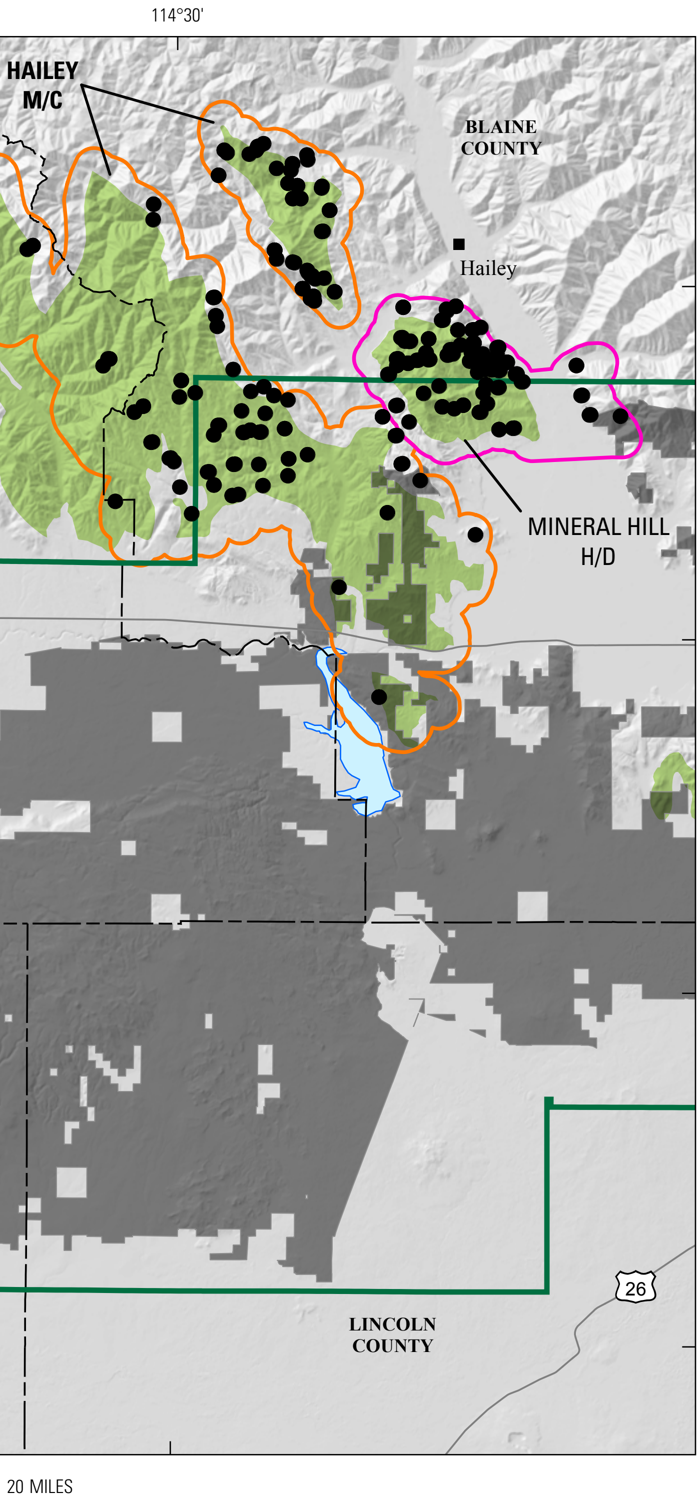
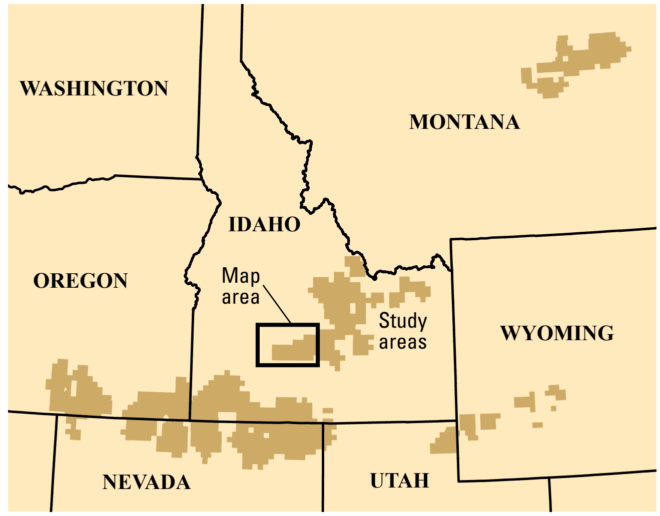


Figure 20. Inset map showing mineral-resource-potential tracts for polymetallic-vein/replacement/skarn type deposits in context of permissive geology and occurrences in the western part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – polymetallic vein/replacement

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

(approximately 94 and 84 Ma, respectively; see Link and Worl [2001] for locations) and northeast-striking Eocene dikes. The northwest-striking granodiorite Hailey stock intruded Paleozoic sedimentary formations and the Croesus stock to the east, and was intruded by younger Cretaceous biotite granite (fig. 3; Worl and Johnson, 1995; Kaufman and Othberg, 2008). The Hailey pluton is in fault contact with Eocene Challis Volcanics and is partly overlain by Miocene to Pliocene volcanic rocks in the west. In the south, the Hailey pluton is in fault contact with and unconformably overlain by Eocene Challis Volcanics rocks and Pliocene-Pleistocene basalt flows and cinder cones of olivine tholeiite, as well as unconsolidated gravel, sand, and silt deposited in fans, streams, and lakes. The Deer Creek stock intruded Paleozoic sedimentary formations on the east and west, and is covered by Eocene Challis Volcanics units on the north and south (fig. 3; Worl and Johnson, 1995).

Mineralization in the Hailey tract consists of abundant polymetallic veins hosted mainly by the Hailey and Deer Creek stocks, but also in roof pendants and the contact-metamorphosed zones of Paleozoic sedimentary rocks. Northeast-striking aplitic, pegmatitic, and lamprophyric dikes are spatially associated with veins at several locations (Worl and Lewis, 2001). Available dating indicates that mineralization is 79.5 Ma (Worl and Lewis, 2001).

Polymetallic veins in the Hailey tract include two types: a common Au-Ag ± Cu and a sparse Ag-Pb ± Zn-Cu-Au type. Au-Ag ± Cu veins were principally mined at the Camas, Golden Star, Jumbo, Princess Blue Ribbon, and Tip Top mines. These veins also occur at the Croy Creek, Bullion, Black Cinder, Happy Day, Red Rock, and Rustler Claims, Oriental, and Treasure Vault historic mines, and numerous other prospects (U.S. Geological Survey, 2005; Fernette and others, 2016a). Ore minerals include pyrite, pyrrhotite, arsenopyrite, chalcopyrite, galena, sphalerite, siderite, and locally accessory molybdenite (Happy Day mine) and uraninite (Camas mine). Ag-Pb ± Zn-Cu-Au veins are present at the larger Princess Blue Ribbon and Tip Top mines, as well as the smaller Oriental, Black Cinder, Jenny R., and Big John Claim mines. These quartz-calcite-siderite veins typically contain pyrite, arsenopyrite, sphalerite, galena, tetrahedrite, native silver, and chalcopyrite. Polymetallic veins are associated with skarn and replacement systems at the Croy Creek and Patsy No. 3 tungsten prospects; the Eureka, Narrow Gauge and Red Elephant Pb-Cu-Ag-Au ± Zn skarns; and the Arizona, Black Barb, Democrat, Idahoan, Pass Group, Whale, and Wolftone Ag-Pb replacement systems (Umpleby and others, 1930; Anderson and others, 1950; Link and Worl, 2001; Worl and Lewis, 2001; U.S. Geological Survey, 2005; Fernette and others, 2016a).

Lead-silver deposits were known along the Hailey-Bellevue mineral belt in the 1860s but little attention was given to them until about 10 years later. From the late 1870s through 1880s, the area bustled with activity. The largest production from Au-Ag ± Cu veins came from the Camas, Golden Star, Jumbo, Princess Blue Ribbon, and Tip Top mines. The Princess-Blue Ribbon Ag-Pb-Zn ± Cu-Au-W vein located in the Hailey stock has been worked intermittently since late 1800s and has had significant past production. Production in 1947–49 was 285 oz gold, 3,421 oz silver, 2,017 lb copper, 51,115 lb lead, and 44,366 lb zinc; in 1949–50 production was 438 oz gold, 4,350 oz silver, 3,453 lb tungsten, 87,827 lb lead, and 55,540 lb zinc. This property was active in 1989, but recent production data are unavailable (Worl and Lewis, 2001). On the western margin of the Deer Creek stock, mines on the Mayflower lode (including Bullion) were in operation with few interruptions from 1882 to 1908. During that period, mines along the Mayflower lode produced at least 11,000 tons of ore containing 1.5 million ounces of silver and 13 million pounds of lead (Umpleby and others, 1930). The Bullion has had intermittent production amounting to a few tens of tons of ore since 1908 (Link and Worl, 2001). Both mines lie outside of the study area. In the study area, one active lode claim is in the section that contains the Primitive Claims prospect, three active claims are located in the adjacent section that contains the Treasure Vault Au-Ag ± Cu vein, and two active claims are in the section that contains the Croy Creek Au-Ag ± Cu vein.

The Hailey tract contains many samples with anomalous concentrations (Smith and others, 2016), but most of these are outside of the study area. A number of them are located between the two separate tracts. Rock samples from this tract are anomalous for Ag, As, Au, B, Bi, Cd, Cu, Ge, Hg, Mo, Pb, Sb, W, and Zn; they are weakly anomalous for Ga. Sediment or soil geochemistry samples are anomalous for Ag, As, Au, Bi, Cd, Cu, Ga, La, Mn, Mo, P, Pb, Sn, V, and Zn; these are weakly anomalous for Hg. Heavy-mineral concentrate samples are anomalous for Ag, As, Au, B, Ba, Bi, Cd, Cu, La, Mo, Nb, Pb, Sb, Sn, Th, V, W, and Zn.

ASTER data (Rockwell, 2016) show intense ferric iron in the southwestern and south-central parts of the tract in Cretaceous granodiorite, including near polymetallic-vein deposits at Rustler Claims and Winner Prospect. There is local argillic and ferric iron to phyllic alteration near prospects adjacent to the Princess Blue Ribbon mine in similar Cretaceous intrusive rocks. Strong ferric iron anomalies are present south and southwest of the mine. Ferric iron and strong sericite/smectite ± ferric iron are identified in Cretaceous granodiorite and two-mica granite near the southwest edge of tract. Possible argillic to advanced argillic alteration and ferric iron are present near mines and prospects 0.3 to 2.7 km west and 3.4 km northwest of Patsy No. 3 tungsten prospect Ferric iron and sericite/smectite are identified less than 500 m east of Glengaril (Au-Cu-Ag-Pb bearing) and Ada Jane and Bismuth (Mo-As bearing) deposits in Permian and Pennsylvanian sedimentary rocks. Strong sericite/smectite and ferric iron (possible phyllic alteration) is present in Eocene Challis Volcanics rocks. A SWIR scratch-error region passes through the western and eastern parts of the tract.

Radiometric data (Anderson and Ponce, 2016) indicate the presence of an Eocene pluton at the western and northern extent of the tract. Magnetic data also indicate the anomalously high magnetic signature of an Eocene pluton in the west but the anomaly loses the high character to the southeast. The magnetic low signature over the Cretaceous pluton in the east is typical of the Cretaceous intrusive rocks. At the south end of the tract, radiometric mapping identifies the presence of the Eocene Challis Volcanics. There is no indication from the magnetic data of an Eocene pluton beneath the volcanic rocks at the south end of the tract.

Previous assessments mark the area of this tract as permissive for porphyry copper, for polymetallic replacement, and for skarn zinc-lead deposit types (U.S. Geological Survey National Mineral Resource Assessment Team, 1998; Parks and others, 2016).

Lava Creek Polymetallic-Vein Tract M/C—There is moderate potential, with certainty level C, for Ag-Pb±Zn-Cu-Au-Sb intrusion-related polymetallic-vein and associated quartz-adularia epithermal vein deposits in the Lava Creek tract (fig. 21), Lava Creek Mining District of Butte and Blaine Counties, 30 km southwest of Arco, Idaho (fig. 1). The tract is drawn to reflect the geometry of a subvolcanic Eocene pluton and to include Mississippian carbonate country rocks at its margins (Kuntz and others, 2007; Skipp and Kuntz, 2009). The tract is trimmed to 1 km into the footwall of the normal fault on the northeast and 1 km into country rock around the subvolcanic granite exposures on the west. The tract is also trimmed to 1 km into valley fill from the edge of bedrock on the southwest and southeast. The Lava Creek polymetallic-vein tract is coincident with the Lava Creek porphyry tract based on the local geology and the overlapping locations of several types of mineral occurrences.

The geology of the Lava Creek polymetallic-vein tract is characterized by Mississippian sedimentary formations that are overlain by Challis Volcanics (fig. 3). These rocks were, in turn, intruded and contact metamorphosed by Eocene alkalic granite and granite porphyry stocks and dikes (Anderson, 1929). Pliocene-Pleistocene and Quaternary volcanic and sedimentary units cover parts of the area (Kuntz and others, 2007; Skipp and Kuntz, 2009).

North- to northwest-striking veins are mainly hosted by Eocene volcanic rocks. However, veins are also hosted in sedimentary, volcanic, and intrusive rocks, and their contact zones. Few of the veins were mineralized for more than 100 m along strike and most of them were mineralized for less than 10 m. Veins formed at mesothermal to epithermal temperatures (Anderson, 1929; Winkler and others, 1989). Low-temperature epithermal conditions of formation are represented by the mineralogy of the Hub and Silver Bell veins, whereas higher-temperature mesothermal conditions are indicated by the mineralogy of the Paymaster vein. Veins in the district are also temporally associated with high-temperature copper and tungsten skarn deposits (see Lava Creek Porphyry tract description).

At the Hub silver-lead mine, a vein with comb, drusy, and chalcedonic quartz also contains calcite, rhodochrosite, polybasite and other sulfosalts that are associated with pyrite, arsenopyrite, galena, and lesser sphalerite and chalcopyrite. The vein is enveloped by quartz-sericite-pyrite alteration that preferentially replaced the hanging wall. This vein is hosted by metamorphosed tuff in the footwall and porphyritic rock in the hanging wall (Umpleby, 1917). The Silver Tip mine contains a similarly mineralized vein; however, vein quartz there exhibits banding. The Silver Bell Ag-Pb-Cu vein consists of a quartz- and calcite-filled brecciated fracture zone in volcanic rocks. The vein contains argentiferous galena and subordinate sphalerite and chalcopyrite. Covellite and azurite are present in the oxidation zone. Similar deposits are described at the Edna mine. The Paymaster Ag-Zn-Pb-Cu quartz vein was emplaced in a fissure along the granite porphyry and quartzite contact. The alteration envelope consists of silica, chlorite, and clay (including beidellite) that preferentially replaced the quartzite host. Mineralization is characterized by fine-grained galena that is interstitial to pyrite, pyrrhotite, arsenopyrite, abundant sphalerite, and subordinate chalcopyrite. Secondary smithsonite is relatively abundant in the oxidation zone. An antimony vein is also reported in the area. Stibnite is found in shoots in the brecciated and silicified limestone host rock (Anderson, 1929).

Mining in the district began in 1883 but was halted in 1887 after known bodies of rich, oxidized silver ore were exhausted. During the 1920s, the district had a revival of activity in an attempt to process sulfides; interest was renewed in 1943 and continued until 1946 (Nelson and Ross, 1968). The Hub mine, the largest in the tract, was discovered and worked in 1886. The Paymaster mine was the second largest in the tract and had reported production of gold, silver, lead, zinc, and silver (table 9). The Silver Bell mine shipped its first ore in 1928. The rich grade of this oxidized ore initiated an intensive prospecting campaign that continued into 1929. However, exploration was abandoned because the ore body was deemed too small to support a large-scale operation. At present, there are no active exploration projects and no active claims in the Lava Creek tract (Fernette and others, 2016a).

Geochemical samples collected in the Lava Creek polymetallic-vein tract are discussed as part of the Lava Creek porphyry tract. Two additional rock samples are anomalous for silver or molybdenum, and one sediment or soil sample is weakly anomalous for zinc (Smith and others, 2016).

From Landsat 7 data (Rockwell, 2016), small occurrences of ferric iron and CSM minerals are present in the northwestern half of the tract and 750 m northeast of the Silver Bell mine. In the ASTER data (Rockwell, 2016), a SWIR scratch-error region passes through the tract. Argillic alteration in the Challis Volcanics is also present in the northwestern half of the tract and 750 m northeast of the Silver Bell mine.

Radiometric mapping (Anderson and Ponce, 2016) distinguishes between the general locations of Challis igneous rocks and Mississippian Copper Basin Group rocks. The subvolcanic pluton is mapped by the magnetic data (Anderson and Ponce, 2016) but it is difficult to differentiate between the Eocene pluton and the north-northwest striking Snake River Plain-related rift zone that crosses this tract.

Previous assessments mark this area as permissive for copper, zinc-lead, gold skarn, porphyry copper, polymetallic replacement, and Comstock epithermal and hot-spring deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998).

Leadore Polymetallic-Vein Tract M/C—There is moderate potential, with certainty level C, for Ag-Pb ± Zn-Cu-Au polymetallic-vein type deposits in the Leadore tract (fig. 19). Mineral occurrences in the Leadore tract are primarily in Ordovician to Mississippian carbonate strata (fig. 19). The mineralized rocks are primarily along the western front of the Beaverhead Mountains, where a complex structural setting provided ample Cretaceous and Eocene structural pathways and the juxtaposition of critical lithologic units of contrasting character. The tract is drawn to encompass 21 mines and prospects that are hosted by complexly faulted Ordovician to Mississippian strata in the lower plate of a thrust fault that was subsequently cut by numerous normal faults. Production records are available for the Kimmel mine and Leadville (Sunset) property (table 7). The geometry of the tract is also based on argillic alteration determined by remote sensing, and extended along the range front to the northwest to encompass additional clusters of mines and prospects, as well as exposures of an Eocene pluton. The tract is trimmed to 1 km depth to unexposed bedrock beneath valley fill along the range front and across a buried bedrock high extending southward into the valley as determined from geophysical interpretation.

In the Leadore tract, Ag-Pb-Zn polymetallic mineral occurrences (Ruppel and Lopez, 1988; Johnson and others, 1998) are in replacement and vein deposits in the Ordovician Saturday Mountain, Devonian Jefferson, Mississippian Middle Canyon, and Scott Peak Formations (Lund and others, 2003). A major, east-vergent Cretaceous thrust fault carried Cambrian syenite and Mesoproterozoic strata in the upper plate over multiple slivers of Ordovician, Devonian, and Mississippian carbonate rocks (fig. 3). These thrust slivers were reactivated and cut by Cenozoic normal faults of several generations (Lund and others, 2003). The mineral occurrences are primarily in this complex structural setting where carbonate rocks of different compositions were juxtaposed against quartzite, fine-grained arkosic strata, and syenite. The structurally disrupted Eocene pluton near Little Eightmile Creek (see Lund and others, 2003, for location) is a possible source of hydrothermal activity. Both Cretaceous thrust faults and Eocene normal faults probably formed the fluid pathways. The mineralized zones were truncated on the south-southwest by range-front normal faults.

Historic mines in the Leadore tract include the Kimell, Leadville, Maryland, Commodore, Mineral Hill, Digmore, Silver Bell, Grizzly Hill, and Buckhorn, along with numerous other occurrences (Ruppel and Lopez, 1988; Johnson and others, 1998). There is active exploration at the Leadville property (Fernette and others, 2016a).

Intense sericite/smectite + ferric iron are mapped by ASTER data in Paleozoic carbonate rocks and in Cambrian syenite surrounding mines and prospects along the range front. Argillic to local phyllic alteration increase in intensity along the range front to the west edge of the tract. Mapped occurrences of jarosite are present near the range front west of the tract.

Rock samples collected in the Leadore tract are anomalous for Ag, As, Au, B, Bi, Cd, Ce, Co, Cu, Hg, La, Mo, Nb, Pb, Sb, Se, Sn, Ta, U, V, or Zn. Sediment or soil samples are anomalous for Ag, Au, Cd, Cr, Mn, Pb, Sb, Se, or Zn; and three samples are weakly anomalous for As. The one heavy mineral concentrate sample collected in this tract was split into a magnetic fraction (C1), a weakly magnetic fraction (C2), and a nonmagnetic fraction (C3). All three fractions were analyzed for this one site. The C1 fraction is anomalous for V. The C2 fraction is anomalous for Cu. The C3 fraction, which commonly contains sulfide and oxide ore minerals, is anomalous for Ag (50 ppm), B, Ba (more than 10,000 ppm), Cu, La, Mo, Nb, Pb (more than 50,000 ppm), Sn, V, and Zn.

Radiometric data indicate the presence of the sedimentary rocks and does not provide the expected signature (high values) for the exposed Eocene pluton. Magnetic data do image the pluton and suggest the presence of a larger buried Eocene pluton at the northwest extent of the tract. Depth of valley fill along the range front is modeled from the geophysical data and identifies a buried bedrock high at shallow depths beneath valley fill, projecting southward toward Leadore (Anderson and Ponce, 2016).

The USGS has not previously published a mineral-resource assessment in the area covering the Leadore tract.

Mackay Polymetallic-Vein Tract M/C—There is moderate potential, with certainty level C, for intrusion-related polymetallic skarn, replacement, and vein deposits in the Mackay tract (fig. 21) of the Alder district, 6 km west of Mackay, Idaho (fig. 1). The tract is based on the presence of numerous mines and prospects in the roof zone of the Eocene Mackay pluton and, locally, its carbonate roof rocks. The tract was trimmed along 1-km buffers on normal faults on the northwest and southeast sides and to 1 km into valley fill on the east. The tract was extended southwest to encompass an area of alteration from ASTER remote sensing data. The Mackay polymetallic-vein/replacement/skarn tract surrounds the Empire porphyry tract.

The Mackay tract is characterized by carbonate rocks of the Mississippian White Knob Limestone and McGowan Creek Formation that were intruded by the Eocene Mackay pluton (fig. 3). The pluton consists of quartz monzodiorite, granite porphyry, granite, and numerous syn- and post-mineralization dikes. The Mackay pluton is exposed in a horst that is bounded by east-northeast striking normal faults (Skipp and Kuntz, 2009) and was subsequently also tilted to the northeast (see description of Empire porphyry tract, above).

Intrusion-related mineral occurrences include the Au-Ag-Pb ± Zn-Cu Grand Price and Black Daisy (Kennedy Lead) polymetallic vein; the Au-Ag-Pb-Zn ± Cu Doughboy, Silver King, Mk Claims, Puzzler, and Silver Gem polymetallic replacement; the Au-Ag-Pb-Zn-Cu ± W Blue Bird, Champion, George Washington Nos. 1-4, Kenneth Wayne, and Mammoth polymetallic skarn; the Fe ± Ag-Cu Red Sky and Saddle Fe skarn; and the Ag-Au Royal Ruby and Ag ± Pb-W Joan skarn deposits (Umpleby, 1917; Nelson and Ross, 1968; U.S. Geological Survey, 2005; Fernette and others, 2016a). Polymetallic-replacement sites are relatively distal (1 to 3 km) to the Mackay pluton, whereas skarn sites are proximal to the Mackay pluton.

Past production data are reported from the Black Daisy, Blue Bird, Champion, Doughboy, George Washington Nos. 1–4, Grand Prize, and Silver King mines (Mitchell and others, 2015). Of the PLSS sections that are in the tract, 17 contain 87 active lode claims. These are distributed on the eastern half of the Mackay pluton. In addition, three active placer claims are located in the western margin of the Mackay pluton (table 7).

Because the Mackay tract encloses the Empire tract, only the geochemistry for the Mackay tract area outside of the Empire tract is discussed here (see Empire tract geochemistry description to include elements from that tract). The two rock samples collected in the Mackay-only part of this tract are anomalous for Ag, As, Bi, Co, Cu, Mo, Pb, W, and Zn. There are three sediment or soil samples collected in the Mackay-only area, and one or more of these are anomalous for Ag, Bi, Cd, Co, Cu, Mn, Mo, Nb, Pb, Sn, Th, W, and Zn. Only two heavy-mineral concentrate samples were collected and these contain anomalous concentrations of Bi, Nb, or W. For information on samples and data interpretation, see Smith and others (2016).

ASTER (Rockwell, 2016) satellite imagery shows intense phyllic and argillic (and locally ferric iron) alteration in the White Knob Mountains. Sericite and ferric iron surrounds zones of argillic and weathered phyllic alteration. The tract contains possible small zones of advanced argillic alteration. Calcite, sericite, and ferric iron are mapped in the south-western and central parts of the Mackay pluton and in adjacent Mississippian carbonate strata. Intense sericite and ferric iron are mapped in mine workings near Darlington Shaft.

Radiometric data (Anderson and Ponce, 2016) identify the location of Challis igneous rocks and of Mississippian carbonate strata. Magnetic data (Anderson and Ponce, 2016) identify the exposures of the Eocene Mackay pluton and suggest that it continues beneath the surface for a distance of 5 km south and west of the tract.

Previous USGS mineral-resource-potential assessments have assessed the area encompassed by this tract as permis-sive for copper, zinc-lead, gold skarn, porphyry copper, and polymetallic-replacement deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998), and moderately to highly favorable for polymetallic skarn and vein deposits (Worl and others, 1989; rendered in digital form in Carlson and others, 2007; Parks and others, 2016).

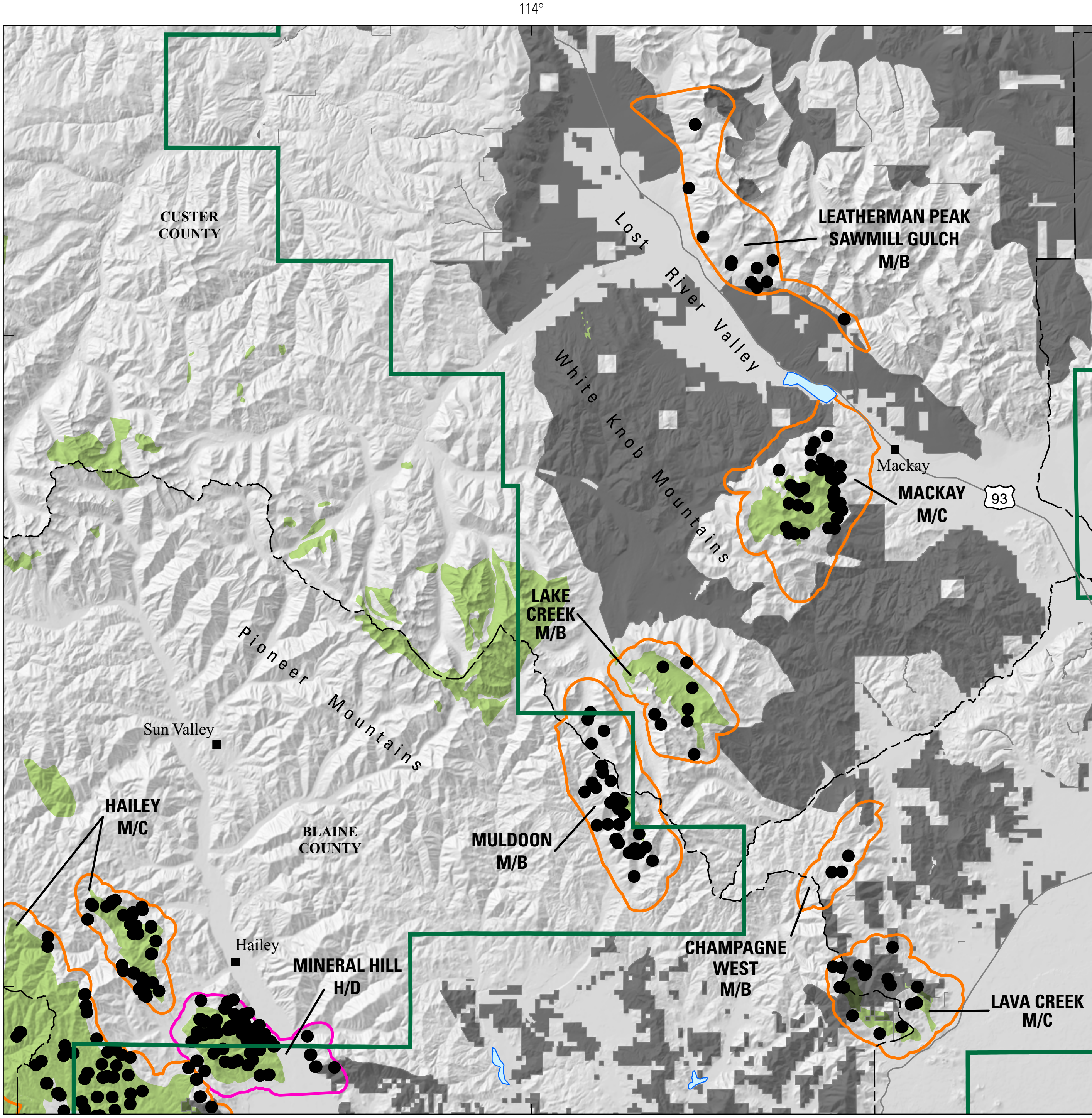
Southwest Lemhi Polymetallic-Vein Tract M/C—A moderate potential, with certainty level C for polymetallic-vein type deposits, is determined for the Southwest Lemhi tract (figs. 19, 20). Many historic mines and prospects are reported in this tract and Ag-Pb-Zn ± Cu-Au production is reported from three mines. Devonian and Ordovician dolostone units are the most common host rocks for the vein deposits encompassed by the tract. However, some deposits are in Mississippian limestone and others are in Neoprotero-zoic and Mesoproterozoic strata. The mineral occurrences are near a discontinuously mapped thrust fault near the western foot of the Lemhi Range, and mostly in deformed Ordovician to Mississippian footwall rocks. Structural controls are evident but insufficiently mapped and interpreted. The tract geometry is drawn around 73 mines, prospects, and other types of mineral occurrences that extend along about 30 km of the southern Lemhi Range. The tract is trimmed on the west side to 1 km into the upper plate of the thrust fault and (or) 1 km into valley fill. On the east side, the tract is limited to 1 km into Mississippian rocks to include all mineral occurrences.

The Southwest Lemhi tract is primarily associated with host rocks of the Devonian Jefferson Formation, but also both older and younger strata. In the most completely mapped southwestern part of the tract, Cambrian Tyler Peak Formation; Ordovician Summerhouse Formation, Kinnikinic Quartzite, and Saturday Mountain Formation; Devonian Jefferson Formation; and Mississippian Middle Canyon Formation (figs. 3, 4) are isoclinally folded beneath an east-directed thrust fault that carried Mesoproterozoic Lemhi Group units (Skipp and Kuntz, 2009). In this part of the tract, the Ag-Pb-Zn ± Cu-Au vein deposits are located in the lower plate of the thrust fault. Along the west side of the range, north of the well-mapped area, that structural relation is discontinuously mapped at reconnaissance scale (Wilson and Skipp, 1994) and the bounding thrust fault is inferred from map interpretation. Combining the datasets, it can be inferred that the mines and prospects of the Southwest Lemhi tract are in the footwall of the large, regional unnamed thrust fault that probably provided structural fluid pathways at many scales.

There are 46 deposits recognized in this tract; 17 of these are recognized as mines, including the May Queen, Ajax, Badger Creek, Wilbert, Bighorn, Lookout, Great Western, and Copper Mountain. Production is recorded from the Wilbert (total value of $1,952,216 in 100,000 oz silver, 10,000 lb copper, 40,000,000 lb lead, and 100,000 lb zinc), Bighorn (1,001 oz silver and 50,001 lb lead), and Badger Creek (5,001 oz silver, 51 lb copper, and 100,001 lb lead) mines (tables 7, 9). Other named deposits and prospects include Camp Creek Prospects Nos.1, 2, and 3; Eightmile Canyon Placer; Copper Mountain No. 8; and Dome. There are no active claims in the tract.

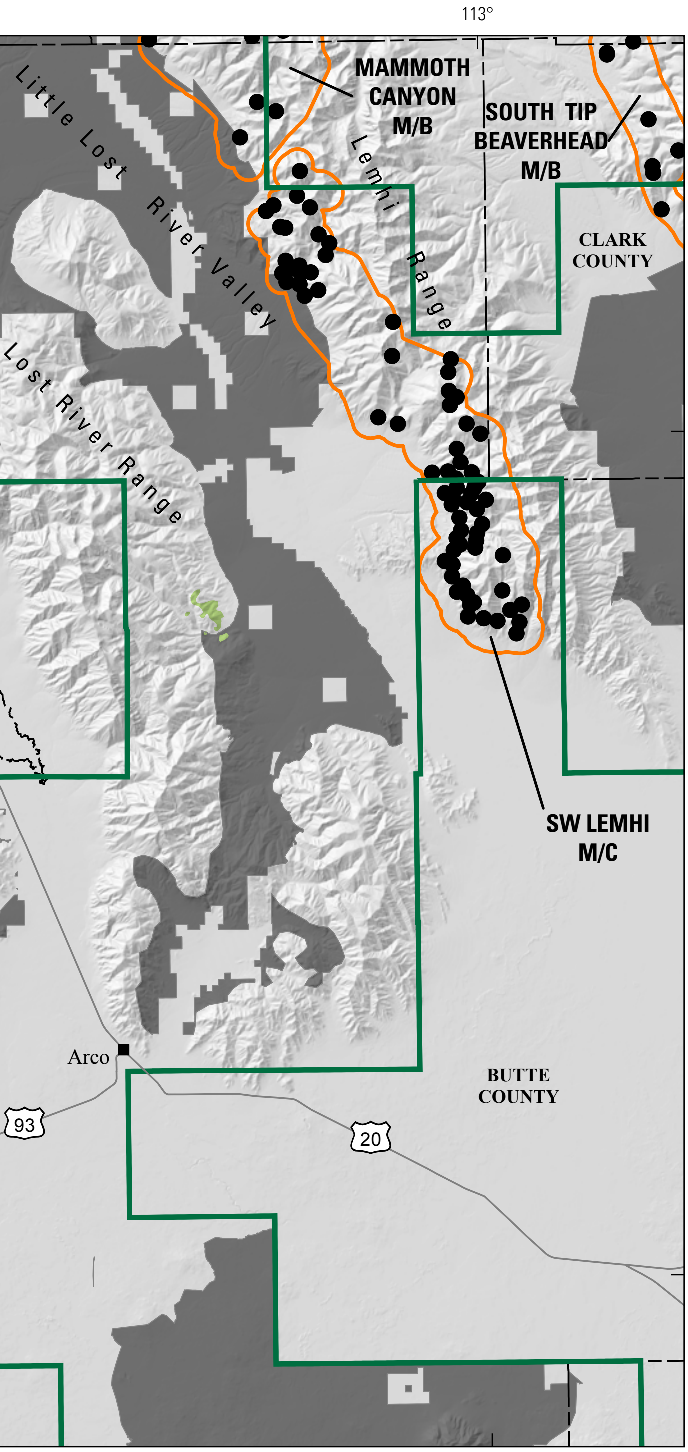
There are no analyzed samples of heavy mineral concen-trates in the geochemical databases (Smith and others, 2016) for the Southwest Lemhi tract. Rock samples collected in the tract are anomalous for Ag, As, B, Ba, Cd, Cu, Mo, Pb, and Zn; and weakly anomalous for Sb. Sediment and soil samples are anomalous for Nb and Pb, and weakly anomalous for As, Cd, and Zn.

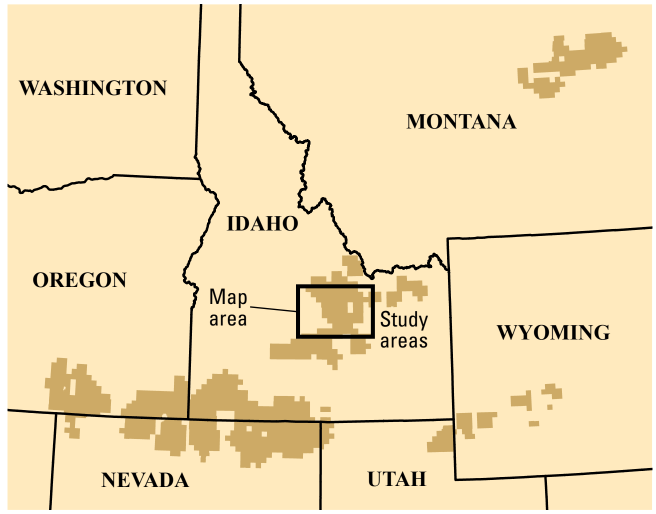
ASTER and Landsat 7 data (Rockwell, 2016) indicate significant alteration present along this tract. Pervasive argillic + ferric iron or weathered phyllic alteration is identified along ridgelines in the southern part of the Southwest Lemhi tract. Intense argillic to phyllic alteration is identified 1 km west of the Bighorn polymetallic-replacement deposit (Au, Ag, Pb, Zn, Ba). Argillic (± ferric iron) and possible phyllic alteration is identified 0.5 and 1 km west, respectively, of the Williams Creek prospect (Pb, Ag; distal polymetallic vein) near the north end of the tract. A small zone of argillic to advanced argillic alteration is identified 1.2 km south of the



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 21. Inset map showing mineral-resource-potential tracts for polymetallic-vein/replacement/skarn type deposits in context of permissive geology and occurrences in the central part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – polymetallic vein/replacement/skarn

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) or low (B) certainty

Permissive geology

Occurrences

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

Iron Cap prospect (Ag, Fe, Cr; polymetallic replacement) at the extreme north end of the tract. Argillic with local phyllic alteration, including some jarosite identified in Neoproterozoic to Cambrian Wilbert Formation and Mississippian carbonate rocks near Silver King, South Creek No. 121, South Creek No. 36, and South Creek No. 147 prospects (distal polymetallic-vein type), is identified in the southern part of the tract. Calcite and dolomite (±sericite/smectite±ferric iron) is identified 1.4 km to the east of the tract in Devonian to Ordovician carbonate rocks.

Radiometric data (Anderson and Ponce, 2016) show a low response over the sedimentary host rocks. Magnetic data show a moderate anomaly adjacent to part of the western tract boundary that may indicate a buried Eocene (or younger) pluton or Snake River Plain rift-related basalts below valley fill.

The Southwest Lemhi tract is partly studied by previous USGS mineral-resource-potential assessments and is overlapped by several tracts from those earlier studies. The present tract is partly coincident with a tract for polymetallic veins in quartzite and a tract with potential for lode veins (Worl and others, 1989; tracts from previous mineral resource assessments rendered in digital format in Carlson and others, 2007).

Volcano Polymetallic-Vein Tract M/C—There is moderate potential, with certainty level C, for intrusion-related Au-Ag-Cu-Pb-Zn polymetallic-vein deposits in the Volcano tract (fig. 20), 36 km southwest of Fairfield, Idaho (fig. 1). The tract geometry is based on encompassing the mineral occurrences in Cretaceous granite and granodiorite. The Cretaceous intrusive rocks are in the roof zone above an Eocene pluton. The tract is drawn using a 1-km buffer around the Cretaceous exposures.

The geology of the tract is characterized by Cretaceous granodiorite and two-mica granite intruded by Eocene granite and subvolcanic dacite. These rocks are partly covered by Miocene rhyolite in the south and by Pliocene-Pleistocene basalt in the north. Quaternary unconsolidated alluvium overlies these rocks north of the tract (Worl and Johnson, 1995). The mineralization is undated and presently available data do not clarify if mineral occurrences are related to Cretaceous or Eocene events.

Mineral deposits in the Volcano tract consist of northeast-striking Au-Ag±Cu-Pb-Zn quartz veins that are hosted in Cretaceous granodiorite. In addition, many northeast-striking granophyric and rhyolitic dikes of probable Eocene age are spatially and temporally associated with mineral occurrences (Allen, 1952; Bennett, 2001). Intrusion-related veins were exploited at the Ajax, Index, Volcano, Revenue, and Bowerman historic mines. Quartz-calcite veins contain pyrite, chalcopyrite, argentiferous galena, sphalerite, magnetite, specular hematite, and gold, and are enveloped by sericite, albite, and epidote alteration halos. Adjacent to the veins, feldspars are pervasively replaced by sericite, and hornblende rims are replaced by biotite that was altered locally to muscovite and subordinate chlorite (Allen, 1952). At the Revenue mine, molybdenite is present in addition to these sulfides.

The Bowerman, Index, and Revenue mines had discontinuous production from 1914 to 1942. From 1902 until closing, the Bowerman mine produced 1,416 oz silver from 41 tons of ore; and the Index group produced 240 oz of silver from 60 tons of ore. These mines produced no more than a few ounces of gold (Bennett, 2001). No sections have active lode claims (Dicken and San Juan, 2016).

There are no samples of rocks and only one heavy-mineral concentrate sample in the geochemical databases (Smith and others, 2016) for the Volcano tract. The single concentrate sample was collected along the southern border of the tract and may not be representative of the mineralized system. No element was found to be anomalous in this concentrate sample. Anomalous concentrations of uranium and thorium, plus weakly anomalous concentrations of lead and vanadium are found in the sediment or soil samples collected in this tract. The uranium and thorium anomalies are probably unrelated to any porphyry mineralization but to the generally high values found in Eocene igneous rocks (Bennett, 1980; Millard and others, 1981).

Landsat 7 remote-sensing data (Rockwell, 2016) indicate small local occurrences of ferric iron and sericite/smectite. Argillic minerals are imaged locally. In the ASTER data (Rockwell, 2016), a SWIR scratch-error region passes through the central part of the tract. Northeast-striking bands of possible argillic/advanced argillic alteration are present in Miocene rhyolitic volcanic rocks.

Radiometric data (Anderson and Ponce, 2016) map the Eocene felsic igneous rocks but not the Cretaceous rocks. Magnetic data (Anderson and Ponce, 2016) suggest that the Eocene pluton extends to the north beneath mapped basalt.

A previous USGS mineral-resource-potential assessment marks this area as permissive for porphyry copper-, Comstock-, and hot-spring-type deposits (U.S. Geological Survey National Mineral Resource Assessment Team, 1998; Parks and others, 2016).

Champagne West Polymetallic-Vein Tract M/B— The Champagne West tract is determined to have moderate potential for polymetallic-vein deposits, with a certainty level of B (fig. 21). The Champagne West tract encompasses an elongated zone of polymetallic-vein mineral occurrences, geochemical anomalies, and alteration. The mineral deposits are primarily hosted by Mississippian and Pennsylvanian carbonate rocks along a normal fault that cut a Cretaceous thrust fault; mineral deposits are controlled by the normal fault. The tract is drawn around four mines and mineral occurrences in the carbonate rocks and an alteration zone identified from remote sensing. On the west side, the tract is trimmed to extend 2 km into the volcanic rocks of the hanging wall west of the normal fault, and 1 km eastward into the footwall of the normal fault.

The mineral deposits in the Champagne West tract lie along a northeast-striking, down-to-the-west normal fault that probably controlled mineralization. The normal-fault hanging wall units are Challis Volcanics rocks, including the lower dacite flow and dome complex, upper rhyolite flow and dome complex, and tuff of Stoddard Gulch. The normal-fault footwall units, the Mississippian McGowan Creek, Middle Canyon, and Scott Peak Formations, are tightly folded and lie in the upper footwall to the Copper Basin thrust fault that was cut by the deposit-hosting normal fault (fig. 3; Skipp and Kuntz, 2009).

Mineralized occurrences in the tract include the Butte-Antelope and Lead Belt mines, Lowboy and Footwall deposits, and Silver Haze prospect (Anderson, 1929). Historic production is reported for the Butte-Antelope and Lead Belt mines. Production figures for Butte-Antelope mine are 10,000 oz silver; 1,000 lb copper; 10,000 lb lead; and 10,000 lb zinc, and for the Lead Belt mine are 51 oz gold; 10,000 oz silver; 1,000 lb copper; and 500,000 lb lead (table 7). The tract is adjacent to epithermal mineralization in the Champagne epithermal tract but mineralization had different characteristics.

There are no analyzed samples of heavy mineral concentrates in the geochemical databases (Smith and others, 2016) for the Champagne West tract. Six rock samples collected in the tract are anomalous for Ag, As, Au, B, Cd, Pb, or Sn, and weakly anomalous for Ba, Hg, or Zn. Soil or sediment samples are anomalous for Ag, As, Au, Cd, Cu, Mn, Pb, or Zn.

The presence of sericite/smectite alteration minerals along the ridgeline near prospects in the Mississippian carbonate rocks is indicated from ASTER data (Rockwell, 2016). This anomaly is possibly related to the lithologic character of the exposed Mississippian carbonate units. There is a small occurrence of argillic alteration in Eocene Challis Volcanics rocks west of the tract-bounding normal fault. A SWIR scratch-error region passes through the eastern part of the tract. Radiometric data map the presence of both volcanic and sedimentary rocks. Magnetic data (Anderson and Ponce, 2016) indicate the presence of a positive anomaly beneath the tract, signaling the potential of an underlying Challis-age intrusion.

The Champagne West polymetallic-vein tract overlaps permissive tracts from previous U.S. Geological Survey mineral-resource assessments for lode veins, polymetallic veins in black-shale, and polymetallic veins in carbonate rocks (Worl and others, 1989; rendered in digital format in Carlson and others, 2007; Parks and others, 2016).

Lake Creek Polymetallic-Vein Tract M/B—The Lake Creek tract is determined to have moderate potential for polymetallic-vein deposits, with a certainty level of B (fig. 21). The Lake Creek tract incorporates an Eocene pluton and volcanic rocks, as well as minor Mississippian carbonate rock. The geometry of the tract is based on a 1-km buffer in volcanic and Mississippian carbonate roof and country rocks around an exposed and mineralized Eocene Challis pluton. The tract encloses minor anomalous results from rock geochemical data, and areas of alteration identified from ASTER data.

The shallowly emplaced Eocene Challis granite pluton that makes up most of the tract, its related overlying Challis Volcanics, and minor exposures of Mississippian Copper Basin Group carbonate roof rocks (Skipp and Kuntz, 2009) all contain small mineral occurrences. The setting and many nearby occurrences suggest the possibility of a larger pluton-related hydrothermal system. The adjacent tracts suggest a north-northeast striking mineralized belt parallel to the orientation of Eocene Challis vent systems and dike swarms (Worl and Johnson, 1995).

Six Ag-Pb-Zn-Au mineral occurrences, including the Upper Lake Creek deposit (Fernette and others, 2016b), are in the Lake Creek polymetallic-vein tract. The Upper Lake Creek deposit had reported past production of zinc, lead, silver, and gold although the production details are not provided (McHugh and others, 1991). The Lake Creek polymetallic-vein tract is in a belt with two larger tracts, the Muldoon polymetallic/replacement/skarn tract and the Copper Basin porphyry tract (figs. 14, 16). There are polymetallic veins in country rocks of the adjacent Muldoon polymetallic-vein tract and previous production from the adjacent Copper Basin porphyry tract. The setting and occurrences suggest the possibility of a larger pluton-related hydrothermal system. The adjacent tracts suggest a north-northeast striking mineralized belt encompassing a complex system may parallel the orientation of nearby Eocene Challis vent systems and dike swarms (Worl and Johnson, 1995).

There are no analyzed samples of heavy mineral concentrates in the geochemical databases (Smith and others, 2016) for the Lake Creek tract. Rock samples collected in the tract are anomalous for Ag, As, B, Ba, Cu, Pb, and Zn. Only one of the sediment or soil samples collected in this tract is weakly anomalous for zinc.

Landsat 7 data (Rockwell, 2016) show locally intense CSM and ferric iron zones along ridgelines near the northern extent of the tract, and small but intense CSM and ferric iron zones on the ridgeline on the east edge of the tract. The ASTER data (Rockwell, 2016) image an intense propylitic alteration (carbonate/epidote and possibly sericite/smectite or ferric iron) in Eocene Challis Volcanics rocks in the central part of the tract. A smaller argillic to phyllic alteration zone, with possible local advanced argillic alteration, is identified near the north boundary. A smaller argillized zone is identified 830 m further northwest, near the Unnamed prospect (Ag, Pb, Zn, and Au). Argillic alteration and ferric iron (likely representing phyllic alteration) are identified in the Challis Volcanics rocks near the north boundary. This altered zone corresponds with an anomalous mineral exposure identified using Landsat 7 data. Jarosite and sericite/smectite + ferric iron alteration signatures (likely strong phyllic alteration) are identified in propylitized Challis volcanic rocks. The radiometric data (Anderson and Ponce, 2016) show the common, anomalously high response over Eocene Challis intrusive and extrusive rocks. Magnetic data (Anderson and Ponce, 2016) show an anomalous high at depth beneath the tract. This anomaly could be due either to an Eocene Challis intrusion or to a rift feature related to the Snake River Plain rift zone.

In a previous mineral-resource potential assessment, the area of the Lake Creek polymetallic-vein tract is partly encompassed by permissive tracts for a lode-vein tract and for polymetallic veins in a black-shale tract (Worl and others, 1989; rendered in digital form in Carlson and others, 2007; Parks and others, 2016).

Leatherman Peak-Sawmill Gulch Polymetallic-Vein Tract M/B—The Leatherman Peak-Sawmill Gulch tract is determined to have moderate potential for polymetallic-vein deposits with a certainty level of B (fig. 20). The tract geometry is based on a polymetallic-vein deposit-type tract from a previous USGS mineral-resource assessment (Worl and others, 1989) and several barite, zinc, lead, and silver occurrences that do not have reported production. Geochemical anomalies help define the tract. Most of these occurrences are not associated with aeromagnetic anomalies, so intrusions may be absent. The mineral occurrences and geochemical anomalies are hosted primarily by Ordovician to Devonian dolostone units. The tract is delimited by 1-km buffers into the overlying Mississippian units that are not preferential hosts for the mineral occurrences, and into the valley fill west of the Lost River Range.

The Leatherman Peak-Sawmill Gulch tract lies low on the west side of the Lost River Range (fig. 20). The range is an east-tilted fault block that exposes the oldest rocks on the west side. Country rocks are the Ordovician Saturday Mountain Formation, Silurian Laketown Dolomite, and Devonian Jefferson Formation that are predominantly dolostone units with intervening unconformities (figs. 3, 4). The western margin of the tract is bounded by a down-to-the-west, range-front normal fault (Wilson and Skipp, 1994). There are no exposed plutons in the Lost River Range, so the origin and controls of the fluids for the mineral occurrences are poorly understood.

Several mineral occurrences are shown in the mineral databases. These include the Mt. Borah prospect, as well as the Hilltop 1–4, Jayrock, and Upper Cedar Creek deposits. There are also 41 closed lode claims listed in the BLM data (Causey, 2007; Dicken and San Juan, 2016; Fernette and others, 2016a). These deposits are reportedly lead-zinc-silver bearing and are somewhat unique in the study area because the veins are also barite bearing. None of the records for the occurrences include production figures.

Rock samples (Smith and others, 2016) contain anomalous concentrations of Ag, B, Ba, Cd, Cr, Cu, Ga (300 ppm), Ge (more than 100 ppm), Mo, Ni, Pb, Sb, Sn, U, and Zn. Sediment or soil samples were found with anomalous concentrations of gold and barium, and a single sample with high tungsten. Heavy-mineral concentrate samples (Smith and others, 2016) are most enriched in Ba and Sr, but also have a few samples with anomalous concentrations of Ag, B, Be, Cd, Mo, Ni, Pb, W, or Zn.

From the ASTER dataset, pervasive argillic and ferric iron to weathered phyllic alteration are identified in the host Devonian to Ordovician carbonate rocks, including in the vicinity of the Jayrock deposit (Pb, Zn, Ag, and Ba). Small zones of argillic alteration surrounded by sericite/smectite are identified less than 1 km south of the Unnamed prospect (Ag, Cu, and Ba) near the range-front fault. Large zones indicative of carbonate minerals (mainly calcite ± sericite/smectite) are identified directly northwest of the mapped alteration.

Radiometric data (Anderson and Ponce, 2016) show a low response over the carbonate host rocks. Aeromagnetic data do not indicate the presence of a buried pluton in, or directly adjacent to, this tract.

The Leatherman Peak-Sawmill Gulch polymetallic-vein tract is partly overlapped by a zone that was included in permissive tracts from two earlier USGS mineral-resource potential studies. These permissive tracts from previous reports include the "base- and precious-metal veins, replacements, and disseminations at depth" tract (Worl and others 1989; called polymetallic in digital version by Carlson and others, 2007) and the polymetallic-replacement permissive tract (U.S. Geological Survey National Mineral Resource Assessment Team, 1998; Parks and others, 2016).

Mammoth Canyon Polymetallic-Vein Tract M/B—The Mammoth Canyon tract has moderate potential for polymetallic-vein and related deposits, with certainty level B (fig. 19). The Mammoth Canyon tract is primarily located in Devonian and Ordovician dolostone and minor Mississippian limestone, which are in a lower-plate thrust zone. The tract encompasses nine silver-lead-zinc and copper-gold mines and several other mineral occurrences. The mineral occurrences are not apparently spatially associated with a pluton. The tract is fault bounded; boundaries are drawn to encompass the mineralized units as well as linking several normal faults and the trace of a discontinuously mapped thrust fault system. The west side of the tract is defined as extending 1 km into the hanging wall of a range-bounding normal fault of the Lemhi Range (Wilson and Skipp, 1994). The northeast side of the tract is truncated at about 1 km depth into valley fill (Lewis and others, 2012).

The primary host rock for mineralization in the tract is dolostone of the Devonian Jefferson Formation, but also includes Mississippian limestone units (figs. 3, 4). These units are tightly folded into large, upright and eastward-overturned folds (Wilson and Skipp, 1994; Skipp and Kuntz, 2009).

The Bell Mountain group, Lost Cabin and Copper Buff mines, and the Maggie Springs, Davis Canyon, and Copper Bell prospects are in the tract. These are primarily lead-silver occurrences in vein and replacement deposits (Anderson, 1948a; Ruppel and Lopez, 1988) but no studies have been conducted to provide detailed information about the deposits. Production figures are available for the Bell Mountain group and Lost Cabin deposits (table 9). The production for the Bell Mountain group is about 5,000 lb copper, 100 lb lead, and small amounts of gold and silver. The Lost Cabin production is listed as about 1,000 lb lead and small amounts of silver and copper.

There are no analyzed samples of rocks or heavy mineral concentrates in the geochemical databases (Smith and others, 2016) for this tract. Sediment samples are anomalous for cadmium and zinc, and weakly anomalous for arsenic. One rock sample directly south of this tract (and possibly unrelated to any Mammoth Canyon tract mineralization) is moderately anomalous for barium.

Two zones of intense argillic, argillic + ferric iron, and (or) phyllic alteration are mapped by ASTER data. The southernmost of these zones is located less than 1 km southwest of the Copper Bell prospect (lead and zinc). Phyllic alteration with local argillic + ferric iron surrounds the Mammoth Canyon prospect No. 2 (zinc) in Mississippian limestone units. In the same area, there are other zones of possible phyllic alteration (sericite/smectite + ferric iron). Sericite/smectite + ferric iron signatures are mapped near the Maggie Springs prospect (gold-copper polymetallic veins). Dolomite and local calcite is mapped in Devonian and Ordovician dolostone units (Rockwell, 2016).

Radiometric data (Anderson and Ponce, 2016) show a low response over the carbonate host rocks. Aeromagnetic data show a magnetic anomaly low over the entire tract; thus, there is no evidence of a buried pluton associated with mineralization in this tract.

The Mammoth Canyon tract area is not covered by a previous U.S. Geological Survey mineral-resource assessment.

Muldoon Polymetallic-Vein Tract M/B—There is moderate potential for polymetallic-vein and related deposits in the Muldoon tract (fig. 21). The extent of the Muldoon polymetallic-vein tract includes six historic mines and several prospects. The known deposits are in the roof zone of an Eocene granite pluton, where the pluton is in contact with Mississippian carbonate rocks (fig. 3). The tract extends along the zone of mineral occurrences and is also based on alteration mapped by remote sensing and on geochemical anomalies. Tract boundaries are drawn to provide a 1-km buffer above the contact of the granite on the east, and the outcrop of the host carbonate member of the Copper Basin Group on both east and west.

The host rocks for mineral occurrences in the tract are Mississippian Copper Basin Group carbonate rocks in the roof of an unnamed Eocene Challis granite pluton (Skipp and Kuntz, 2009). The host rocks dip west in a deformed panel under an east-vergent Cretaceous thrust fault that was reactivated by Eocene or younger normal faulting. The host rocks in the footwall were deformed into map-scale folds during the Cretaceous deformation.

Mines and deposits in the tract include the Carrier, Gamebet, John Larson, Mackinaw Group, Star of Hope, and Drummond Copper deposits, as well as the Bent Pine Tree No. 10 and Hecla-Carrier prospects (Fernette and others, 2016b). These are Ag-Pb-Zn-Cu vein systems, but have had little production and geologic descriptions are lacking. Production at the Gamebet mine is recorded at about 1,000 lb copper (Fernette and others, 2016b). This tract lies in the roof rocks between the Muldoon porphyry tract and the Lake Creek polymetallic-vein tract in Eocene granite.

ASTER data (Rockwell, 2016) document a zone of intense argillic + ferric iron and (or) phyllic alteration 1 km northwest of the Drummond copper mine (Cu-Au-Pb-Ag). Sericite/smectite surrounds the zones of argillic and (or) phyllic alteration. Possible advanced argillic alteration extends to 1.5 km west of the Drummond mine. Extensive sericite is mapped along several ridgelines, most likely related to the lithology of Mississippian carbonate rocks. Intense argillic + ferric iron sericite + ferric iron (phyllic) and local jarosite is also identified 750 m southeast of the Star Hope mine Pb-Zn-Ag-Cu-Au polymetallic-replacement or vein deposit. Small local occurrences of argillic alteration ± ferric iron are present in other parts of the tract.

There are no analyzed samples of heavy mineral concentrates in the geochemical databases (Smith and others, 2016) for the Muldoon tract. Rock samples collected in the tract were anomalous for Ag, As, Ba, Bi, Cd, Cu, Mo, Pb, Sn, W, and Zn. Sediment or soil samples are anomalous for Cd, Co, Mo, Mn, Ni, and Zn; and weakly anomalous for Ag, Cu, and V. Anomalies for almost all of these elements in sediment and soil samples continue west and northwest outside of the tract and may indicate additional mineralization or possibly lithologic associations.

Radiometric data map sedimentary and volcanic host rocks. A magnetic anomaly high overlying the tract may indicate a larger buried Challis pluton that is exposed in the adjacent Lake Creek tract.

The Muldoon polymetallic-vein tract geographically overlaps with two tracts from a previous U.S. Geological Survey mineral-resource potential assessment. The area is part of permissive tracts for lode veins, and polymetallic veins in black-shale tract (Worl and others, 1989; rendered in digital form in Carlson and others, 2007; Parks and others, 2016).

Sheephorn Polymetallic-Vein Tract M/B—There is moderate potential for polymetallic-vein deposits, with certainty level B, in the Sheephorn tract (fig. 19). The Sheephorn polymetallic-vein tract is based on known mines and prospects that are primarily hosted in Ordovician to Devonian dolostone units and also Ordovician quartzite and Mesoproterozoic strata. The tract includes small, Eocene Challis Volcanics-related granite exposures and evidence from magnetic data of the presence of a larger buried pluton. The tract boundaries are limited based on 1-km buffers along down-to-the-west normal faults that juxtapose Eocene Challis Volcanics against the older, mineralized strata. The tract is trimmed to 1 km depth of valley fill along the faulted eastern front of the Lemhi Range based on geophysical and drill-hole data.

A wide variety of host strata in the tract include the Devonian Jefferson Formation, the Silurian Laketown Dolostone, and the Ordovician Saturday Mountain Formation. To a lesser extent it also includes the Mesoproterozoic Gunsight and Swauger Formations and Ordovician Kinnikinic Quartzite (figs. 3, 4; Wilson and Skipp, 1994; Lund and others, 2003). The available geologic maps in this tract are based on compilations, and structural details are contradictory and discontinuous. Based on the limited data, the mineralized units may lie mostly in the footwall of a thrust fault carrying Mesoproterozoic strata that is discontinuously mapped and down-dropped along normal faults into the valley on the west side of the Lemhi Range. Mineralized rocks were truncated on the eastern margin by the Cenozoic range-front fault.

The Zn-Pb-Mn-Au Lady May mine and the Utah, Roosevelt, Carlyle, Herbert Carlyle, Trey, and Idaho deposits and prospects are located in the tract (McHugh and others, 1991; Johnson and others, 1998). A number of adits and pits explore nearly horizontal quartz and barite veins and breccia zones. These mineralized zones lie along fractures related to faults of unspecified origin (Ruppel and Lopez, 1988). There are no production records from mineral occurrences in this tract. Polymetallic veins with significantly more records of production and exploration history are present in the adjacent Gilmore polymetallic-vein tract (with higher resource potential ranking and certainty, fig. 19). Porphyry mineralization is present in the adjacent Latest Out tract and the nearby Blue Jay tract (fig. 14).

ASTER imagery (Rockwell, 2016) shows intense phyllic and argillic alteration near high ridgelines along the east edge of the tract. Intense argillic alteration with possible ferric iron or advanced argillic alteration is imaged surrounding polymetallic-vein mineral occurrences and on the eastern side of the tract. A small zone of argillic alteration is identified 750 m northwest of the Herbert Carlyle prospect (Zn-Au-Pb-Mn) in Mesoproterozoic metasedimentary rocks of the Lemhi Group. Intense phyllic and argillic alteration is identified along the east edge of the tract, with argillic and possible advanced argillic alteration identified 1.5 km to the west-northwest, both in Mesoproterozoic metasedimentary rocks of the Swauger and Lawson Creek Formations. Intense phyllic alteration is located in the northwestern part of the tract. Jarosite is mapped at the northernmost part of the tract. Argillic alteration surrounded by sericite/smectite is identified in the northeastern part of the tract. Sericite/smectite and ferric iron is imaged in Miocene volcaniclastic rocks, but this zone probably indicates clay in the section rather than indicating hydrothermal alteration.

There are no analyzed samples of heavy-mineral concentrates in the geochemical databases (Smith and others, 2016) for the Sheephorn tract. Rock samples collected from the western part of the tract are anomalous for Ag, Au, B, Ba, Cd, Mo, Pb, and Zn, and weakly anomalous for Co and Cu. Sediment samples have anomalous concentrations of Cd, Pb, Sb, U, and Zn. It is possible that the uranium anomaly is related to transported sediment and was not derived from rocks in the tract. For the northern part of the tract, sediment samples are moderate to weakly anomalous for cesium, copper, lead, and tin. It is possible that the cesium anomaly is unrelated to rocks in the tract.

Radiometric data (Anderson and Ponce, 2016) show a moderate response over Challis intrusive and extrusive rocks. Magnetic data show central low values surrounded by high values adjacent to the tract boundary. These data also show a positive anomaly approximately 5 km south of the Sheephorn tract, indicating the location of a potential Eocene Challis pluton at depth.

The Sheephorn tract area is not covered by previous USGS mineral-resource assessments.

South Tip Beaverhead Polymetallic-Vein Tract M/B—In the South Tip Beaverhead polymetallic-vein tract (fig. 19), mineral occurrences are in Mississippian carbonate rocks and in Devonian and Ordovician dolostone. The tract is drawn to encompass nine mines and prospects, including three with past production records, in Cambrian to Mississippian rocks located in a lower-plate thrust zone. The tract also includes mineralized Devonian Jefferson Formation. A normal fault on the east bounds the mineralized strata. The tract is trimmed on the west to 1 km into the upper plate of the thrust fault and (or) 1 km into areas covered by valley fill.

The South Tip Beaverhead tract is underlain by Mesoproterozoic through Permian strata (fig. 3). Mineralized zones are principally in Ordovician to Devonian dolostone units (primarily Saturday Mountain and Jefferson Formations) and Mississippian limestone and shaley limestone units (primarily Middle Canyon and Scott Peak Formations). The only digital geologic map available is the statewide compilation (Lewis and others, 2012), but more detailed mapping in the Italian Peaks Wilderness Study Area to the north (Skipp and others, 1983; Skipp, 1984) indicates a series of east-vergent thrust faults and related folds, which are both upright and overturned, that can be extended southward into the South Tip Beaverhead tract. These Cretaceous contractional structures were disrupted by Cenozoic normal faults that both reactivated thrust faults and offset them (Skipp, 1985). No Cretaceous or Eocene plutons are mapped in the southern Beaverhead Range and none are inferred from geophysical interpretation. Although the age and origin of deposits in the South Tip Beaverhead tract remains largely unstudied, Cretaceous- through Eocene-aged structures probably provided pathways for mineralizing fluids from distal sources (Skipp and others, 1983; Skipp, 1984).

Mines in the tract are in the form of Ag-Pb-Zn bearing polymetallic-vein and replacement deposits. The mineral occurrences include the Rainbow Hill, Weimer, Scott, Scott Butte, Hill No. 3, IDI-31430 mines, and one additional unnamed mine. Other deposits include Long Valley, Peterson, George Ridge Uranium Co., and an unnamed prospect (Fernette and others, 2016b). Production figures are unavailable for mineral occurrences in the tract. Active exploration is ongoing at the Long Valley and Scott Butte prospects (Fernette and others, 2016b).

There are no analyzed samples of heavy-mineral concentrates in the geochemical databases (Smith and others, 2016) for the South Tip Beaverhead tract. Six rock samples were collected from three sites in this tract and may or may not be representative of mineralization. Of these six rocks, two are anomalous for boron, two are weakly anomalous for neodymium, and one is weakly anomalous for barium. Only one sediment sample in the tract is anomalous for cadmium. No other sediment or soil samples are anomalous.

Mapping by ASTER (Rockwell, 2016) indicates the presence of alteration systems in the tract. A SWIR scratch-error region passes through the northern part of tract. Argillic to advanced argillic alteration minerals are present along Long Canyon in the vicinity of the Hill No. 3 and Rainbow Hill prospects (silver-lead polymetallic vein). Phyllic alteration (sericite/smectite + ferric iron and local argillic + ferric iron) is identified surrounding the Peterson prospect (iron; distal polymetallic vein). Small occurrences of possible phyllic alteration are imaged at the extreme north end of the tract in Mesoproterozoic metasedimentary rocks of the Lemhi Group. Argillic (± ferric iron) and possible phyllic alteration are identified in Pliocene to Miocene rhyolite 800 m south of the Scott mine polymetallic-replacement deposit (Ag-Au-Cu-Zn-Pb-U) and Scott Butte exploration property (Cu-Pb-Zn). Calcite and dolomite (± sericite/smectite ± ferric iron) are identified south of those occurrences in upper Paleozoic sedimentary rocks.

Radiometric data (Anderson and Ponce, 2016) show a low response over the host sedimentary rocks. Magnetic data show a moderate to low response over most of the tract. At the south edge of the tract, a magnetic anomaly is interpreted as Snake River Plain basalt flows that are partly obscured by younger valley-fill deposits.

The South Tip Beaverhead tract area is not covered by previous USGS mineral-resource potential assessments.

Polymetallic-Vein Low Tract L/B—There is low potential, with certainty level B, for polymetallic-vein deposits across a broad part of the study area (fig. 14). This tract is based on the presence of permissive geology in the form of Eocene Challis granitic plutons. The tract is based on exposures of these plutons from geologic maps and extended into country rocks using a 10-km buffer to account for the generalized mapping and shallow burial beneath older roof/wall rocks or younger cover.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in 2 tracts and moderate mineral-resource potential in 11 tracts for polymetallic-vein type deposits. This type of deposit is characterized by enrichment in Ag, Pb, Zn, Cu, Au, and Ba. For economic analysis of these commodities, see Bleiwas (2016).

Carlin-Type Gold

Deposit Type Description

Carlin-type gold deposits are located in Paleozoic sedimentary rocks underlain by extensionally thinned continental crust that was affected by the southward sweeping Eocene magmatic arc (for example, Hofstra and Cline, 2000). In Nevada, most of the Carlin-type gold production and resources are located in Paleozoic sedimentary rocks deposited near the platform margin in slope environments, although gold deposits also are present in marginal basin, shelf, foreland basin, and overlap successions (Cline and others, 2005; Berger and others, 2014; Cook, 2015). Deposits generally are located at intersections between high-angle faults and permeable reactive strata. Gold-bearing disseminated pyrite precipitates when H_2S-bearing hydrothermal fluids react with iron-bearing minerals or fluids in sedimentary rocks (Hofstra and Cline, 2000).

Permissive Geology and Occurrences in Study Area

The geotectonic history and geologic setting of the North Central Idaho study area is analogous to that in Nevada. Eocene intrusive and volcanic rocks are scattered across the study area. Permissive host rocks were deposited in marginal basin, slope, shelf, foreland basin, and overlap settings (DCs, DSOs, Ms, OCs, TKs, PPs, PMs on fig. 3 and Lewis and others, 2012).

Exploration and Mining History

Although it is possible that Carlin-type gold resources are present in the study area, and the potential for these deposits was considered by Hall and others (1995), we could find little or no evidence of exploration for, or descriptions of, any Carlin-type gold occurrences. As explained in the next section, the bodies of jasperoid present in the study area are unlike those associated with Carlin-type gold deposits.

Resource Assessment

Carlin-Type Gold Low Tract L/B—There is low potential, with certainty level B, for Carlin-type gold deposits in the aforementioned permissive rock units of the study area (tract details available in appendix 2 and in San Juan and others, 2016). For this tract, no other evidence was found to substantiate mineralizing processes. Based upon the lack of additional mineral occurrence, geochemical, or alteration evidence, no tracts with moderate or high potential could be identified.

Jasperoid Precious Metals

Deposit Type Description

Jasperoid is pervasively silicified rock that is best developed in calcareous sedimentary rocks. Jasperoid forms in many different deposit types where hot fluids infiltrate cool country rocks. The geochemistry of jasperoid can provide an indication of the nature of associated deposit types and, in some cases, it can contain enough gold and silver to be mined.

Permissive Geology and Occurrences in Study Area

In the study area, jasperoid is preferentially located along normal faults and fractures near the contact between rocks of the Eocene Challis Volcanics and the underlying Paleozoic marine carbonate and siliciclastic strata. The permissive geology shown on figure 23 corresponds to the Eocene Challis Volcanics.

Exploration and Mining History

Jasperoids in the study area have been prospected for gold (Soulliere and others, 1995) and mined for agate slab samples at the Prudent Man mine (fig. 12). Jasperoid can only be profitably mined for metals if it contains high concentrations of precious metals, such as gold and silver, which is not the case in the study area (Wilson and others, 1988; Soulliere and others, 1995).

Resource Assessment Tracts

Jasperoid Precious-Metals Tract M/B—There is moderate potential, with certainty level B, for distal disseminated and epithermal gold-silver deposits in the vicinity of jasperoids located in the study area (fig. 22). This tract is based on the Jasperoid Precious-metal Tract from the Challis National Forest assessment (Worl and others, 1989) and mapped jasperoid units (unit Tj from the Challis National Forest map of Wilson and Skipp, 1994, and from the Arco 30' × 60' quadrangle map of Skipp and Kuntz, 2009). A 1-km buffer was applied to those jasperoid map polygons to account for associated alteration.

The resulting jasperoid tracts are located on the periphery of Eocene porphyry/intrusion-related tracts (Empire and Mackay porphyry-related tracts), in the subvolcanic parts of epithermal tracts (for example, Navarre-Lehman and Champagne), and at subvolcanic sites that are not spatially associated with known mineralization (fig. 23). The permissive geology is the base of the volcanic rocks where they are, or were prior to erosion, in contact with older carbonate units (fig. 23).

The geochemistry of these jasperoids is typical of those associated with the distal parts of porphyry systems and the subvolcanic parts of epithermal systems (Wilson and others, 1988; Soulliere and others, 1995). They have very low Au:Ag ratios (≤0.02) and weak Au-Cu (0.29) and Zn-Cu (0.43) correlations. Their Au:Ag ratios are much lower than those in Carlin-type gold deposits, which typically are greater than 3 (Hofstra and Cline, 2000). Thus, we conclude that the jasperoid tract polygons in the focal area are distal/shallow manifestations of Eocene porphyry-epithermal systems. Together with the porphyry, intrusion-related, and epithermal tracts they define a north-northwest striking mineral belt that is mostly in the White Knob Mountains (fig. 13).

The tract includes sections with two active and seven closed notices and one closed plan of operations for precious metals, as well as numerous active and closed lode claims (Causey, 2007; Dicken and San Juan, 2016; Fernette and others, 2016b).

In previous mineral-resource potential assessments (Parks and others, 2016), a jasperoid precious-metals tract from the Challis National Forest assessment (Worl and others, 1989) overlaps the present tract.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has moderate mineral-resource potential in one tract for jasperoid precious-metals occurrences associated with distal disseminated and epithermal gold-silver deposits. For economic analysis of these commodities, see Bleiwas (2016).

Hydrothermal-Volcanic Mineral System

Epithermal/Hot-Spring Precious-Metal Veins

Deposit Type Description

Epithermal/hot-springs deposits are related to shallow hydrothermal systems active in calc-alkaline volcanic edifices and shallowly eroded volcanic rocks (Berger, 1986a,b; Simmons and others, 2005). The main commodities are gold and silver. Primary criteria for the epithermal/hot-spring precious-metal deposit type are the presence of shallow hydrothermal features such as sinter and hydrothermal breccias in association with known felsic eruptive centers and lava domes. Host rocks are commonly stratovolcano complexes, but country rocks of any composition may host the deposits. Wall-rock alteration predates mineralization and is typically well zoned, ranging from acid sulfate and clay alteration in the central zone, through argillic zones, to peripheral propylitic alteration. Ore mineralogy ranges from shallow cinnabar and gold; to central copper sulfide minerals and sulfosalts, sphalerite, galena, and gold; and peripheral sphalerite, galena, and siderite. Pyrite is ubiquitous in central, peripheral, and deep zones. The sulfidation states of these deposits range from high sulfidation in the shallow parts of the deposits to intermediate sulfidation states in deeper and peripheral zones (Simmons and others, 2005; Sillitoe, 2010). Characteristics of the deposit type include (1) Cu, As, W, Au, Pb, and Zn geochemical anomalies, (2) aeromagnetic lows possibly caused by hydrothermal alteration, and (3) low thorium and potassium radiometric data possibly caused by relative potassium enrichment due to metasomatism (Berger, 1986a,b; Plumlee and others, 1995; Simmons and others, 2005).

Permissive Geology and Occurrences in Study Area

Hot-spring and slightly deeper epithermal processes were active across much of the study area in association with both the Eocene Challis igneous event and the Miocene and Pliocene rhyolitic volcanism of the early Snake River Plain event. Appropriately shallow crustal levels, where hot springs and shallow hydrothermal processes were active, remain preserved across most of the study area. For this reason, the entire study area is permissive for mineral deposits of the epithermal/hot-springs precious-metal type.

Exploration and Mining History

An epithermal precious-metal deposit, hosted in Eocene Challis Volcanics rocks, was mined at the Champagne mine intermittently up until the early 1990s. Another epithermal precious-metal deposit is presently being mined at the Spencer mine, directly adjacent to the east edge of the study area. It is hosted in Pliocene-Miocene rhyolite related to the Snake River Plain volcanism. Mineral-resource-potential tracts for epithermal/hot-spring precious-metal veins combined with epithermal precious opal and epithermal gypsum are located in the study area (fig. 24).

Resource Assessment Tracts

Champagne Tract H/D—There is high potential for epithermal/hot-spring type precious-metal vein deposits in the Champagne tract (fig. 25). The permissive unit for the Champagne tract is limited to the Eocene Challis Volcanics. The Champagne Creek, Ella, Hornsilver, Last Chance, and St. Louis mines, as well as seven unnamed deposits (Fernette and others, 2016a) are in the tract. Boundaries of the tract are drawn to reflect geology, occurrences, geochemical anomalies, and alteration products (from ASTER data) that are all centered on the location of the Champagne mine. The tract includes a northeast-striking Eocene dike swarm, the mineral occurrences in a large graben containing Eocene Challis Volcanics, and jasperoid in carbonate rocks along the normal-fault boundary zones. The tract includes a 1-km buffer around jasperoid exposures on the southeast side of the main tract. The Champagne tract also includes a small area of possible mineralized rock buried beneath adjacent Pleistocene and Pliocene basalt of the Snake River Plain.

The Champagne tract lies directly north of the Snake River Plain. The mineralized rocks are primarily hosted in a tuff and a dacite flow-and-dome complex, both units that are in the lower part of the Eocene Challis Volcanics. The base of the volcanic section overlies folded Mississippian limestones of the McGowan Creek and Scott Peak Formations (fig. 3; Skipp and Kuntz, 2009). The Challis Volcanics are in a large northeast-striking graben. The series of down-to-the-west normal faults forming the east and southeast sides of the graben bound the mineralized zones. Large jasperoid deposits are mapped in the zone between the upper part of the Mississippian rocks and the overlying volcanic rocks, indicating significant hydrothermal activity in the location of the tract (Wilson and others, 1988; Souliere and others, 1995; Skipp and Kuntz, 2009).

Veins and wallrock-replacement deposits are present along north-northeast striking, steeply northwest-dipping breccia zones that parallel the strike of Eocene dike swarms in the tract and region-wide. Jasperoid outcrops east and northeast of the mine area provide evidence of additional hydrothermal activity in the vicinity. The north-northeast striking fault zones and fractures may have acted as fluid pathway structures. Quartz-sericite-pyrite alteration is reported around veins and hydrothermal breccias. There are extensive areas of argillic alteration in volcanic rocks and dikes, and areas of jasperoid in Paleozoic carbonates (Skipp and others, 1989). The Champagne mine produced ore most recently in the 1980s. District-wide production for 1886–1993 is recorded as 61,475 oz gold at 0.0167 troy ounces per metric ton (opt); 850,974 oz silver at 0.23 opt; 80,000 lb copper; 1,576,000 lb lead; and 2,922,000 lb zinc (Long and others, 1998). There are four closed plans of operations for lode gold in the tract.

Rock geochemistry samples (Smith and others, 2016) have anomalous concentrations of Ag, As, Au, B, Ba, Bi, Cd, Cu, Hg, Mo, Pb, Sb, Se, Sn, Te, and Zn plus weakly anomalous concentrations of Cr, Ga, and V. Sediment or soil geochemistry samples display anomalous concentrations of Ag, Au, B, Bi, Cr, Ga, Hg, Pb, Te, and V plus weakly anomalous concentrations of Co, Cu, Ni, and Zn. Heavy-mineral concentrate samples contain anomalous concentrations of Ag, Ba, Bi, Cd, Co, Cu, Ga, La, Nb, Pb, Sb, Sn, W, and Zn.

ASTER remote-sensing data (Rockwell, 2016) show scattered, advanced argillic, kanditic (characterized by halloysite and other clay minerals of the kaolinite group), and sericitic alteration in Eocene volcanic rocks in the tract. More intense argillic, sericitic, and ferric iron alteration signatures are present in limestone east of the Champagne mine where there is also intense jarosite (after pyrite).

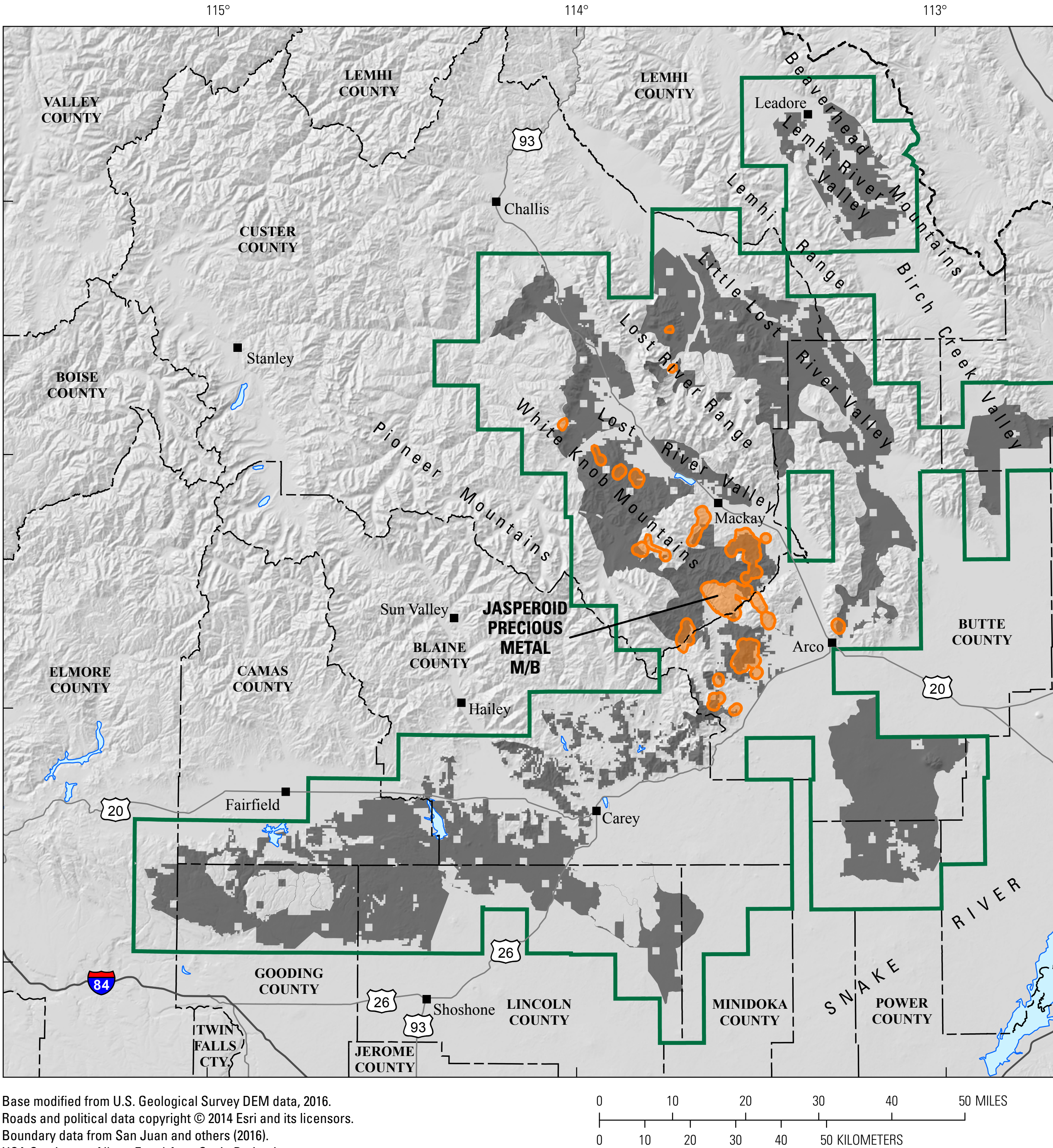
Radiometric data (Anderson and Ponce, 2016) indicate that the tract is sited over a residual magnetic low. One magnetic high in the subsurface several kilometers to the west, and another magnetic high southeast of the tract, are interpreted as plutonic centers of possible Eocene age.

The Champagne epithermal/hot-spring precious-metal tract is in an area studied by previous USGS mineral-resource potential assessment studies. The Champagne tract overlaps the north end of the Lava Creek mineralized area as categorized in Klein (2004) and the northern extension of a hot springs gold-silver mineral resource tract as shown in Box and others (1995).

Navarre-Lehman Tract M/C—There is moderate potential for epithermal/hot-spring precious-metal vein deposits, with certainty level C, in the Narvarre-Lehman tract (fig. 25). The Navarre-Lehman tract is underlain by rocks of the Eocene Challis Volcanics in a down-dropped block. Exposed jasperoid bodies are included near the northern extent of the tract. The tract includes the Navarre Creek deposit. Additional factors used to determine the extent of the tract include an area of alteration minerals identified by ASTER imagery on the south end of the Mackay reservoir. The tract is bounded by a normal fault west of Lehman Creek and a major northeast-striking fault on the north side. The northeast boundary of the tract is trimmed against valley fill and the Mackay reservoir.

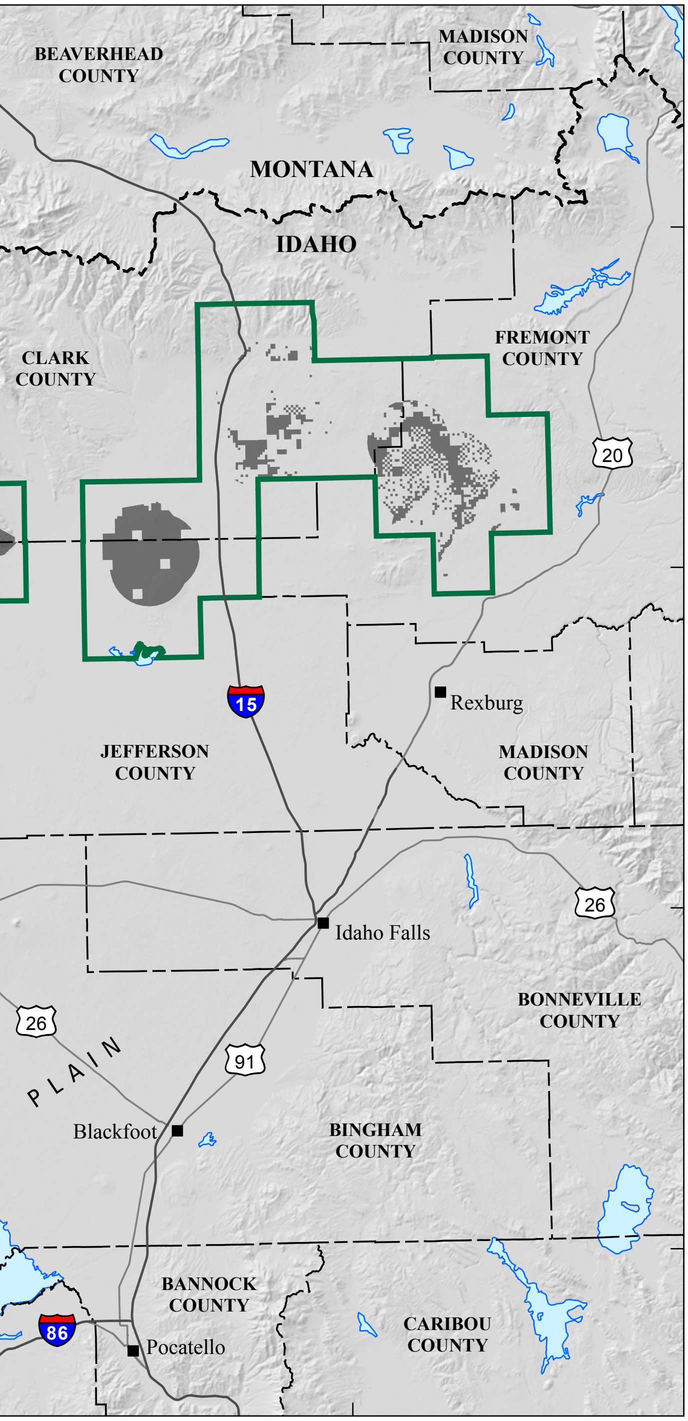
Host-rock units include the tuff of Cliff Creek, tuff of Cherry Creek, and porphyritic rhyolite intrusions that are part of Navarre Dome Complex of the Challis Volcanics. Other rocks in the tract include the upper latite lavas of the Challis Volcanics and intrusions (Skipp and Kuntz, 2009). Jasperoid bodies included in the tract indicate significant Eocene hydrothermal activity. The tract is in a block that was down-faulted relative to deeper-seated rocks of the Eocene subvolcanic Mackay Granite to the southeast.

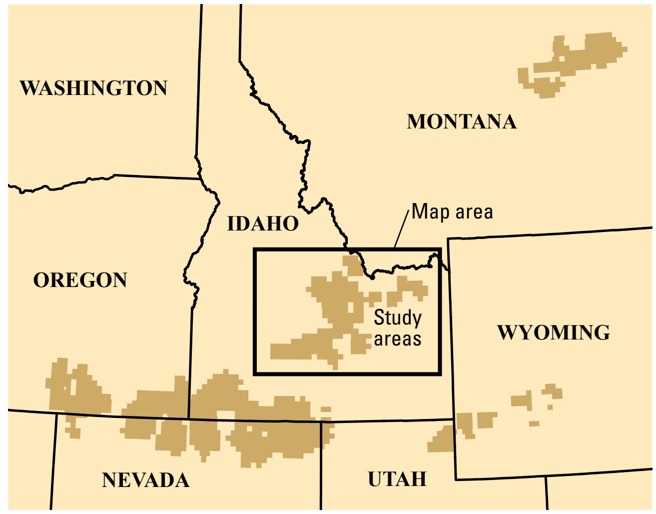
Within the tract, the Navarre Creek deposit previously produced a small amount of antimony (McHugh and others, 1991). There is no reported production at the Lehman Creek prospect. Geologic characteristics indicating mineralization processes in this tract include argillic and silicic alteration along northeast-trending faults and silicified zones and quartz veins with orientations of N15°E, 75S°E (McHugh and others, 1991).



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 22. Map showing mineral-resource potential for jasperoid precious-metals occurrences in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – jasperoid precious metal

Moderate-potential (M) tract with low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

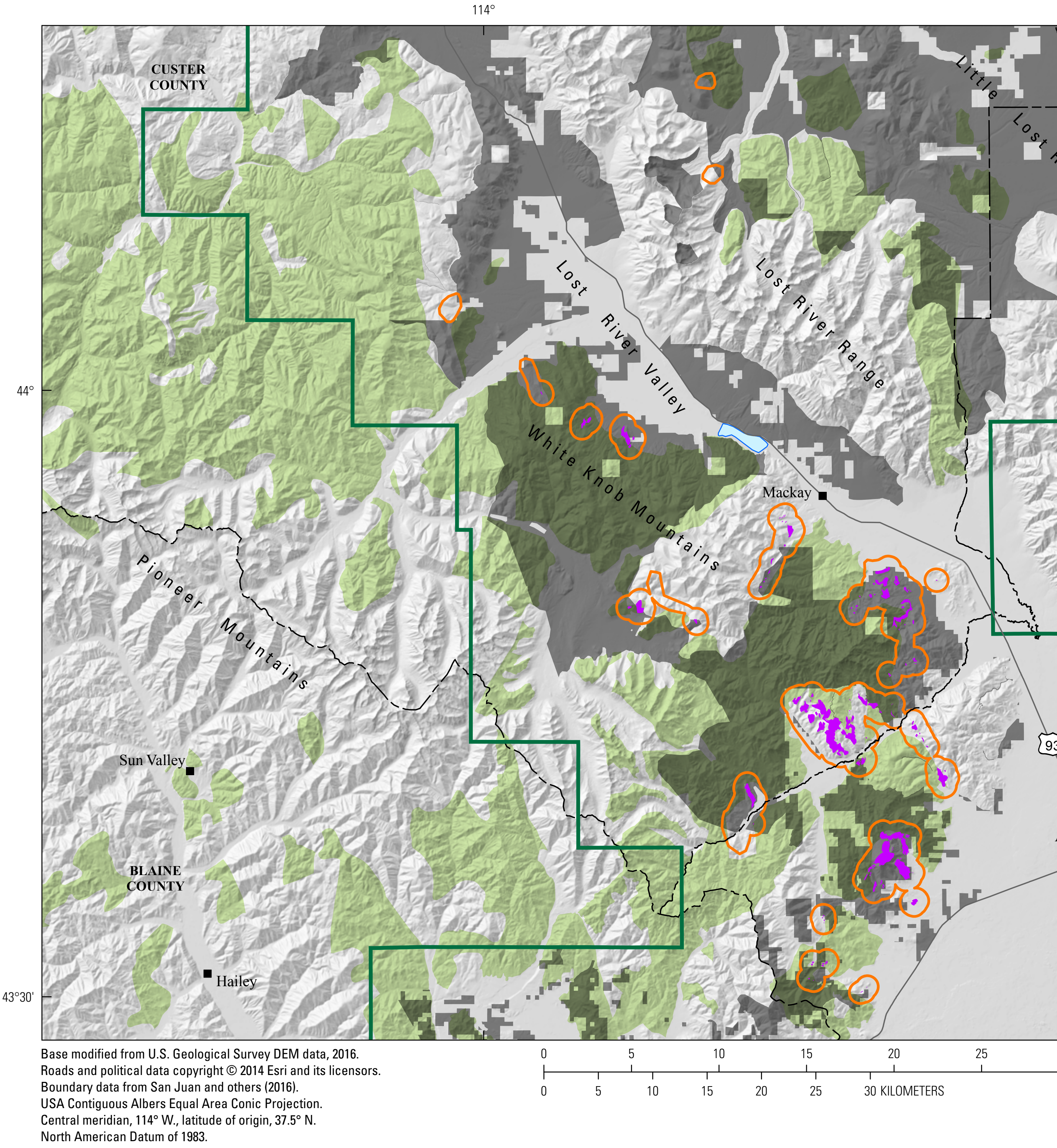
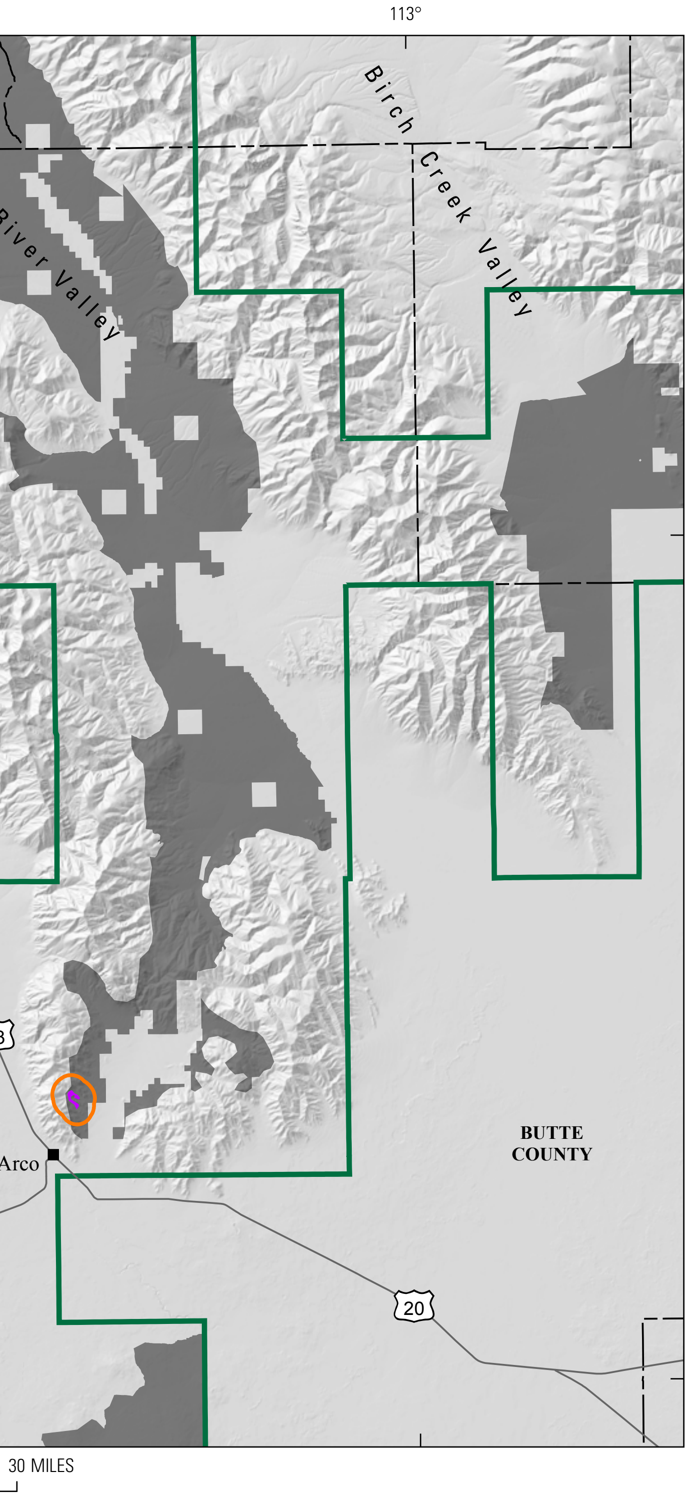
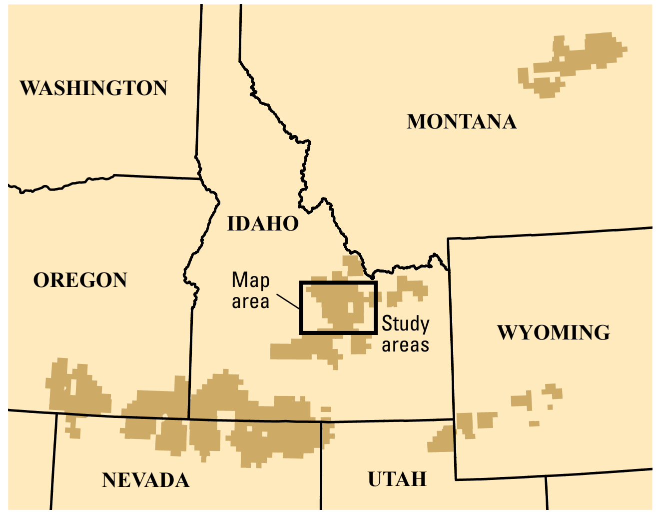


Figure 23. Inset map showing details of mineral-resource-potential tracts for jasperoid precious-metals occurrences in context of permissive geology in the central part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – jasperoid precious metal

Moderate (M) potential tracts with low (B) certainty

Jasperoid exposures

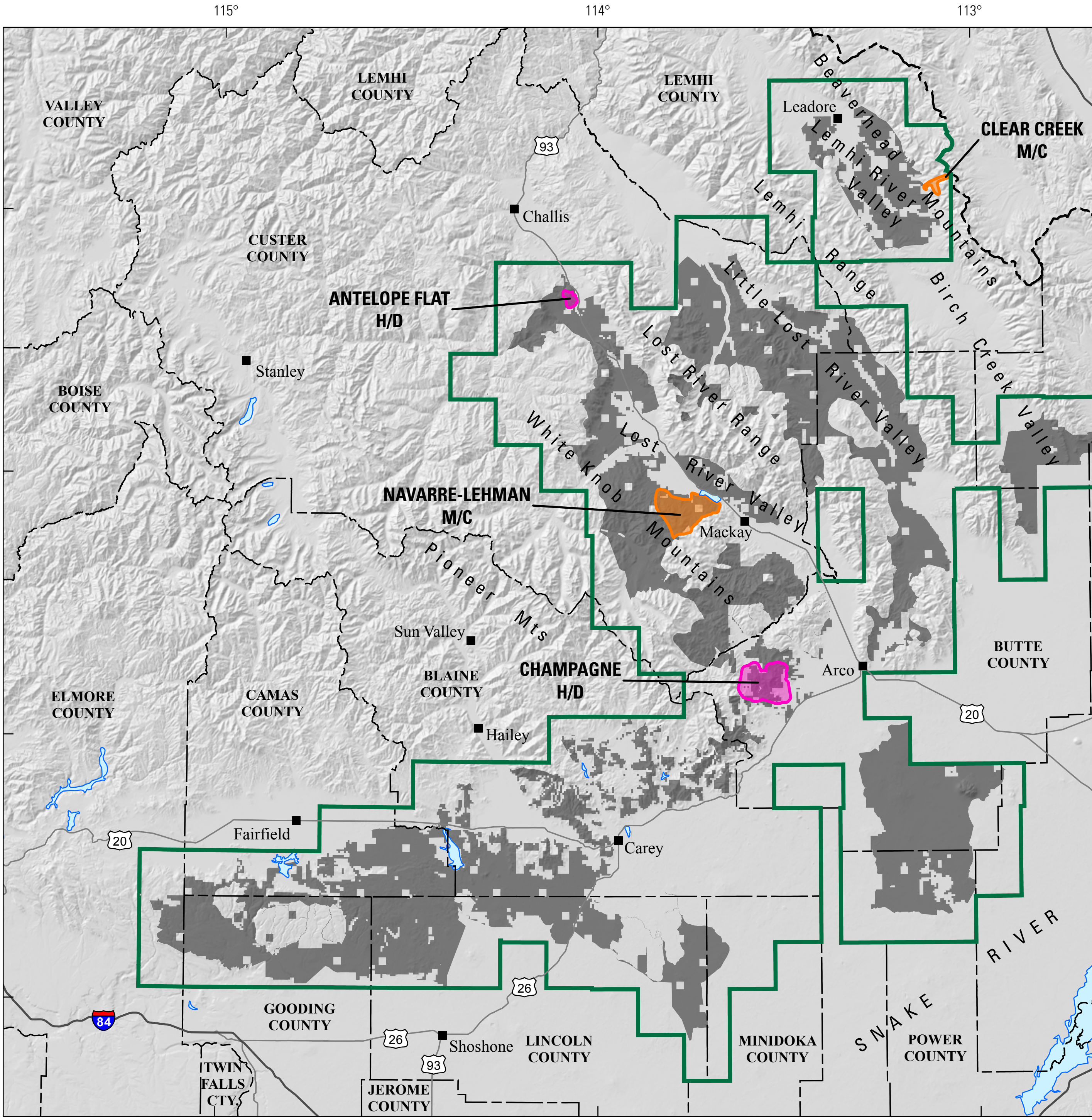
Challis volcanics

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries



Base modified from U.S. Geological Survey DEM data, 2016.
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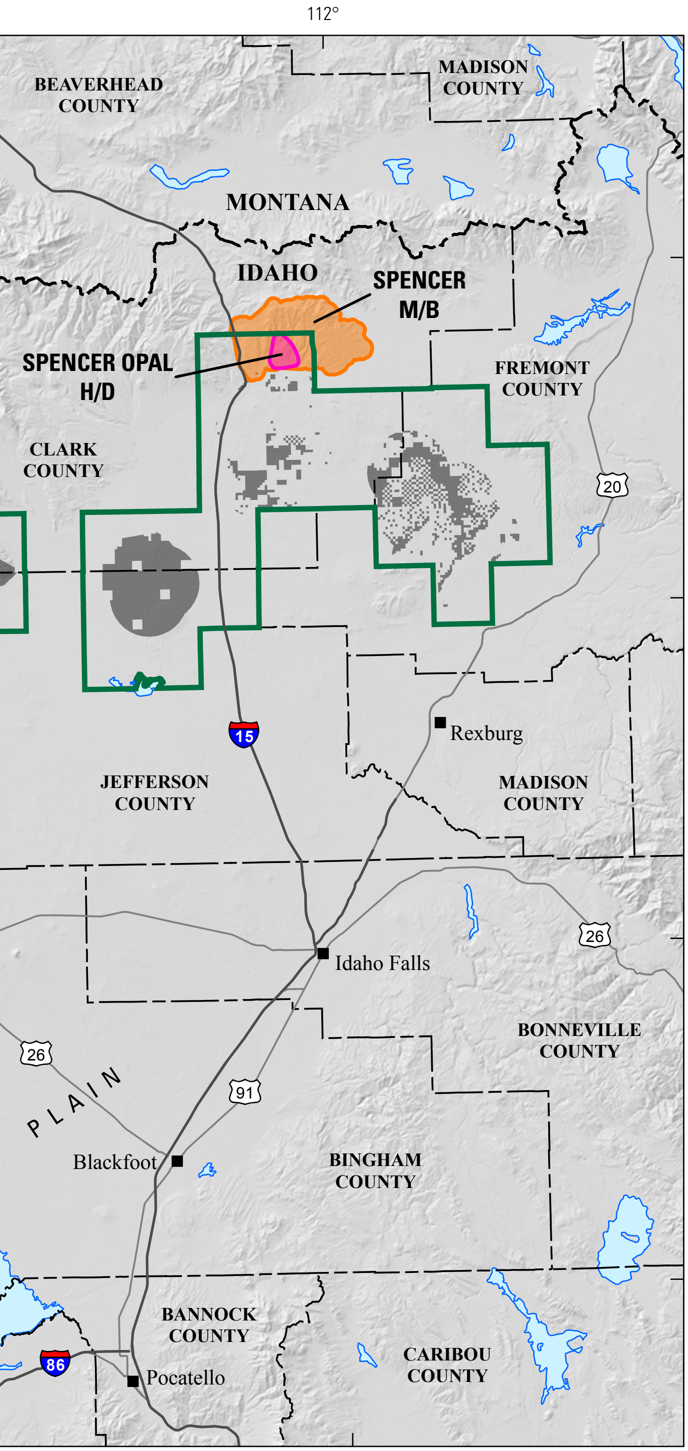
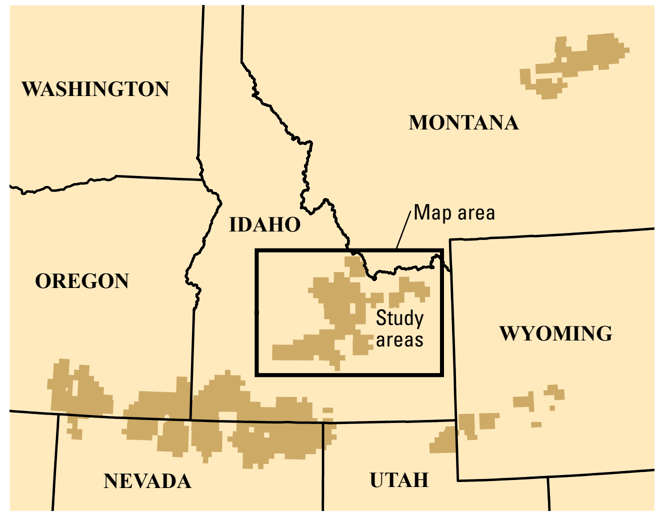
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 24. Map showing mineral-resource potential for epithermal gold-silver, zeolite mineral specimen, precious opal, and gypsum deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – epithermal

High-potential (H) tract with high (D) certainty

Moderate-potential (M) tract with moderate (C) or low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

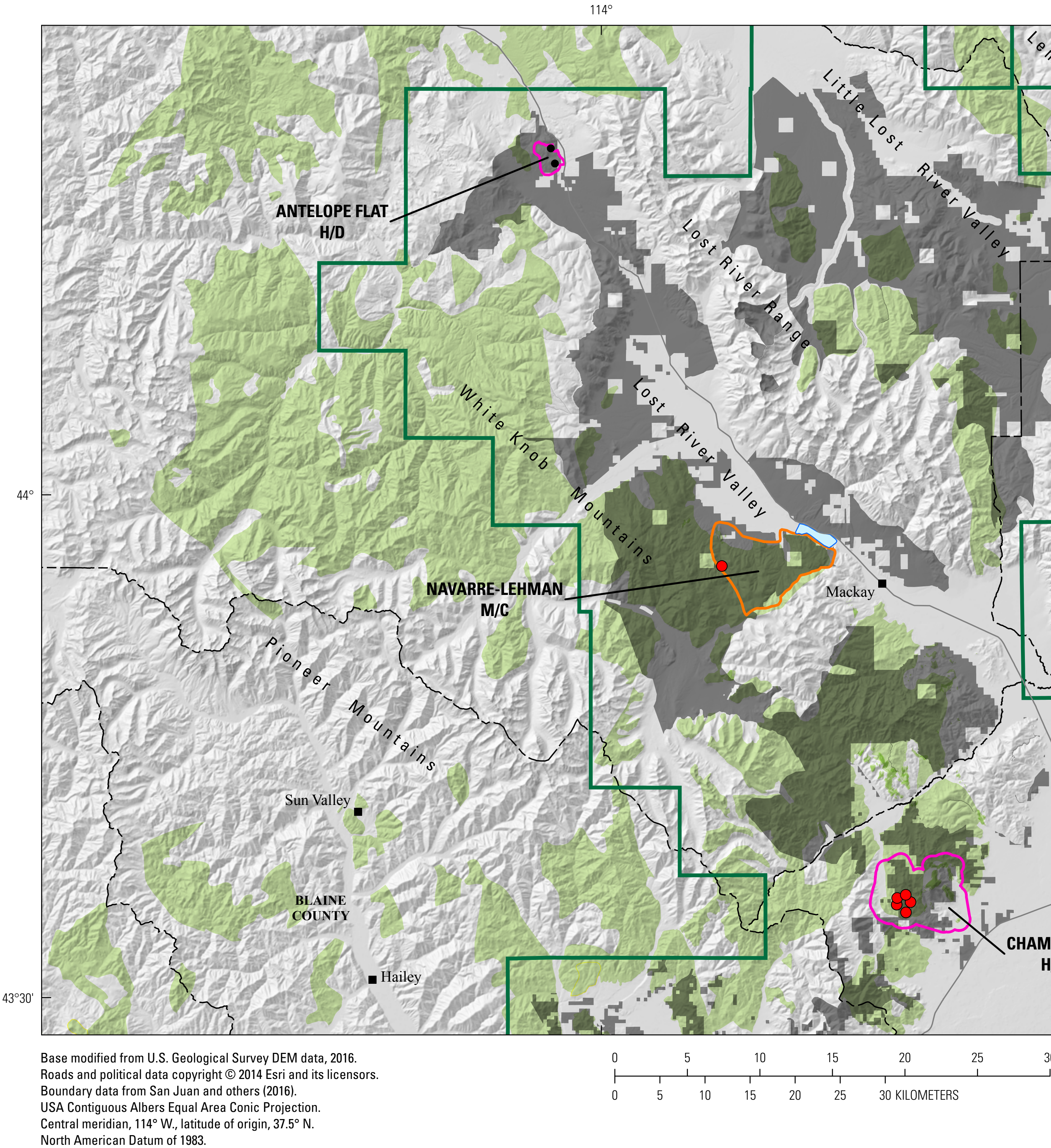
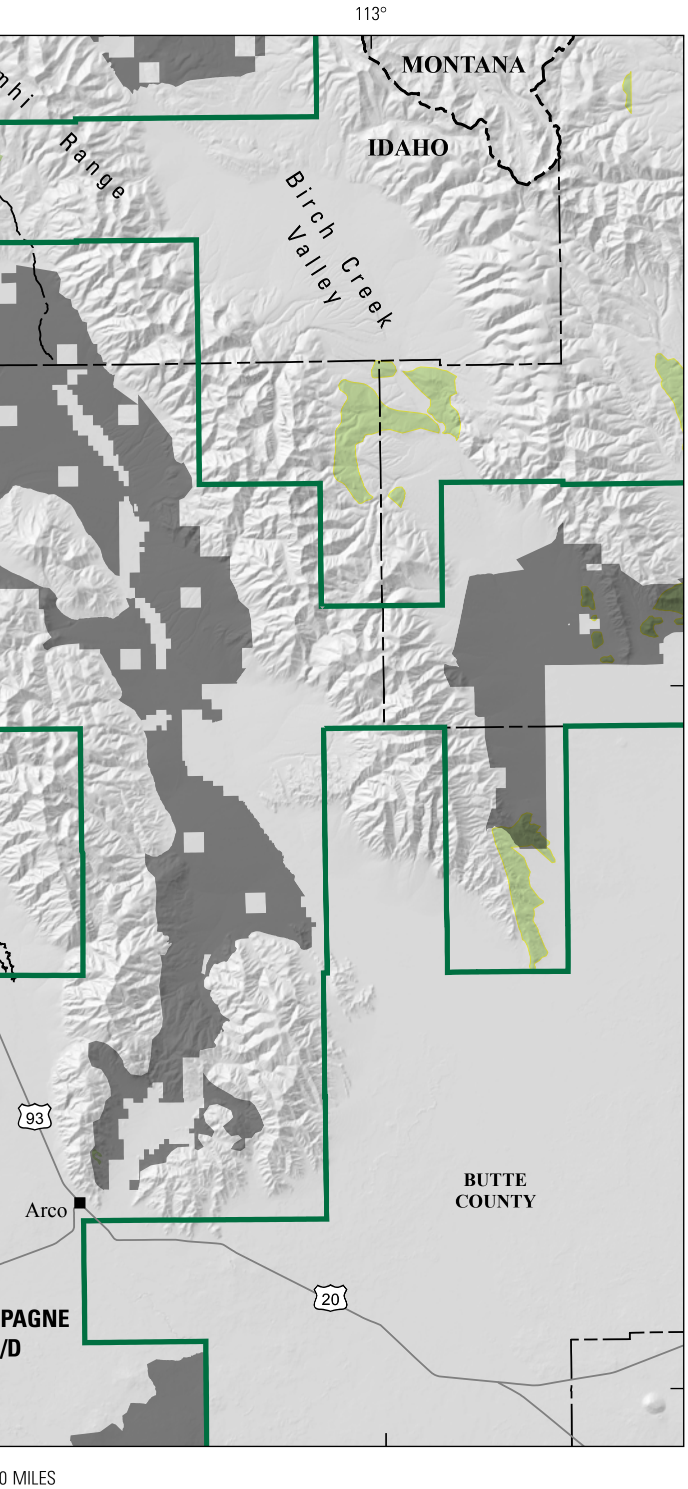
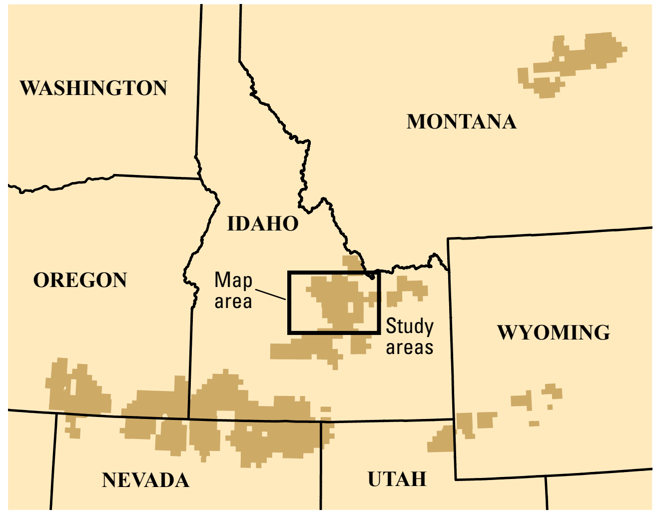


Figure 25. Inset map showing mineral-resource-potential tracts for epithermal gold-silver deposits and zeolite in context of permissive geology and occurrences in the central part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – epithermal

- High-potential (H) tract with high (D) certainty
- Moderate-potential (M) tract with moderate (C) certainty
- Permissive geology
- Gold or silver occurrence
- Zeolite mineral specimen occurrence

Base data

- USGS study area boundary
- Proposed withdrawal areas
- State boundaries
- County boundaries

Rock samples collected in the Navarre-Lehman tract (Smith and others, 2016) are anomalous for silver and barium, and weakly anomalous for lead. Sediment geochemistry show moderately high barium and zinc, plus weak silver and copper anomalies. Six heavy-mineral concentrate samples were collected along the westernmost edge of this tract. It is unknown whether these samples are relevant to the remainder of the tract. However, all samples contained highly anomalous concentrations of barium, with at least one sample containing moderately anomalous concentrations of Ag, Be, Pb, Th, and Zn, and several with weakly anomalous concentrations of Sn.

ASTER data indicate advanced argillic and kandite argillic alteration extending southwest across the tract and sericite/smectite alteration in the northeastern part of the tract. Kandite argillic alteration is present in porphyritic rhyolite intrusive units.

Radiometric data reflect the presence of the volcanic rocks. Aeromagnetic data show low values over the volcanic rocks and high values over the Mackay pluton southeast of the normal-fault tract boundary.

From previous USGS mineral-resource potential assessments, the Navarre-Lehman tract is overlapped by the lode mineral resource and polymetallic veins in carbonate rocks tracts (Worl and others, 1989; rendered in digital format in Carlson and others, 2007). From a subsequent assessment project, the tract also overlaps four tracts, including (1) polymetallic veins in Tertiary extrusive rocks, (2) veins, skarns, replacements, and jasperoid-associated deposits in carbonate rocks at depth, (3) sediment-hosted precious-metal deposits, and (4) jasperoid-associated precious-metal deposits (Worl and Johnson, 1995; rendered in digital format in Carlson and others, 2007).

Spencer Tract M/B—There is moderate potential for epithermal/hot-springs precious-metal veins in the Spencer tract (fig. 26). The Spencer tract is adjacent to the Kilgore mine, which is situated directly north of the study area. The tract is underlain by the same Pliocene-Miocene rhyolites (Bond and others, 1978) as the Kilgore mine (D.E. Cameron, written commun., 2012). There are no known mines in the Spencer tract. The tract is drawn 1 km above the contact between Cretaceous basin deposits and Miocene rhyolite-trachyte ignimbrite and flow units to reflect the geology that is mineralized at the Kilgore mine. The tract is drawn to include anomalies in geochemical data, two prospects, and an aeromagnetic high that extends into the tract. Basalt cover on the southern extent of the tract is estimated to be less than 1 km thick, so this area is included in the tract.

The host rocks, where mapped in detail at the Kilgore mine, are Pliocene-Miocene rhyolite including pyroclastic units, lava flows, and intrusive rocks (dated at around 8 to 6 Ma) of the Heise volcanic field (fig. 3; Bond and others, 1978). The volcanic rocks are in contact with older graywacke, siltstone, and shale of the Cretaceous Aspen Formation. Surficial hydrothermal features include sinter and explosion breccia and silicification. Deeper quartz-adularia alteration is zoned outward to argillic (in other words, illite, sericite), propylitic and tourmaline-dumortierite, and upward to argillic and silicification. The alteration is present along rhyolite dikes that were emplaced along a northwest-striking fault. Adularia alteration from these zones is dated at 5.3 Ma (D.E. Cameron, written commun., 2012). The Kilgore ore is enriched in Au, Ag, As, Hg, Sb, Se, B, Cu, Pb, and Zn, and the Kilgore deposit has measured and indicated resources that are 520,000 oz gold of 0.019 opt (D.E. Cameron, written commun., 2012).

Two rock samples from the Spencer tract are moderately anomalous concentrations of silver. Sediment geochemistry data are moderately anomalous for Sb and weakly anomalous concentrations of As, Hg, and Zn.

Radiometric data (Anderson and Ponce, 2016) discriminates the rhyolite rocks. Aeromagnetic data (Anderson and Ponce, 2016) suggest the presence of a pluton beneath the volcanic rocks but nearby basalts at the south boundary of the tract also contribute to the anomaly. The anomalously high magnetic pattern continues northeast from the tract into the Kilgore mine area, suggestive of a common plutonic source. The high aeromagnetic anomaly continues southwest from the Kilgore mine area to the Spencer tract, suggestive of common plutonic source for the hydrothermal system. Mineralized targets in the Spencer tract are presently undergoing exploration activity (table 7).

No previous USGS mineral-resource assessments cover the Spencer tract.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in one tract and moderate mineral-resource potential in two tracts for epithermal gold-silver deposits. This type of deposit is primarily characterized by gold and silver with lesser tungsten, copper, and lead. For economic analysis of these commodities, see Bleiwas (2016).

Epithermal Gypsum

Deposit Type Description

Epithermal gypsum and anhydrite deposits form in hot springs and related shallow hydrothermal systems active in calc-alkaline intrusive systems where sulfur-rich hydrothermal fluids and groundwaters react with host limestone and other carbonate rocks to form gypsum, or anhydrite at higher temperatures. Primary anhydrite in these systems may hydrate upon cooling to form replacement gypsum. Minor amounts of base and precious-metal sulfides may be found in the vicinity of the gypsum deposits.

Permissive Geology and Occurrences in Study Area

Gypsum mined at the Clear Creek deposit along the southwestern margin of the Beaverhead Range is interpreted as a hydrothermal replacement of fractured Mississippian Scott Peak Formation limestones in a landslide deposit (Skipp and others, 1984, 1988). The main area of the Clear

Creek mine is developed in a Holocene landslide deposit that was likely sourced from an area of gypsum alteration southeast of the Clear Creek mine. In this area, Scott Peak Formation limestones grade into pure gypsum along the cliff face (Skipp and others, 1988).

Exploration and Mining History

Mining was active in the tract at the Clear Creek gypsum mine. Some of the production is pure enough for cement manufacturing, but much of the gypsum is more appropriately mined for agricultural mineral and soil conditioner uses (Skipp and others, 1988).

Resource Assessment Tracts

Clear Creek Area Tract M/C—The Clear Creek tract (fig. 26) has a moderate potential, with certainty level C, for epithermal gypsum deposits. The basis for the tract is the Clear Creek gypsum mine and the surrounding area of hydrothermally altered and fractured limestone.

Altered Mississippian Scott Peak Formation limestones are in a Holocene landslide deposit delineated by Skipp and others (1988). Conodont alteration index (CAI) values for conodont fossils recovered from the Mississippian limestone, where it is not in the landslide deposits, indicate the extent of hydrothermal activity at the site (Rejebian and others, 1987). This hydrothermal system may have developed above a buried intrusion located along an extensional fault zone, channeled by faults and brecciation associated with a local graben structure (Skipp and others, 1988).

Mining was active at the Clear Creek mine between 1964 and 1977. The mine produced about 120,000 tons of ore used in the manufacturing of cement. In the landslide block, some of the gypsum is mixed with calcareous fault gouge and breccia, and is too impure to be used commercially. Because of the impure nature of some of the ore material, much of the gypsum produced from these deposits was used locally as an agricultural mineral and soil conditioner (Skipp and others, 1988). Three claims are patented (Skipp and others, 1988).

Gypsum resource estimates by the BLM indicate approximately 13 million tons of gypsum resources in the Clear Creek mine area (Skipp and others, 1988). Similar deposits are possible in the rest of the landslide block that hosts the previously exploited deposits.

The boundaries of the Clear Creek gypsum tract are based on the gypsum resource tract from an earlier USGS mineral-resource potential study (Skipp and others, 1988).

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in one tract for epithermal gypsum deposits. Gypsum is the only commodity that characterizes this type of deposit. For economic analysis of this commodity, see Bleiwas (2016).

Epithermal Precious Opal

Deposit Type Description

Opal is a hydrated form of amorphous silica that is in open-space fillings and impregnations of seams and voids in volcanic ash or volcanoclastic rocks. The occurrences are found in layers between successive lava flows. Opal is also found as open-space fillings in fractures and voids in massive silicic volcanic rocks and flows. Most deposits are in Tertiary and younger volcanic rocks, as opaline materials tend to devitrify, recrystallize, and dehydrate over long time periods (Paradis and others, 1999). Common opal occurrences may be distributed over large areas; precious opal occurrences are rare, discrete, and localized in distribution (Austin, 1995). Precious opal is used as a gemstone, and is a locatable commodity.

Permissive Geology and Occurrences in Study Area

A Miocene rhyolite flow lobe (Bond and others, 1978) hosts the Spencer opal mine. Lobes of the rhyolite flows are visible on remote-sensing imagery and Pliocene-Miocene rhyolite flows and domes elsewhere in the Snake River Plain may host additional common opal occurrences and possibly localized, rare occurrences of precious opal. ASTER spectral data provide evidence to help delineate hydrous silica alteration, detected as jarosite ± sericite ± smectite, or hydrosilica ± ferric iron class.

The precious opal is found as one or more thin layers in common opal seams that partly filled gas cavities and fractures in a Pliocene-Miocene rhyolite-obsidian flow (unit Tpmr, fig. 3).

Exploration and Mining History

The Spencer opal mine, the largest privately owned gemstone producer in the state, is the major producer of precious opal in Idaho (U.S. Bureau of Mines, 1995). The Spencer opal mine reports producing precious opal in addition to the more prevalent common opal at the site; the mine has produced white and pink varieties of precious opal, and yellow, pink, and white varieties of common opal. A small percentage of the opalized material is categorized as precious opal and about 10 volume percent of the opalized material is thick enough to cut into solid gems (U.S. Bureau of Mines, 1995). Production information for the Spencer opal mine is not available.

Resource Assessment Tracts

Spencer Opal Tract H/D—This is a high potential, certainty level D tract for precious opal deposits. The tract is centered over the permit area of the operating Spencer Opal mine (fig. 26). The tract also includes the existing permit areas and historic prospects.

The host rock unit is a Pliocene-Miocene rhyolite flow and dome located northeast of the Snake River Plain. The

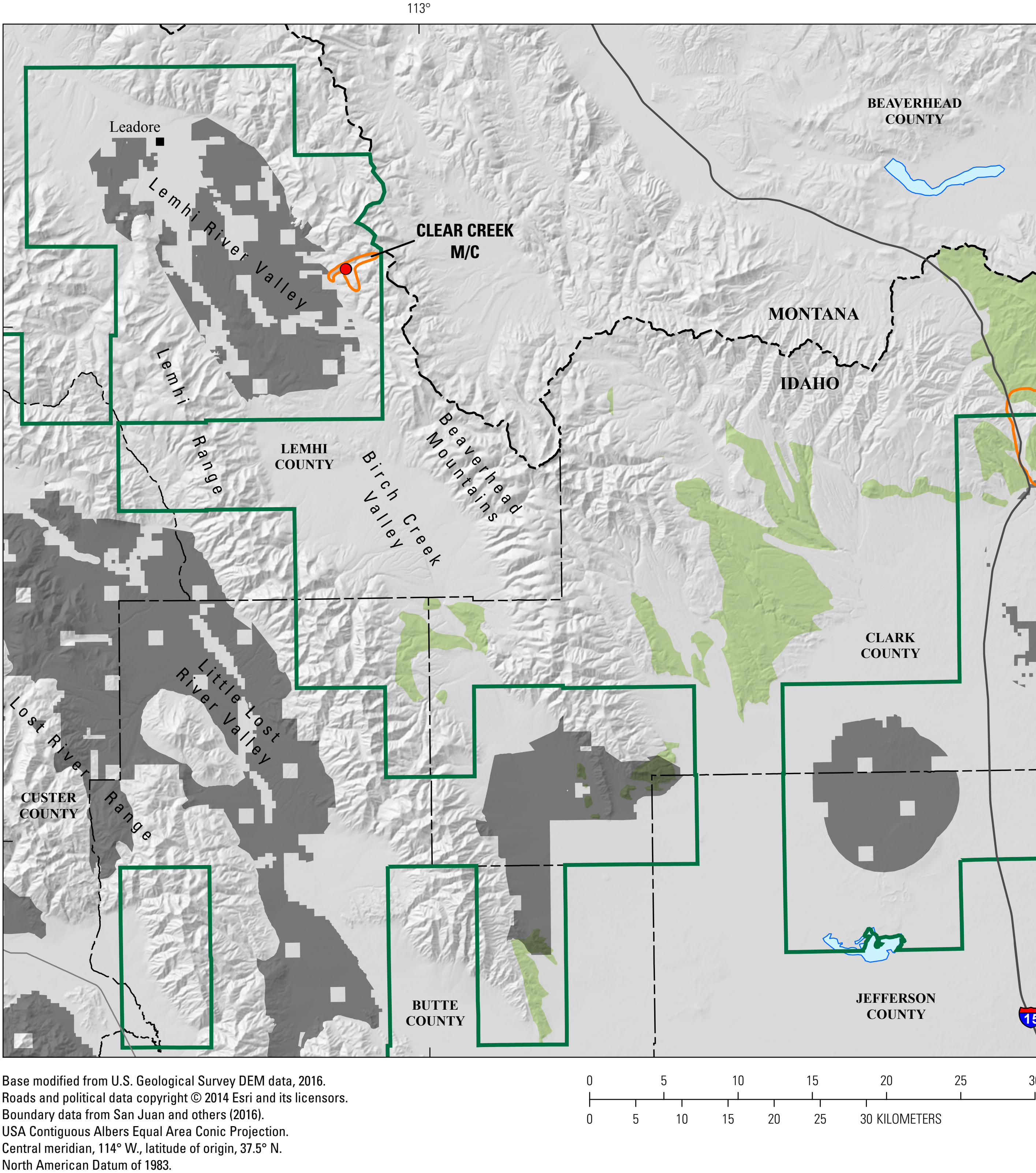
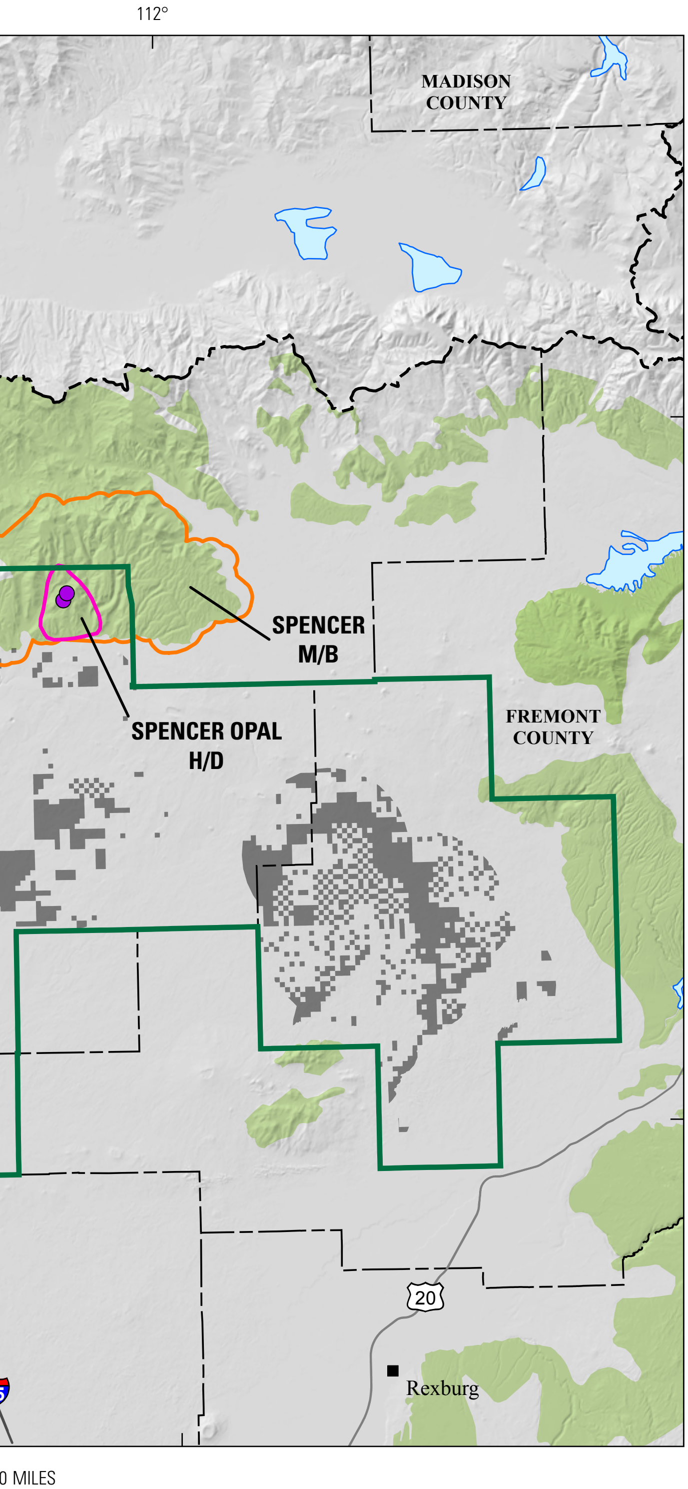
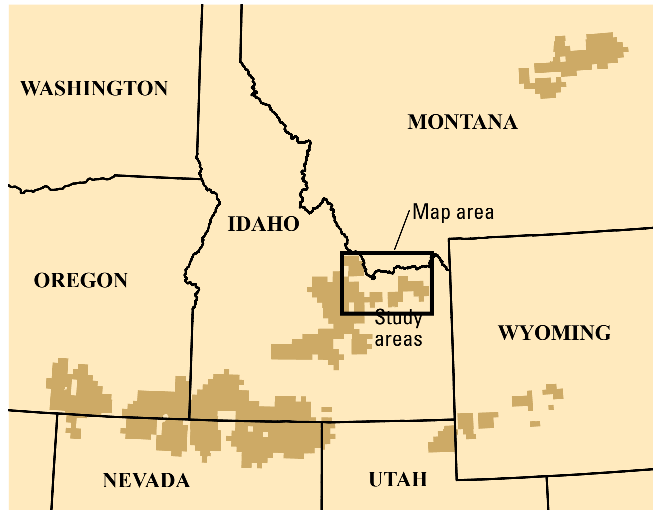


Figure 26. Inset map showing mineral-resource-potential tracts for epithermal gypsum and precious opal deposits in context of permissive geology and occurrences in the eastern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – epithermal

- High-potential (H) tract with high (D) certainty
- Moderate-potential (M) tract with moderate (C) or low (B) certainty
- Permissive geology
- Gemstone occurrence
- Gypsum-anhydrite occurrence

Base data

- USGS study area boundary
- Proposed withdrawal areas
- State boundaries
- County boundaries

precious opal occurs as one or more thin layers in common opal, partly filling gas cavities and fractures.

The Spencer opal mines produce pink and white precious opal in addition to the more prevalent common opal at the site. Production and resource data are not available.

ASTER spectral data (Rockwell, 2016) help delineate the tract. The Spencer mine pit shows an intense argillic alteration envelope surrounding a core of hydrous silica that is detected as jarosite ± sericite ± smectite, or hydrosilica ± ferric iron signatures. Areas surrounding the tract show additional scattered pixels of hydrous silica alteration.

No previous USGS mineral-resource assessments cover the Spencer opal tract.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in one tract for epithermal precious opal deposits. This type of deposit is primarily characterized by precious opal, a gemstone. For economic analysis of this commodity, see Bleiwas (2016).

Zeolite Mineral Specimen

Deposit Type Description

Zeolites are microporous, aluminosilicate minerals. Some common varieties are used as commercial adsorbents or soil enhancements, and for water filtration and environmental cleanup applications. Zeolite of the type found in the study area formed in volcanic vugs and tubes, and is of commercial interest as mineral samples.

Permissive Geology and Occurrences in Study Area

Zeolite deposits in and near the study area are hosted in Eocene-aged volcanic and volcaniclastic sedimentary rocks (unit T of fig. 3; shown as unit Tes of Lewis and others, 2012). The zeolite occurrences are in thin (2-m thick) volcanic flow (or tuff) layers in the mapped unit. The volcanic rocks contain crystal-lined tubes of apophylite and quartz pseudomorphs after apophylite as well as platy calcite.

The two zeolite mineral specimen sites at Antelope Flat and Rat’s Nest, as well as at related prospects, have reported occurrences of apophylite and of heulandite and mordenite, respectively. Platy calcite is also present at the Antelope Flat locality.

Apophylite and calcite found at the Summer Storm claim are collected for mineral specimens (Ream, 2005). Heulandite and mordenite, which are found near the study area occurrence at the Rat’s Nest locality, are also chiefly collected as mineral samples (Ream, 2001).

Exploration and Mining History

The Summer Storm mine is in the study area. The Rat’s Nest mine is adjacent to the study area and has been known for nearly a century of intermittent activity (Ross and Shannon, 1924).

Resource Assessment Tracts

Antelope Flat Zeolite Mineral Specimen Tract H/D—The Antelope Flat tract is a high potential, certainty level D tract for apophyllite mineral samples (fig. 25). These zeolite mineral samples are found in vugs (geodes) in thin volcanic flows. The tract is defined by the area of excavation pits and smectite alteration in the map unit.

The tract is underlain by an Eocene volcanoclastic sedimentary and volcanic unit (unit T on fig. 3 and shown as Tes of Lewis and others, 2012). The unit contains thin interlayered volcanic flow layers that contain the vugs and tubes in which the zeolite mineral samples formed.

This tract is centered on the BLM permit area of the Summer Storm claim for zeolites. The specimens are mined from near-surface exposures and pits that are visible on satellite imagery.

No production records are available for the total quantity of sample produced at the relatively newly discovered Summer Storm mine in the Antelope Flat tract (Ream, 2005). The nearby mine called the Rat’s Nest (or Persistence) mine, which lies adjacent to the study area, contains heulandite, mordenite, and minor laumontite specimens in geode vugs and tubes. At that site, about a hundred kilograms of heulandite mineral specimens are mined each year (Ream, 2001).

No previous USGS mineral-resource assessments cover the Antelope Flat tract.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in one tract for epithermal zeolite deposits. This type of deposit is primarily characterized by zeolite as mineral specimens. For economic analysis of these commodities, see Bleiwas (2016).

Hydrothermal-Metamorphic Mineral System

Cobalt-Copper-Gold Veins

Deposit Type Description

The Blackbird cobalt-copper-gold district, about 80 km northwest of the northern part of the study area, contains cobalt reserves of international importance and is the only ready source of cobalt ore in the United States (Earhart, 1986; duBray, 1995; Slack, 2013). The deposits are hosted by the Mesoproterozoic Apple Creek Formation and at its upper contact with the overlying Gunsight Formation, the middle and upper units of the Lemhi Group, respectively (fig. 4). The host rocks originated as thinly interlayered, arkosic coarse-grained siltstone and fine-grained sandstone deposited by turbidity currents. Host rocks are lower greenschist to middle amphibolite facies regional metamorphic rocks in thrust-slivered packages, located beneath a major regional Cretaceous thrust fault (Lund and Tysdal, 2007). Mineralization was introduced into the country rocks as a series of structurally controlled, quartz-rich veins, biotite-rich breccia veins, and minor albite and siderite veinlets that maintain consistent order and sulfide-mineral associations. Veins are kinematically linked to Cretaceous deformation and lie in mineralized intervals along axial planar cleavage, intrafolial foliation, and shear zones (Lund and others, 2011).

Both early- and late-stage quartz veins contain chalcopyrite and pyrite, whereas intermediate-stage tourmaline-biotite veins host the cobaltite. Barren early- and late-stage albite and late siderite veins are included in the vein systems. Cobaltite forms single and aggregate grains and is disseminated; it also defines fine wisps and laminae parallel to foliation and occurs as core grains in other sulfide minerals and as xenocrysts. Quartz veins also contain chalcopyrite, pyrite, minor arsenopyrite and pyrrhotite, and local safflorite and linnaeite. Bismuth minerals are identified as matrix to cobaltite aggregates and along fractures in cobaltite. Several associated shear zones are enriched in nickel and gold. Trace REE minerals include monazite, allanite, and xenotime, and are associated with both tourmaline-biotite and late-stage quartz veins (Lund and others, 2011). Chlorine is anomalously high in rocks and in biotite, and both K_2O and total iron are anomalously high in rocks (Nash and Hahn, 1989).

Permissive Geology and Occurrences

Mesoproterozoic metasedimentary rocks of the Lemhi Group, including the Apple Creek and Gunsight Formations (permissive tract combines units mapped in detail in Lund and others, 2003, and more generalized regional maps of Wilson and Skipp, 1994; Lewis and others, 2012), crop out in large areas directly north of the study area as thrust-fault slivers along the western margins of the Beaverhead and Lemhi ranges and exist at depth beneath Paleozoic strata in the eastern to central parts of the study area.

One prospect containing erythrite (secondary hydrated cobalt arsenate) is reported in the Lemhi Range in the proposed withdrawal area (Wells prospect, quoted from an unpublished U.S. Bureau of Mines report in Johnson and others, 1998).

Resource Assessment

Cobalt-Copper-Gold Vein Low Tract L/B—There is low potential, with certainty level B, for cobalt-copper-gold vein deposits in the permissive rock units of the study area (tract details available in appendix 2 and in San Juan and others, 2016). Although the nearby and shallowly underlying Mesoproterozoic units of the Lemhi Group (fig. 3) may be considered permissive for cobalt-copper-gold resources, the potential for these Blackbird-type veins is rated low due a lack of known occurrences or evidence of appropriate geochemical anomalies.

Thorium-Rare Earth Element-Bearing Veins

Deposit Type Description

The Lemhi Pass Thorium District straddles the Montana-Idaho border in an area about 25 km north of the northernmost part of the study area. Thorite [$(Th,U)SiO_4$]-bearing veins in this district may host the largest thorium resource in the United States (Staatz and others, 1979; Van Gosen and others, 2009). Although the known thorium deposits of the Lemhi Pass District lie outside of the study area, these deposits are described here because of (1) the potential future significance of this district as a source of thorium for thorium-based nuclear power, and (2) equivalent Mesoproterozoic host rocks extend into the northernmost part of the study area.

In the Lemhi Pass District, Staatz (1972, 1979) mapped 219 veins enriched in thorium and REEs. Most are quartz-hematite-thorite veins that fill fractures, shear zones, and brecciated zones in Mesoproterozoic quartzite and siltite host rocks. Thorium also is present in monazite-thorite-apatite shear zones and replacement zones with specularite, biotite, and alkali feldspar. Thorium- and REE-bearing allanite and monazite are locally abundant. Other reported ore minerals include brockite, xenotime, and thorite. The thorium veins of the district range from 1 m to at least 1,325 m in length and from a few centimeters to as much as 12 m in width (Staatz, 1979; Staatz and others, 1979). Fifteen thorium veins in the district exceed 300 m in length. The thorite veins of the Lemhi Pass District contain approximately equal concentrations of thorium and REEs. Staatz (1972) reported the REE analyses of 31 vein samples, which had average total REE-oxide contents of 0.428 weight percent, similar to the average thorium oxide content of 0.43 weight percent found in the 10 largest veins in the district.

Resource Assessment and Permissive Geology

Thorium-Rare Earth Element-Bearing Vein Low Tract L/B—There is low potential, with certainty level B, for thorium-rare earth element-bearing vein deposits in the permissive rock units of the study area (tract details available in appendix 2 and in San Juan and others, 2016). Mesoproterozoic metasedimentary rocks similar to the host rocks of the Lemhi Pass District crop out in small areas of the Idaho proposed withdrawal area (fig. 3). However, thorite veins similar to those at Lemhi Pass have not been reported in these rocks outside of the Lemhi Pass area. Thorough prospecting of this region for radioactive mineral shows by prospectors and geologists in the past would have likely discovered a thorium-REE-rich vein deposit if one existed.

Hydrothermal-Exhalative Sedimentary Mineral System

Sedimentary Exhalative Zinc-Lead-Silver

Deposit Type Description

In sedimentary exhalative (SEDEX) mineral deposit systems, basinal brines are produced by the evaporation of seawater beyond halite saturation on the carbonate platform. Such brines can evolve to become hydrothermal ore fluids as they migrate through basal siliciclastic sequences. Ore minerals precipitate in black shales where metal-laden brines ascend along growth faults and then vent into euxinic seawater in bathymetric lows (for example, Emsbo, 2009).

Permissive Geology and Occurrences in Study Area

In areas directly adjacent to the study area, SEDEX deposits are in the following stratigraphic units: Devonian Milligen Formation (Triumph deposit, Otto and Turner, 1989; Turner and Otto, 1995), Cambrian to Mississippian Salmon River assemblage (Hoodoo and Livingston deposits, Hall, 1995b), and perhaps in correlative formations. In maps of the study area, organic-rich black shales are combined differently according to either lithology or age (unit Dc of Bond and others, 1978; unit Dm of Wilson and Skipp, 1994; units Pzsr and Op of Fisher and Johnson, 1995). The permissive geology used for resource assessment consists of map polygons of these units plus a 1-km buffer to account for cover and uncertain contacts.

Exploration and Mining History

In central Idaho, the only SEDEX deposits to have been mined are in the aforementioned areas north of the study area. Several correlative formations have been the focus of past exploration. Hall (1995b) considered the potential for SEDEX deposits in the Challis 1° × 2° quadrangle.

Resource Assessment Tracts

Long Canyon SEDEX Tract M/C—There is moderate potential, with certainty level C, for SEDEX zinc-lead-silver deposits in Ordovician to Devonian organic-rich black shales in the study area (fig. 27). This tract is based on a published report on the Long Canyon prospect (Otto and Zeig, 2003) and map polygons of the Ordovician to Silurian Phi Kappa Formation, Silurian Trail Creek Formation, and an unnamed Devonian siltstone (units SOp, St, and DSs of Kuntz and others, 2007). The permissive geology shown consists of map polygons of these units plus a 1-km buffer to account for cover. Parts of this tract overlap the BLM proposed withdrawal area (fig. 27).

The strata in this tract consist of complexly deformed Ordovician Phi Kappa and Silurian Trail Creek Formations faulted over unnamed Devonian black shales generally equivalent to the Milligen Formation (figs. 3, 4). These rocks are exposed primarily in structural windows in which they were over-ridden by units of the Pennsylvanian-Permian Sun Valley Group (Anderson and others, 1950; Link and others, 1988; Kuntz and others, 2007). The rocks were subsequently dismembered by imbricate low-angle faults. At the Long Valley prospect site, different compositional units of the Phi Kappa Formation are imbricated by the interaction of low-angle faults from both Cretaceous and Eocene structural events (Otto and Zieg, 2003).

The Long Canyon prospect consists of a gossan horizon that was drilled in Ordovician graptolitic mudrock. Oxidation extends about 230 m below the surface. Surface rock-chip and soil samples have anomalous concentrations of Pb (≤3,000 ppm) and Zn (≤1,000 ppm; Otto and Zeig, 2003). A regional discussion of the potential host rocks for SEDEX zinc-lead-silver deposits is in Hall and others (1995). There are closed lode claims in the Long Canyon tract (Causey, 2007; Dicken and San Juan, 2016).

No rock, soil, or sediment geochemical samples were analyzed by USGS in this tract (Smith and others, 2016), and no previous USGS mineral-resource assessment tracts cover the Long Canyon tract.

SEDEX Low Tract L/B—There is low potential, with certainty level B, for SEDEX zinc-lead-silver deposits in the permissive Ordovician to Devonian organic-rich black shale units of the study area (tract details available in appendix 2 and in San Juan and others, 2016). The tract is based only on permissive geology, and evidence for mineralizing processes such as geochemical anomalies or previous exploration are absent.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has moderate mineral-resource potential in one tract for SEDEX zinc-lead-silver deposits. This type of deposit is primarily characterized by zinc, lead, and silver-bearing minerals. For economic analysis of these commodities, see Bleiwas (2016).

Bedded Barite

Deposit Type Description

In sedimentary basins, barite precipitates from reduced basinal fluids that vent into seawater containing sulfate (Johnson and others, 2009).

Permissive Geology and Occurrences in Study Area

In adjacent areas of Idaho, barite was produced from bedded deposits in the Permian Dollarhide Formation of the Sun Valley Group, Mississippian Copper Basin Group, and Cambrian to Mississippian Salmon River assemblage (Poole, 1988; Poole and others, 1992, Hall and Kiilsgaard, 1995). The permissive geology consists of map polygons of these units (unit Mc from Bond and others, 1978; unit Pzsr from Fisher and Johnson, 1995; and unit PPs from Lewis and others, 2012) combined into a single data layer plus a 1-km buffer to account for uncertain contacts.

Exploration and Mining History

The Muldoon barite deposit, which is located in the tract directly adjacent to the study area boundary, was mined in the past and exploration is ongoing in adjacent areas (Fernette and others, 2016b). Hall and Kiilsgaard (1995) discuss the potential for bedded barite in the Challis 1° × 2° quadrangle.

Resource Assessment Tracts

Muldoon-Pioneer Bedded-Barite Tract M/C—There is moderate potential, with certainty level C, for bedded-barite resources in the Muldoon-Pioneer tract (fig. 28). Because bedded-barite deposits are known to occur in clusters (Papke, 1984), the tract (fig. 29) was delineated by applying a 2.7 km buffer to known bedded-barite mines and prospects in the Mississippian Copper Basin Group (as shown on Bond and others, 1978). The size of the buffer corresponds to the 90th percentile spacing between bedded-barite deposits in the Roberts Mountains allochthon in Nevada (U.S. Geological Survey, 2005; Fernette and others, 2016b). The resulting tract was trimmed to the bedded-barite permissive tract.

Bedded-barite zones at the Muldoon barite deposit are about 70 m long and concordant with limestone lenses in calcareous quartzite of the Mississippian Copper Basin Formation (figs. 3, 4; Nelson and Ross, 1968). Other bedded-barite deposits near the study area are lenticular masses in carbonaceous units of the Sun Valley Group (Umpleby and others, 1930; Hall and Kiilsgaard, 1995). The correlative carbonaceous rocks of the Salmon River assemblage may also host these deposits (Hall and Kiilsgaard, 1995).

The Muldoon-Pioneer tract has closed mine claims and a closed surface management notice (Causey, 2007). The northern part of the Muldoon-Pioneer tract is an active exploration area (Fernette and others, 2016a). The southern part of the Muldoon-Pioneer tract extends into the proposed withdrawal area (fig. 28).

Barium in rock samples (Smith and others, 2016) is associated with both the northern and southern parts of the bedded-barite tract. The northern area has at least 6 rock sample sites (some with multiple samples) that are anomalous for barium and more than a dozen other rocks are weakly anomalous for barium. The southern area has only one site (with seven samples) that is anomalous for barium. There are almost no barium anomalies seen in sediment or soil samples in this tract, only two sites in the northern area are weakly anomalous. Heavy-mineral concentrate samples (four sites) were only collected in the southern tract and two of these samples are anomalous for barium, with one nonmagnetic C3 fraction having more than 10,000 ppm barium.

The Muldoon-Pioneer bedded-barite tract was overlapped by a permissive tract for polymetallic veins in black-shale terrane (Worl and others, 1989; rendered in digital form in Carlson and others, 2007). The possibilities of bedded barite in correlative rocks northwest of the study area is discussed by Hall and Kiilsgaard (1995).

Bedded-Barite Low Tract L/B—There is low potential, with certainty level B, for bedded-barite deposits in the permissive Permian Dollarhide Formation of the Sun Valley Group, Mississippian Copper Basin Group, and Cambrian to Mississippian Salmon River assemblage units of the study area (tract details available in appendix 2 and in San Juan and others, 2016). The tract is based only on permissive geology and evidence for mineralizing processes such as geochemical anomalies or previous exploration are absent.

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has moderate mineral-resource potential in one tract for bedded-barite deposits. This type of deposit is primarily characterized by barite. For economic analysis of this commodity, see Bleiwas (2016).

Hydrothermal-Sedimentary Mineral System

Mississippi Valley-Type Lead-Zinc

Deposit Type Description

In Mississippi Valley-type (MVT) systems, basinal brines produced by the evaporation of seawater well beyond halite saturation evolve to become ore fluids as they migrate from foreland basin settings into carbonate rocks on the shelf during contractional orogenies (Leach and others, 2010). Such migration is commonly marked by occurrences of hydrothermal dolomite. Deposits occur near basement highs, facies transitions, high angle faults, and in karst breccias. Ore minerals, mainly sphalerite and galena, precipitate where metal-laden basinal brines mix with contrasting fluids, or natural gas, containing H_2S (Leach and others, 2010). In adjacent areas of Nevada, dolomitized limestones and occurrences of hydrothermal dolomite trace brine migration pathways and MVT showings, with potentially extractable concentrations of zinc, lead, silver, and barium identified at several locations (Papke, 1984; Diehl and others, 2005, 2010; and references therein).

Permissive Geology and Occurrences in Study Area

The geologic setting in the study area contains the necessary elements for MVT deposits. These include deformation related to the contractional Antler orogeny west of the study area, a Mississippian foreland basin succession in the central study area, and karst breccias and hydrothermal dolomite in the Devonian Jefferson Formation in the eastern part of the study area (Dorobek and Filby, 1988; Grader and Delher, 1999; Isaacson and others, 2007). Permissive geology consists of Paleozoic predominantly carbonate rock units shown as deposited on the continental shelf (fig. 4, these include most of the Paleozoic chrono-lithostratigraphic units DCs, DSOs, Ms, OCs, PMs, and PPs from Lewis and others, 2012), and especially those that contain dolostone such as the Ordovician

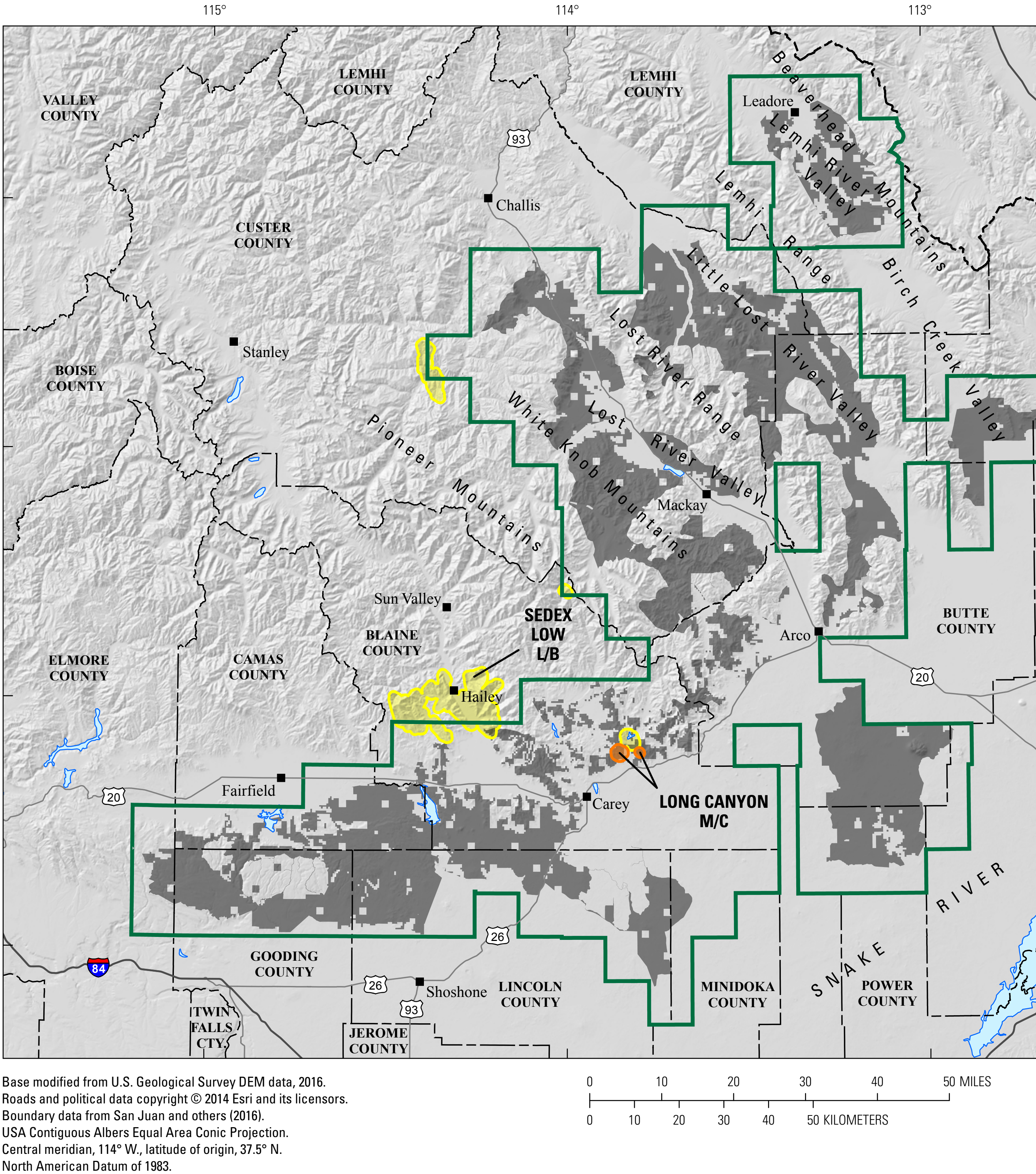
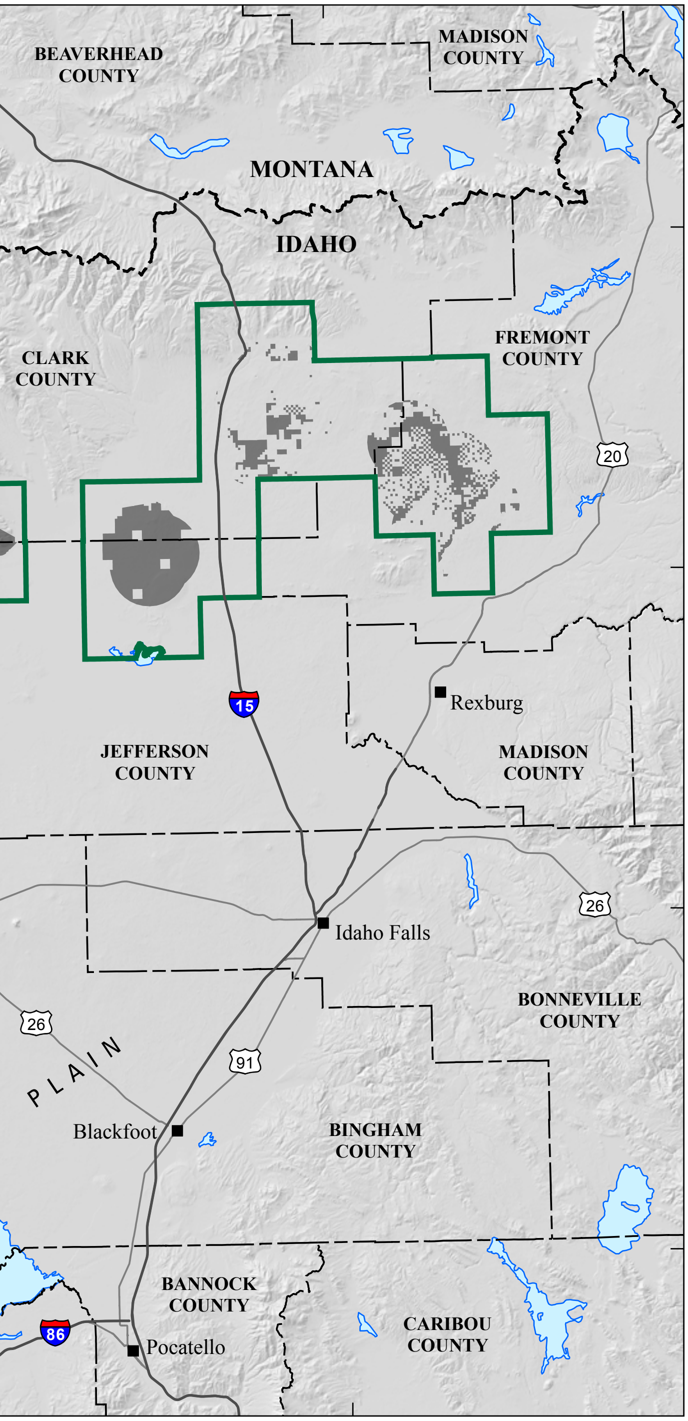
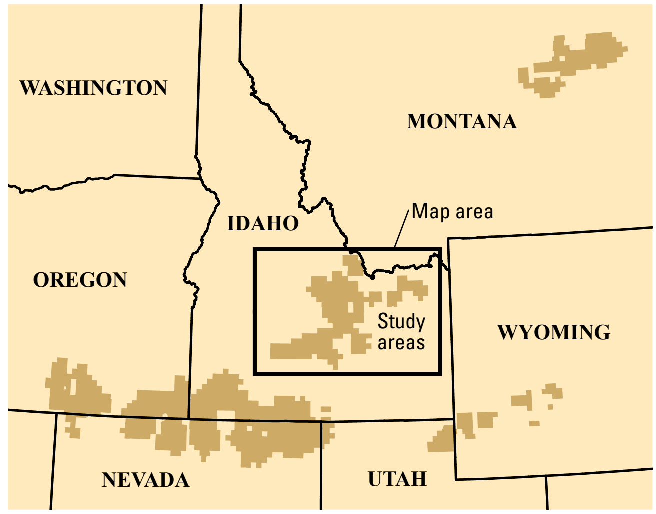


Figure 27. Map showing mineral-resource potential for sedimentary exhalative zinc-lead-silver SEDEX type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – SEDEX lead-zinc-silver

Moderate-potential (M) tract with moderate (C) certainty

Low-potential (L) tract with low (B) certainty

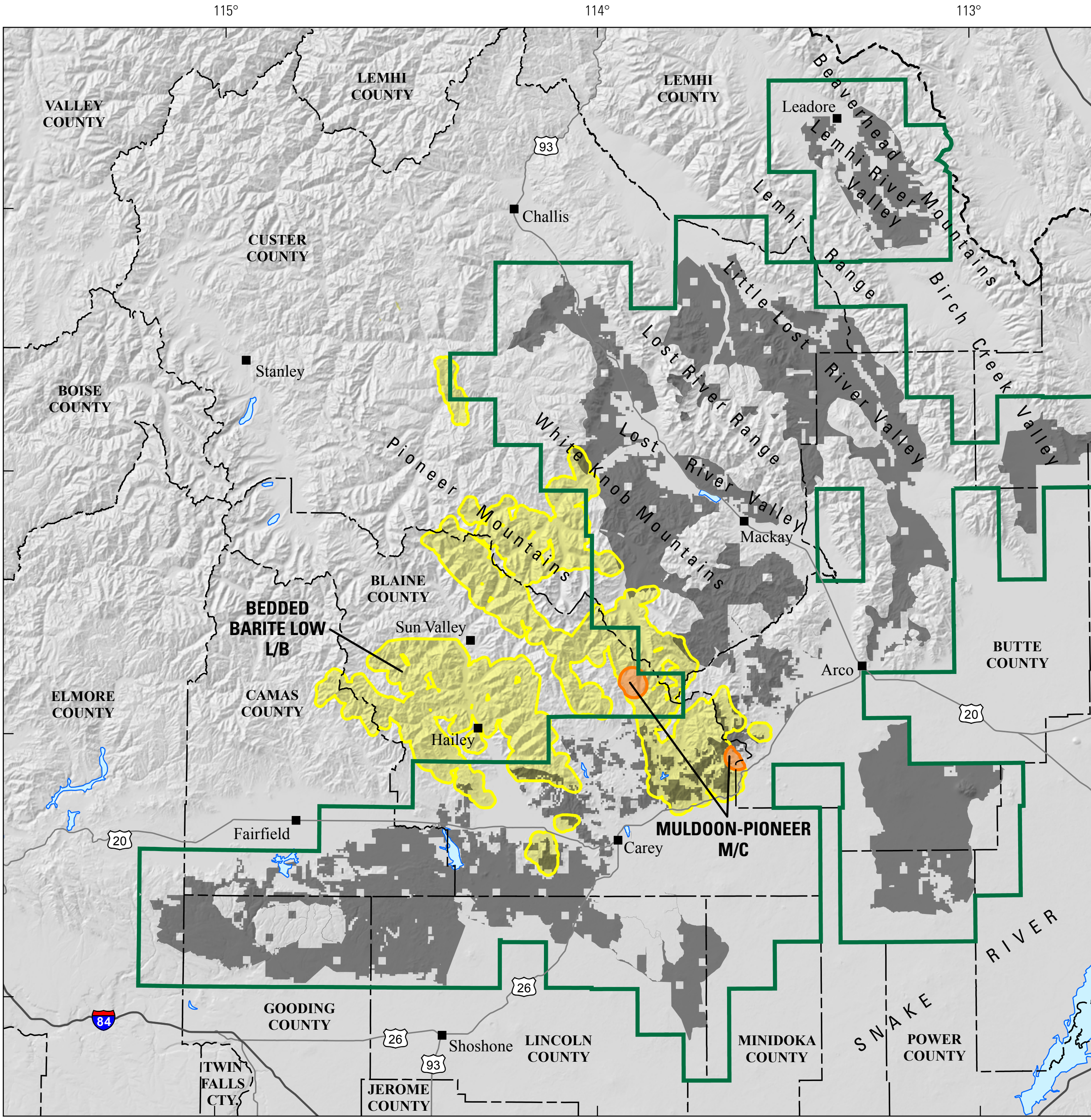
Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

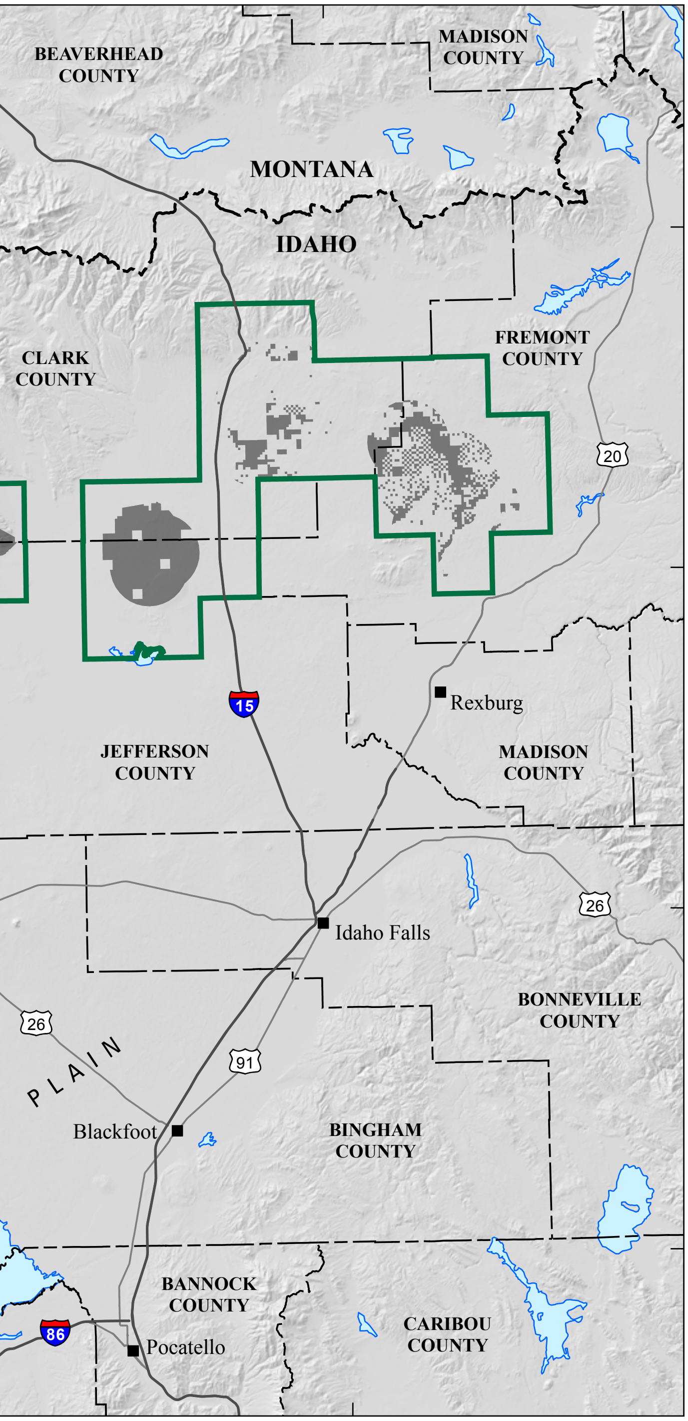
County boundaries

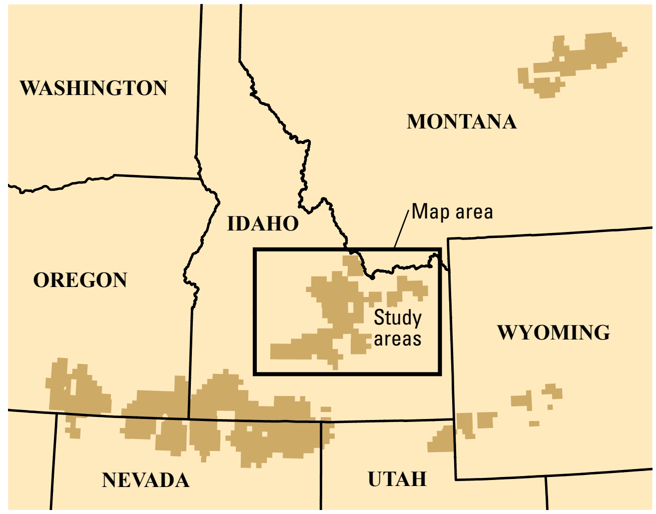


Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

0 10 20 30 40 50 MILES
0 10 20 30 40 50 KILOMETERS

Figure 28. Map showing mineral-resource potential for bedded barite-type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – bedded barite

Moderate-potential (M) tract with moderate (C) certainty

Low-potential (L) tract with low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

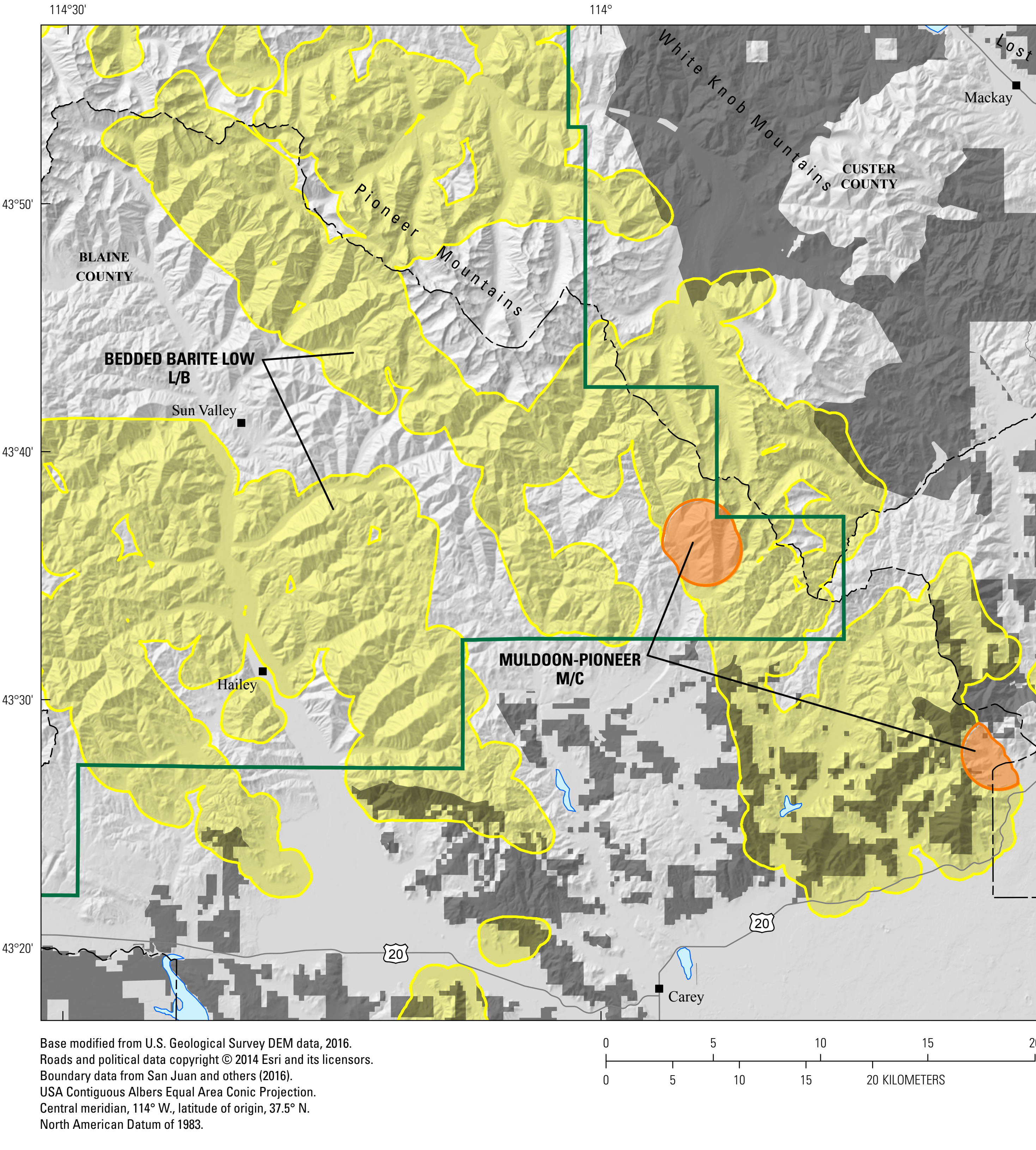
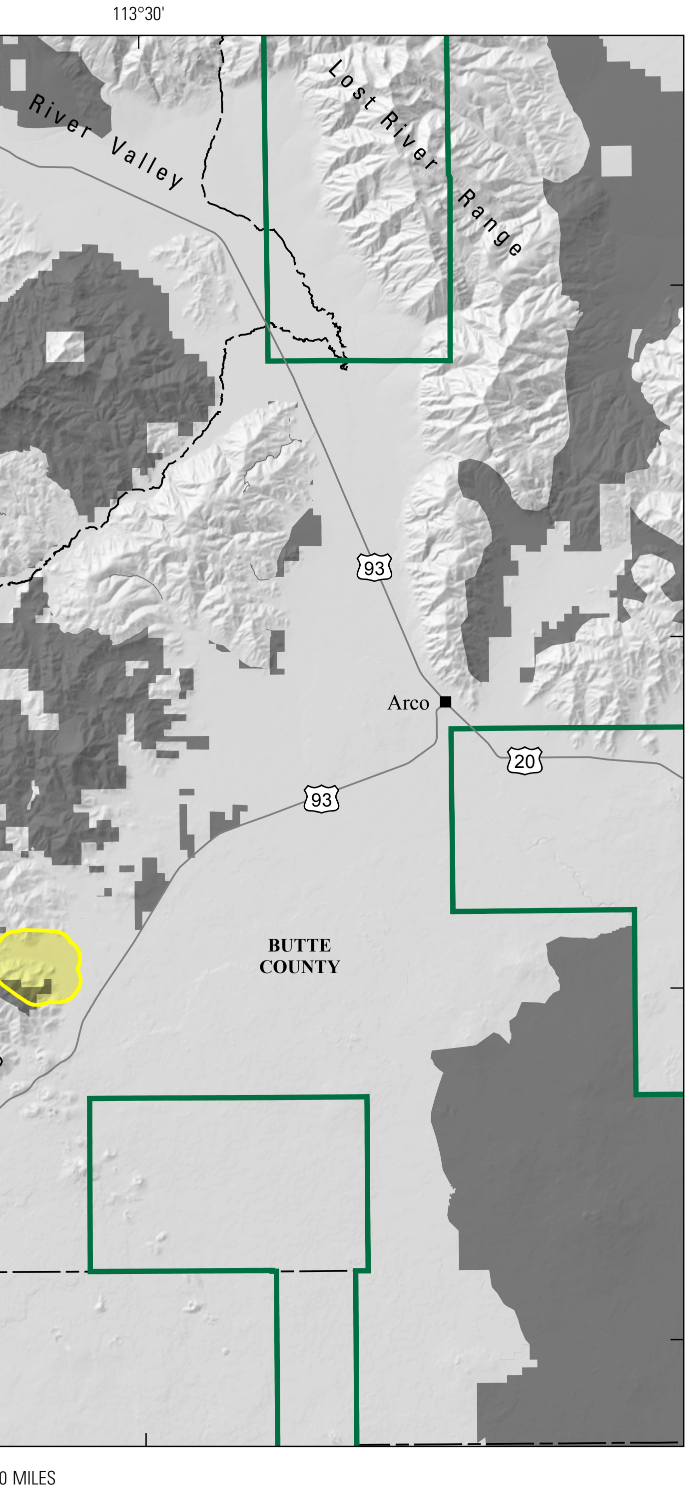
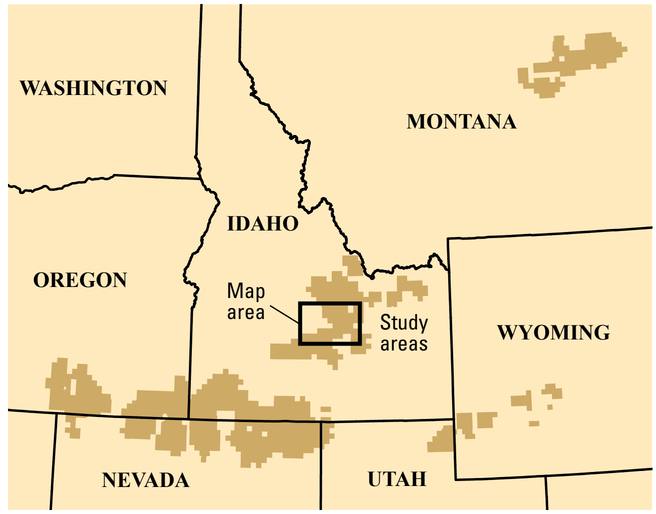


Figure 29. Inset map showing details of mineral-resource-potential tracts for bedded barite-type deposits in context of permissive geology and occurrences in the central part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – bedded barite

Moderate-potential (M) tract with moderate (C) certainty

Low-potential (L) tract with low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

Saturday Mountain Formation, Silurian Laketown Dolomite, and Devonian Jefferson Formation and equivalent rocks (figs. 3, 4; rocks combined in map units D, DO, DS, O, OCc, Ou, S, and SO from Bond and others, 1978).

Exploration and Mining History

Although MVT lead-zinc resources may be present in the study area, we could find little or no evidence of exploration for, or descriptions of, any MVT occurrences in the study area.

Resource Assessment

Mississippi Valley-Type Lead-Zinc Low Tract L/B—There is low potential, with certainty level B, for MVT deposits in the Silurian to Devonian dolostone formations that formed on the continental shelf (tract details available in appendix 2 and in San Juan and others, 2016). The tract is based only on permissive geology; evidence for mineralizing processes such as geochemical anomalies, occurrences, or previous exploration for MVT deposits was not identified.

Stanley District Sandstone-Type Uranium (Unconformity Uranium)

Deposit Type Description

About 9 km northeast of Stanley in central Idaho, small uranium deposits occur along the base of the Eocene-age Challis Volcanics (Kern, 1959; Choate, 1962; Van Gosen and others, 2006). In the Stanley District, the uranium deposits are present in two geologic settings: (1) as disseminated uranium minerals in fluvial-channel arkosic sandstones and conglomerates that rest upon the eroded surface of the Cretaceous Idaho batholith and directly beneath rocks of the Eocene Challis Volcanics, and (2) as thin pockets of uranium minerals in silicified fractures that cut through the granitoid rocks of the batholith (Johnson and Cookro, 1995a,b; Van Gosen and others, 2006). Microscopic textures in the uranium minerals suggest that the uranium mineralization in the stratabound deposits (type 1 above) is genetically linked to the widespread hydrothermal alteration in the area that was associated with igneous intrusions related to the eruption of the Eocene Challis Volcanics (Van Gosen and others, 2006). The largest uranium deposits are the stratabound, sedimentary rock-hosted type, which were developed by the largest mines in the district, all open-pit operations.

Exploration and Mining History

Small quantities of uranium ore were produced from mines in the Stanley District from 1957 to 1962, making it the first commercial uranium district in Idaho. This district consisted of at least 27 uranium mines and prospect claim groups, scattered across an area of about 28 km^2. The average grade (about 0.18 weight percent U_3O_8) of the uranium deposits mined in the Stanley District was comparable to other U.S. producers, but its output (less than 8,000 tons of uranium ore per year) and its mines were relatively small.

Permissive Geology and Occurrences in Study Area

The sedimentary units that host the stratabound uranium deposits in the Stanley District are mapped regionally as unit Tes on the geologic map of Idaho (Lewis and others, 2012). Thus, the permissive geology for this type of uranium deposit corresponds to the extent of this map unit, which includes fluvial conglomerates and sandstones that rest on the eroded surface of the Idaho batholith and lie beneath volcanic and volcaniclastic rocks of the Challis Volcanics.

The only uranium deposits that have been mined in the region are those in the Stanley District, west of the study area, but a few low-grade occurrences of uranium mineralization have been reported in the region of this study area, where they are present in a variety of geologic settings. Nevertheless, no uranium deposits similar to those of the Stanley District are reported and none of these other occurrences are described as significant in uranium content or deposit size.

Anomalous uranium values in some stream sediments occur in the Camp Creek heavy-mineral stream placer deposits in the western part of the study area (discussed in the Heavy-Mineral Placer section). However, this uranium is attributed to uranothorite [$(Th,U)SiO_4$], which forms about 1.2 percent of the heavy mineral content of the Camp Creek placer (Robertson and Storch, 1955). These uranium anomalies are therefore unrelated to the type of uranium deposits described above.

Resource Assessment Tract

Big Creek Unconformity Uranium Tract L/C–There is low potential for uranium resources, with certainty level C, in the Big Creek area of Lemhi and Custer Counties (fig. 30). The tract is underlain by Tertiary sedimentary rocks. The tract boundaries are based on uranium anomalies from stream sediment and rock samples.

No uranium deposits of the types in the Stanley District are reported in this tract but stratigraphically equivalent Tertiary sedimentary rocks are present (shown on fig. 30; map unit Tes of Lewis and others, 2012) and overlain by Challis Volcanics (fig. 30). The units are in a similar stratigraphic setting as those in the Stanley District.

Uranium anomalies in stream sediment and rock samples characterize the valley and tributary drainages of Big Creek. In this valley, stream sediments (Smith and others, 2016) have 31 to 53 ppm uranium, and a sample of a radioactive zone in an intrusive rock of the Challis Volcanics contains 370 ppm uranium.

No previous USGS mineral-resource potential assessments cover the area of the Big Creek uranium tract.

Unconformity Uranium Low Tract L/B–There is low potential for uranium resources, with certainty level B, in the northwest part of the study area (fig. 30). Although no uranium deposits of the types in the Stanley District are reported in the study area, there are areas with similar geologic setting. The permissive geologic setting includes outcrops of Tertiary sedimentary rocks (shown on fig. 30; map unit Tes of Lewis and others, 2012) overlain by volcanic rocks of the Challis Volcanics (fig. 30). The presence of these units suggests that some mineral-resource potential exists for buried and undiscovered uranium deposits of the type found in the Stanley District.

In a previous USGS mineral-resource assessment, this area was included in a low potential tract for stratiform uranium deposits in sedimentary rocks (Fisher and Johnson, 1995).

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has low mineral-resource potential in one tract for unconformity-type deposits. This type of deposit is primarily characterized by uranium. For economic analysis of this commodity, see Bleiwas (2016).

Sedimentary Mineral System

Lacustrine Diatomite

Deposit Type Description

Diatomite is a chalk-like, soft, friable, very fine-grained, generally light-colored, siliceous sedimentary rock that primarily consists of cell walls (frustules) of amorphous hydrous (opaline) silica. It is formed by microscopic, single-celled, golden-brown algae called diatoms that lived in marine and freshwater environments (Kadey, 1983; Harwood, 1999; Wallace, 2003; Wallace and others, 2006; Crangle, 2015). Lacustrine diatomite is the focus of this discussion, as marine deposits do not occur in the study area. Although freshwater (continental) diatoms are preserved in the geologic record from as early as Late Cretaceous time (Ambwani and others, 2003), the majority of commercial lacustrine diatomite deposits are Miocene in age (Harwood, 1999; Wallace, 2003).

Lacustrine diatomite forms in lakes having (1) sufficient nutrients, such as phosphorus and nitrogen, to support the living cells, (2) low input of clastic material, and (3) long periods of persistence in a stable tectonic environment (Moyle and Dolley, 2003). Because diatoms use silicic acid available in the water column to generate their frustules, thick accumulations of lacustrine diatomite are commonly coincident with silicic volcanic terranes in which weathered silicate minerals supply the needed silica in a form that can be utilized by the diatoms (Wallace, 2003; Wallace and others, 2006). Lacustrine diatomite accumulates in the central basins of relatively deep lakes in which planktonic forms dominate, in the shallow margins of deeper lakes, or in shallow lakes where benthic forms reside (Krebs and Bradbury, 1984). If optimal physical and chemical conditions exist, lacustrine diatomite can accumulate in a variety of settings that include glacially or meltwater-carved basins, calderas, impounded graben valleys, and lava- or mud-dammed river drainages (Bradbury, 1999; Cohen, 2003). Postdepositionally, diatomite must not only be protected from erosion but also from the diagenetic effects caused by contact with corrosive alkaline or silica-deficient pore-waters, by burial at depths greater than 600 m, or by elevated heat above approximately 50 °C (Harwood, 1999; Moyle and Dolley, 2003).

Diatomite (also referred to as diatomaceous earth) is very finely porous, has low density, is chemically inert, and is primarily used for filtration, absorption, and filler applications (Moyle and Dolley, 2003; Wallace and others, 2006; Crangle, 2015).

Permissive Geology and Occurrences in Study Area

Regionally, lacustrine diatomites and associated sedimentary rocks were deposited during Miocene to middle Pleistocene time in an active extensional setting coeval with the time when the Yellowstone Hot Spot migratory path extended across southern Idaho (Wood, 1994; Beranek and others, 2006). During Miocene to middle Pleistocene time, the Snake River watershed was dammed along the western margin of the plain by lava flows, faulting, or both. This formed a fluvial-lacustrine system that covered more than 26,000 km^2 in which sediments of the Idaho Group accumulated in a variety of lacustrine, deltaic, floodplain, and eventually, alluvial environments (oldest to youngest: Poison Creek Formation, Chalk Hills Formation, Banbury Basalt, Glenns Ferry Formation, Tuana Gravel, Bruneau Formation, and Black Mesa Gravel; Wood, 1994). The Idaho Group is underlain by the Idavada Volcanics (Malde and Powers, 1962; revised by Wood, 1994). Most diatomite-bearing lacustrine sediments of the Idaho Group in the western Snake River Plain are in the late Miocene Chalk Hills Formation and the Pliocene Glenns Ferry Formation (Kimmel, 1982). Local diatomite exposures associated with the Miocene Banbury Basalt are commonly mapped as part of the basalt unit (Moyle, 1985; Toth and others, 1987) or referred to by a local name (such as the Clover Creek diatomite of Oakley and Link, 2006; Garwood and others, 2014).

For much of the area containing these units, diatomite units are not mapped separately. Available geologic map units are compiled (unit Tpb, described as Pliocene basalt flows, pyroclastic debris, clastic sediments, and diatomite, and Pliocene basaltic volcanic rocks and clastic sediments; and unit Tpd described as Pliocene sandstone, conglomerate, siltstone, tuff, claystone, limestone, and diatomite, and Pliocene tuffaceous alluvial and lacustrine deposits; Bond and others, 1978) to produce permissive geology (fig. 31). Although these map units are largely basaltic, drainages dissect the cap rock, variously exposing underlying diatomite beds or lenses. The Clover Creek and King Hill diatomite tracts (fig. 32) lie in the permissive geologic unit but are further delineated on the basis of more detailed mapping.

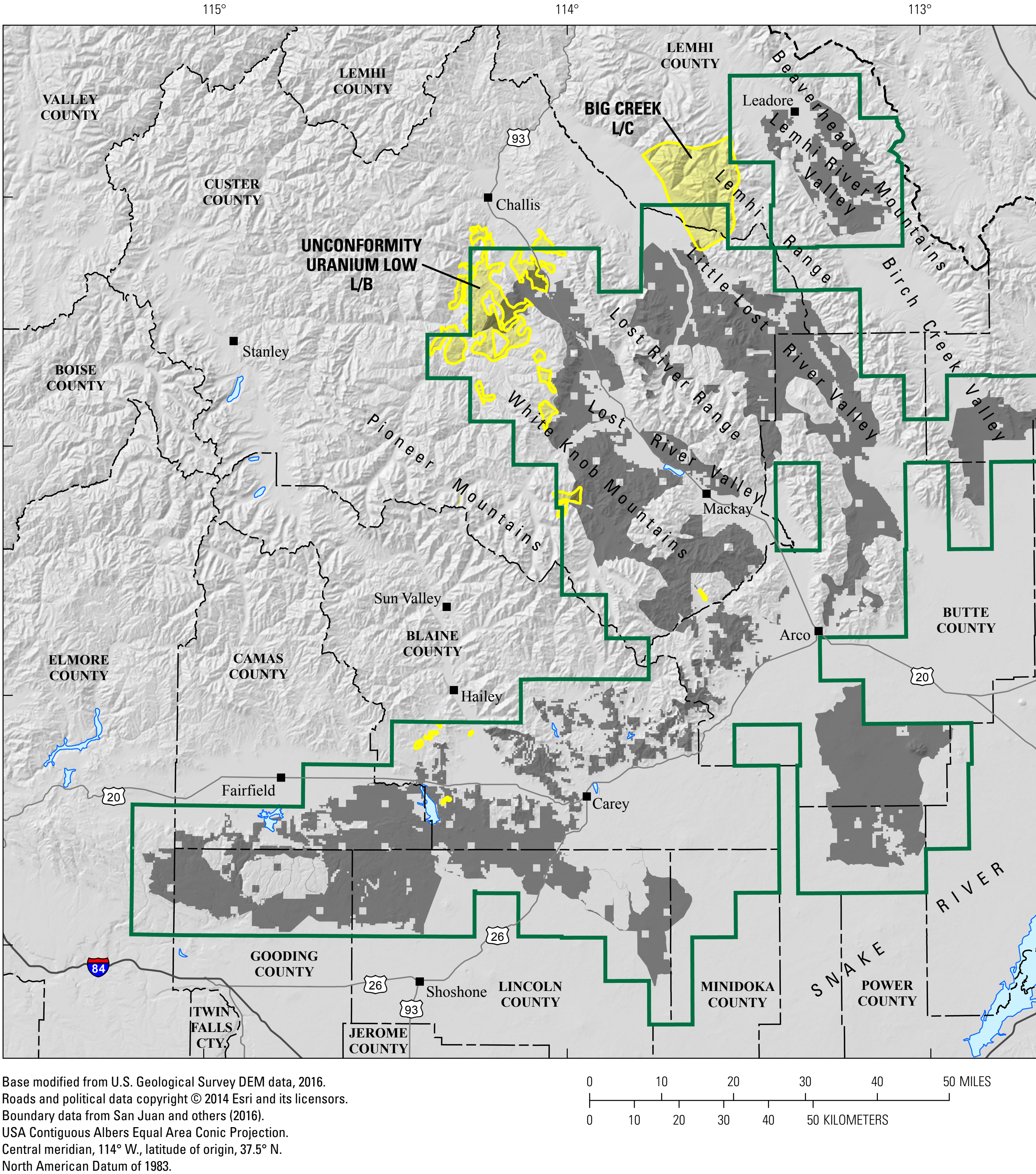
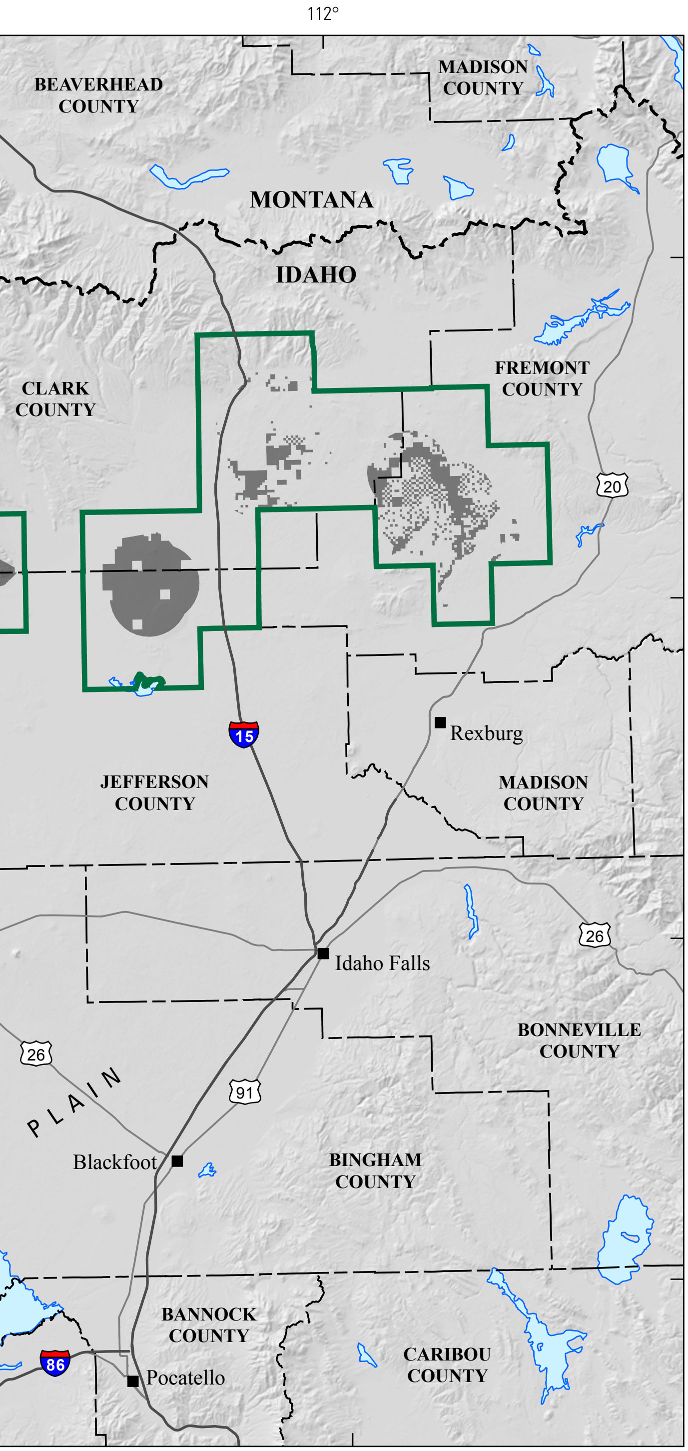
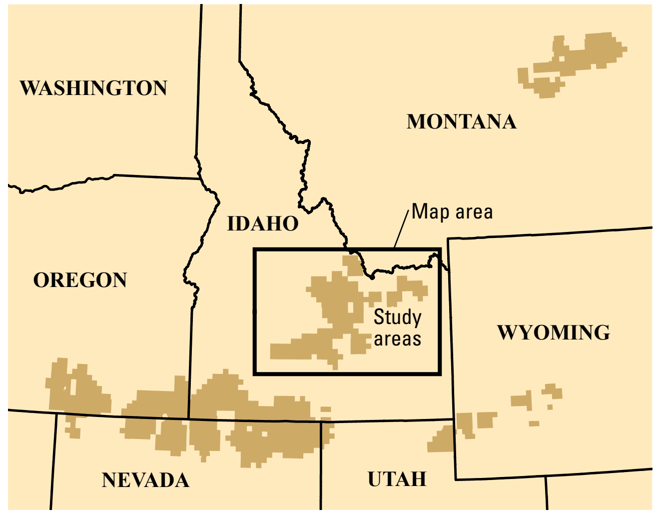


Figure 30. Map showing mineral-resource potential for unconformity uranium deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – Stanley District sandstone-type uranium

Low-potential (L) tract with moderate (C) or low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

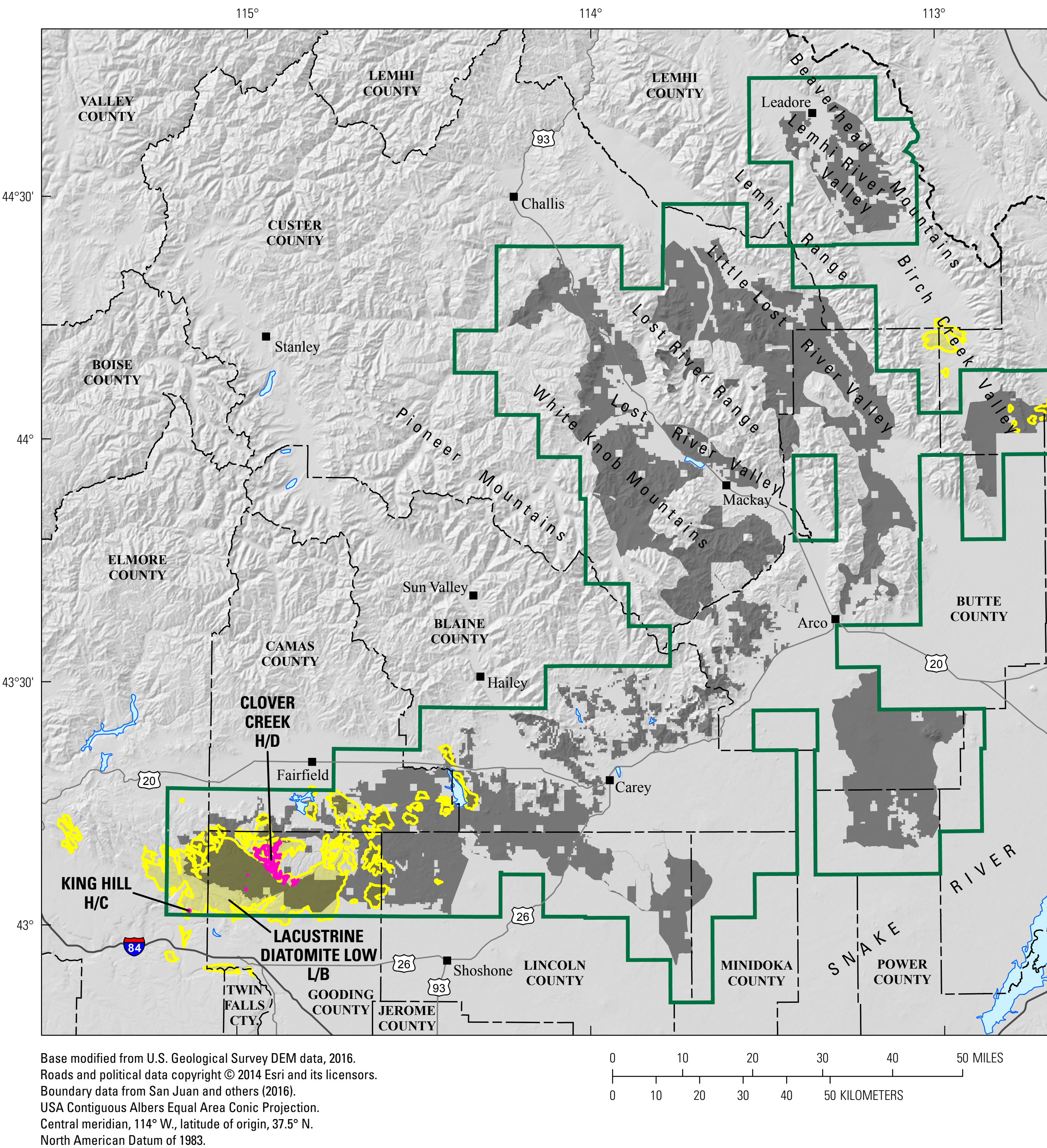
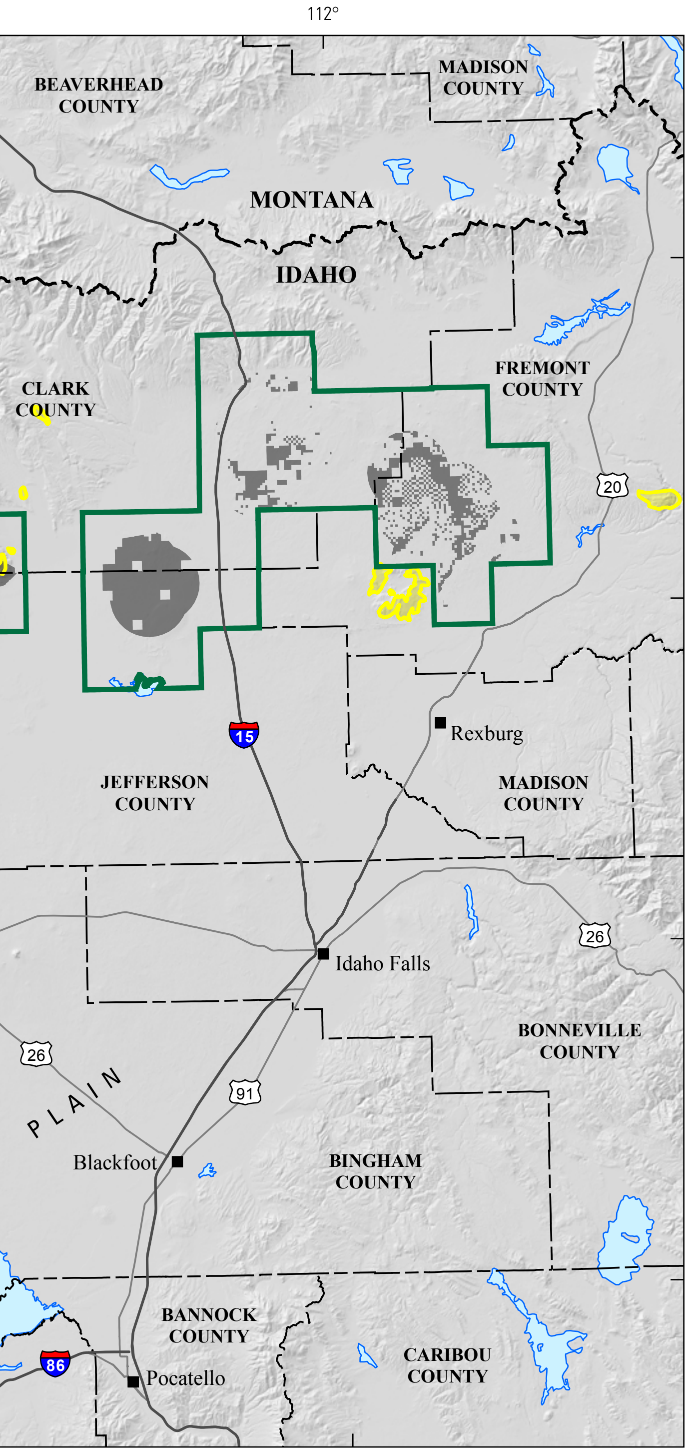
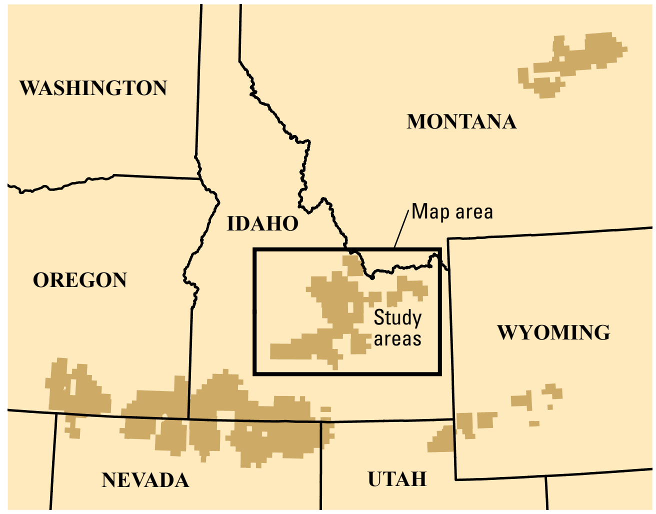


Figure 31. Map showing mineral-resource potential for lacustrine diatomite-type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract types – lacustrine diatomite

High-potential (H) tract with high (D) or moderate (C) certainty

Low-potential (L) tract with low (B) certainty

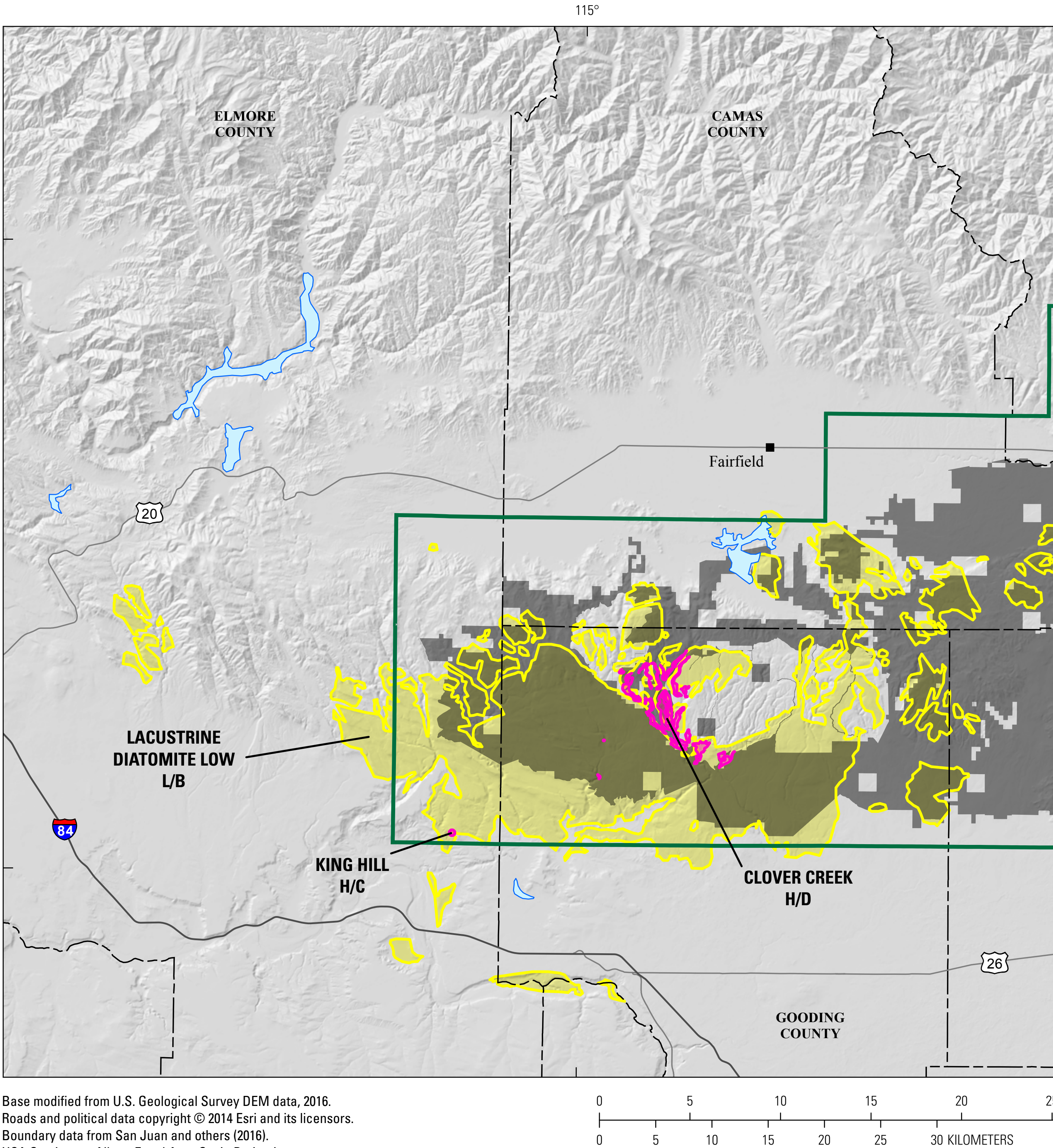
Base data

USGS study area boundary

Proposed withdrawal areas

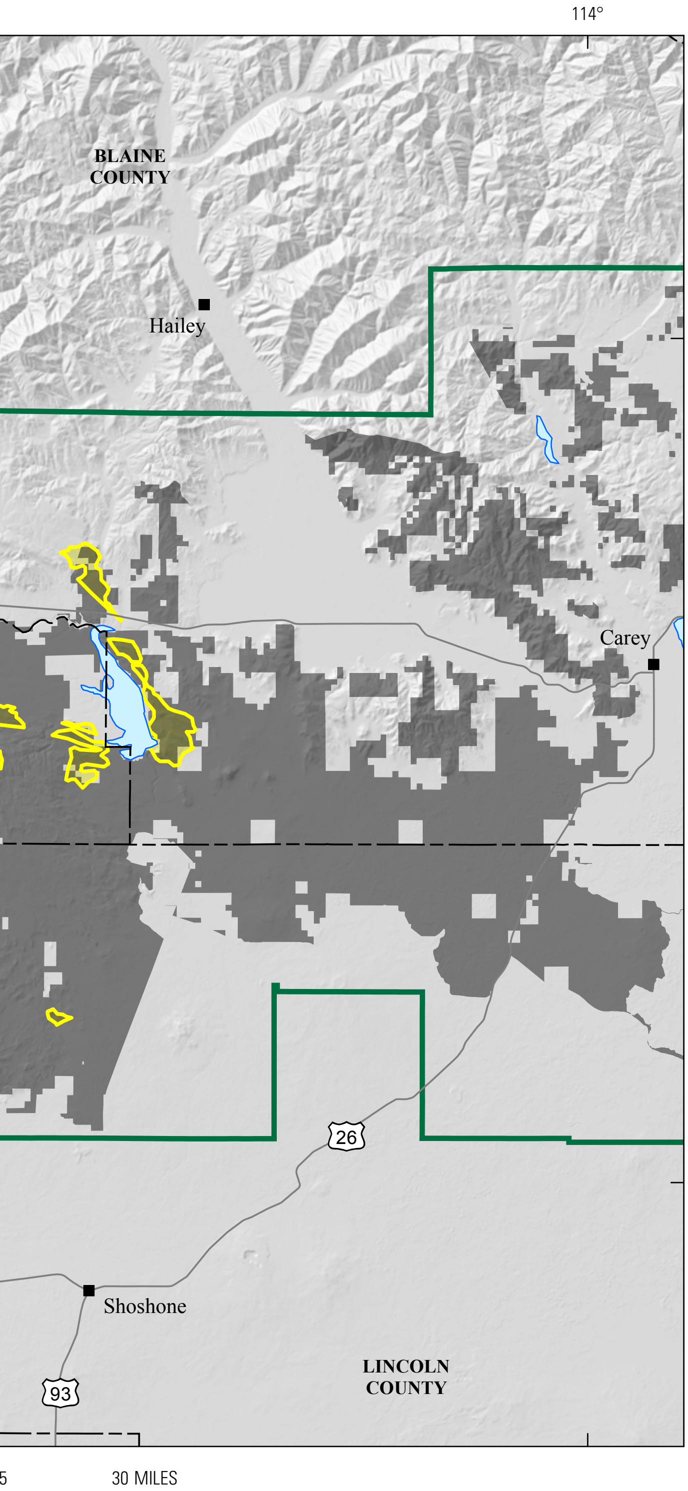
State boundaries

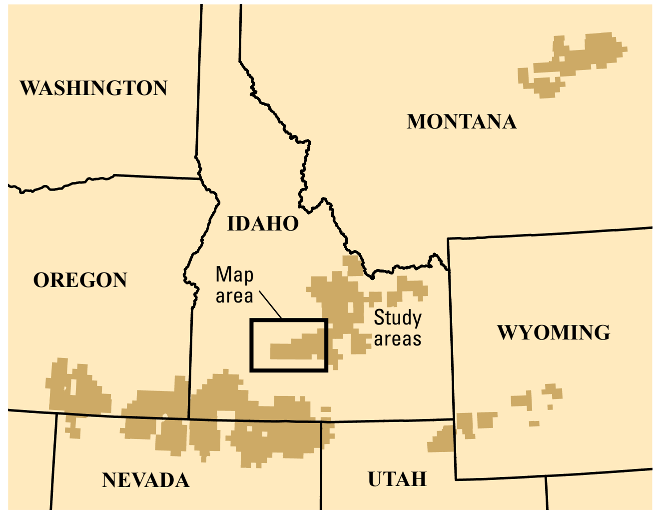
County boundaries



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 32. Inset map showing mineral-resource-potential tracts for lacustrine diatomite-type deposits in the western part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – lacustrine diatomite

High-potential (H) tract with high (D) or moderate (C) certainty

Low-potential (L) tract with low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

Exploration and Mining History

The majority of diatomite produced in the United States is of marine origin, from Miocene deposits in southern coastal California. Additional production comes from lacustrine deposits outside this study area in west-central Nevada, east-central Oregon, and central Washington (Burnett, 1991; Dolley and Moyle, 2003; Wallace, 2003).

In the study area, there are two small past producers, the Clover Creek deposit with the associated Chalk mine in Gooding County in southwestern Idaho (Moyle, 1985; Toth and others, 1987; Wallace, 2003) and a diatomite mine near King Hill in Elmore County (Powers, 1947). As of 1989, the total production from the Clover Creek deposit was about 2,500 short tons (Bennett and others, 1990). At the King Hill mine, an estimated reserve was calculated at 48,000 short tons (Powers, 1947). Additional diatomite occurrences marginal to the study area include a quarried site about 13 km north of Fairfield in Camas County, numerous sites in the vicinity of Glenns Ferry along the Snake River Plain in Elmore County, and sites in Twin Falls County (Powers, 1947). There is currently no production in the study area.

Resource Assessment Tracts

Clover Creek Diatomite Tract H/D—The Clover Creek diatomite tract is rated with a high potential for lacustrine diatomite deposits and a certainty level of D (fig. 32). It is located in Gooding County, Idaho. The basis for the tract includes (1) past diatomite production, (2) well-controlled mapping of the host unit, and (3) high favorability from a previous mineral-resource assessment. The tract is underlain by Pliocene lacustrine rocks (unit Tpd described as siliclastic, limestone, tuffaceous, and diatomite deposits in Bond and others, 1978). More detailed studies show diatomite as discrete map unit (Tbd, described as Miocene diatomite and other sedimentary deposits of the Banbury Basalt in Toth and others, 1987; and unit Tcd, described as Miocene diatomite of Clover Creek in Oakley and Link, 2006; Garwood and others, 2014). The diatomite of Clover Creek is more than 100 m thick. It formed as a lake basin deposit in dissected basaltic terrain and, after erosion of its exposed surface, the diatomite was capped by tuff (Oakley and Link, 2006).

As of 1987, the Clover Creek diatomite deposit consisted of forty-two 160-acre placer claims covering about 6,700 acres. Past production is indicated at the Clover Creek and the Chalk mines (U.S. Geological Survey, 2005). As of 1989, total production from the Clover Creek deposit was about 2,500 short tons (Bennett and others, 1990). Cumulative tonnage of probable diatomaceous sediments in the Clover Creek deposit was estimated at 416 million short tons, approximately 35 million short tons of which would be of diatomite quality potentially suitable for filter aid, filler, insulation, and other applications (Toth and others, 1987). Although there are closed placer claims and a closed notice, there are no currently active BLM claims or notices for diatomite in the tract area.

A previous mineral-resource assessment of the Gooding City of Rocks (East and West) Wilderness Study Areas rated the area of the present tract as having high potential with certainty level C (Toth and others, 1987).

King Hill Diatomite Tract H/C—The King Hill diatomite tract in Elmore County, Idaho (fig. 32) is rated with a high potential for lacustrine diatomite deposits with certainty level C. The basis for the tract is (1) past diatomite production, (2) general map units inclusive of Miocene to Pleistocene sedimentary deposits containing minor diatomite associated with volcanic strata, and (3) a detailed description of a diatomite deposit within the tract area. The bedrock geology is Pliocene basalt flows, pyroclastic debris, clastic sediments, and diatomite (unit Tpb, Bond and others, 1978). Because the map extent of the mined diatomite host unit is undetermined, a 250-m buffer around the point location of the diatomite mine defines the tract. The buffer is based on a description of the deposit, indicating that it is exposed for 37 m in the quarry and is believed to extend for a minimum of 55 m farther, with an estimated minimum length of 152 m (Powers, 1947). The reserve is a block 91 m by 152 m and 61-cm thick, and is estimated at 48,000 short tons dry weight material (Powers, 1947). Currently, there are no active BLM claims or notices for diatomite in the tract area.

No previous mineral-resource assessments include the area of the King Hill tract.

Lacustrine Diatomite Low Tract (L/B)—There is low potential for lacustrine diatomite deposits, with certainty level of B, in the area surrounding the Clover Creek and King Hill tracts. The basis for the lacustrine diatomite low tract includes (1) general map units inclusive of Miocene to Pleistocene sedimentary deposits containing minor or incidental diatomite associated with volcanic strata, and (2) a previous mineral assessment in a part of the area that indicates minor potential for diatomite. The tract encompasses areas underlain by the map units that contain the known lacustrine diatomite deposits described above (units Tpb and Tpd of Bond and others, 1978; and near the Clover Creek tract, Pliocene to late Miocene units Tbwu, Tbw, Tbcc, and Tbwc of Garwood and others, 2014). Although the surface map units are largely basaltic, drainages dissect the cap rock, variously exposing underlying diatomite beds or lenses. In most places, the basalt overburden occludes the geometry of paleo-lake basins that formed in low-lying areas of the eroded pre-existing terrain (Oakley and Link, 2006).

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has high mineral-resource potential in two tracts for lacustrine-type diatomite deposits. This type of deposit is primarily characterized by diatomite. For economic analysis of these commodities, see Bleiwas (2016).

Black-Shale-Hosted Vanadium

Deposit Type Description

Vanadium in seawater is concentrated in organic matter that accumulates in euxinic basins with high organic productivity and low clastic sedimentation rates (Breit and Wanty, 1991; Lehmann and others, 2007). The resulting organic-rich black shales are often petroleum source rocks (Maughan, 1984) and typically contain anomalous concentrations of metals and trace elements (Link and others, 1995; Worl and Johnson, 1995; Hall, 1995a). In some basins, they occur with phosphorite (McKelvey and others, 1986), bedded barite (Papke, 1984), or SEDEX zinc-lead-silver deposits (Emsbo, 2009).

Permissive Geology and Occurrences in Study Area

In neighboring areas of Nevada and southern Idaho, black shales with potentially extractable concentrations of vanadium (for example, ≥1,500 ppm vanadium; American Vanadium, 2011) are present. Coeval stratigraphic units having equivalent depositional settings and rock types include the Permian Phosphoria Formation, Permian Park City Formation, Devonian Milligen Formation, and Cambrian to Mississippian Salmon River assemblage, plus correlative formations (Maughan, 1984; McKelvey and others, 1986; Link and others, 1995; Worl and Johnson, 1995; American Vanadium, 2011, 2016; Smith and others, 2016). By analogy with the Mississippian Chainman Shale in Nevada, Mississippian shales in the Copper Basin Group may also contain anomalous concentrations of vanadium.

Exploration and Mining History

Vanadium was mined on a small scale in the past and resources were estimated for black shales associated with phosphate rock in the Phosphoria Formation of Idaho and Wyoming (McKelvey and others, 1986; Love and others, 2004). Hall (1995a) documented vanadium concentrations (greater than 1,500 ppm) in the Salmon River assemblage and assessed the potential for black shale vanadium resources in the Challis 1° × 2° quadrangle, which covers part of the study area. Such deposits are generally considered to be subeconomic but they may be exploited in the future. There has been no mining of vanadium from black shales in the study area.

Resource Assessment (No Tracts)

Black-shale-hosted vanadium resources may be present in the permissive formations that include the Permian Phosphoria and Devonian Milligen Formations, Cambrian to Mississippian Salmon River assemblage, and Copper Basin Group plus correlative formations (figs. 3, 4). However, we found little or no evidence of exploration, detailed mapping, or analyses for vanadium in the study area. Consequently, no permissive tracts are delineated and no tracts with moderate or high potential could be identified. In the Hawley Creek area (fig. 10), near the northeastern margin of the study area, black shales with vanadium (U.S. Geological Survey, 2005) are wall rocks to phosphatic zones in the Retort Phosphatic Shale Member of the Phosphoria Formation (Oberlindacher and Hovland, 1979). At this site, vanadium might be a potential by-product of future phosphate mining (see Phosphate in Leasable Minerals section). Because phosphate is a leasable commodity, the Hawley Creek area was not delineated as a locatable commodity tract.

Surficial-Mechanical Mineral System

Mixtures of sand, silt, and gravel deposited by streams and rivers (alluvium) can host concentrations of high-density (heavy) minerals of commercial value; gold is the most notable example (Yeend and Shawe, 1989). Initially, the heavy minerals erode with the other mineral grains from bedrocks and mineral deposits (the source materials). After the minerals are disaggregated from the rock by erosion, flowing water acts to effectively sort and concentrate the mineral grains based on particle size and density. Alluvial deposits of this type that contain heavy minerals of economic value are commonly referred to as placer deposits. Gold-bearing placer deposits are formed in alluvium that was deposited in stream and rivers downstream of metallic districts in which the source lode deposits contain gold as a primary or accessory constituent. In addition to gold, placer deposits can contain several other heavy minerals that in some instances are used as sources of other valued commodities, such as titanium, niobium, tantalum, zirconium, thorium, and REEs (these minerals are described below).

Heavy minerals in alluvium are those that are resistant to chemical and mechanical weathering and are able to survive transport from source rock area to streambed. Heavy minerals generally constitute only a small percentage of an alluvial placer deposit, with most of the deposit usually composed of quartz sand grains and silt. The average heavy-mineral content of Idaho placers sampled by the U.S. Bureau of Mines ranged from 0.10 to 1.06 weight percent of the sediments, with an average of 0.5 weight percent (Staatz and others, 1980).

Gold Placer

Deposit Type Description

Heavy minerals, particularly gold, have been recovered from placer deposits in modern streams and rivers in central Idaho (Staley, 1946; Staatz and others, 1980; Wells, 1983; Yeend and Shawe, 1989). A number of historic gold-placer districts were located in the stream valleys of central Idaho, especially in the region that includes the Idaho batholith (fig. 3) and notably in the Yankee Fork District about 20 km northeast of Stanley, Idaho (fig. 1). These gold-bearing placer deposits formed in alluvium deposited downstream from mining districts in which source lode deposits contain gold as a primary or accessory constituent. The principal gold-placer districts of Idaho lie outside of the study area.

Permissive Geology and Occurrences in Study Area

Only one record of a gold-placer operation is in the mineral occurrences database for the entire study area—the Eightmile Canyon placer in the southern Lemhi Range at lat 44.05660°N, long 113.01834°W (Fernette and others, 2016a). No current gold-placer activity is recorded in the study area.

From geochemical studies, the most significant gold concentrations found in stream sediment samples are those associated with polymetallic deposits of the Camas District in the southwestern area of the study area (Volcano tract); in this area, stream sediment samples range from 0.1 to 2.4 ppm gold. Otherwise, stream sediment samples in creeks that enter or cross the remainder of the study area do not exceed 0.1 ppm gold.

Because numerous streams drain historic mining districts with gold in lode deposits, much of the study area could be considered permissive for gold-placer deposits. However, the lack of supporting evidence in the form of placer activity suggests a low potential for gold-placer deposits in the study area. Areas of low potential, with certainty level B, extend along all such drainages issuing from the mining districts containing lode gold, but are not shown as a tract map herein.

Heavy-Mineral Placer Other Than Gold

Deposit Type Description

The most common heavy minerals in the alluvial deposits of central Idaho (in generally decreasing amounts) are ilmenite, magnetite, sphene, garnet, monazite, euxenite, zircon, and uranothorite (uranium-rich thorite) (Staatz and others, 1980). In addition to gold, and REEs and Th in monazite and euxenite, the Idaho placer deposits (and the abandoned historic dredge waste piles) contain associated minerals containing titanium (in ilmenite), niobium and tantalum (from euxenite), and zirconium (zircon) (Anderson, 1958; Storch and Holt, 1963).

Two areas of west-central Idaho north of the study area—Long Valley and Bear Valley—were mined by dredges for monazite in the 1950s (Staatz and others, 1980). Beginning in September 1950, Long Valley was worked by three dredges previously used to recover gold, but were converted to recover monazite. The dredges were redesigned for monazite recovery with assistance from the U.S. Bureau of Mines under the sponsorship of the U.S. Atomic Energy Commission, as part of a program to identify new domestic monazite resources (Storch and Holt, 1963; Staatz and others, 1980). The Long Valley and Bear Valley deposits, although outside of the study area, typify the heavy-mineral placer deposits of interest.

Permissive Geology and Occurrences in the Area

In addition to gold, placer exploration in central Idaho included resource evaluations for the recovery of the mineral monazite [$(REEs,Th)PO_4$], sought as a potential source of several light-REE (Staatz and others, 1980). Heavy minerals of potential economic value (ilmenite, zircon, garnet, monazite, euxenite, zircon, and uranothorite) that occur in alluvial deposits of central Idaho; the most likely source of these deposits was biotite granodiorite plutons of the Idaho batholith (fig. 3; Schmidt, 1964). Thus, the permissive geology determined for heavy-mineral placers, excluding gold, includes drainage basins that drain, or lie adjacent to, granitic plutons of the Idaho batholith (fig. 33).

All valleys of this region contain alluvial deposits, but those adjacent to the Idaho batholith (fig. 3) are most likely to have potential for a heavy-mineral placer deposit. Examples are the Rock-Camp Creek and Dempsey Creek drainages, which enter the southwestern part of the study area. The regional study of Staatz and others (1980) reported that the Camp Creek placers contain accessory amounts of monazite. Similarly, alluvium in the East Fork of the Salmon River drainage has the potential to contain heavy minerals of value because the river drains an area of the Idaho batholith.

Resource Assessment Tracts

Rock-Camp Creek (East) and Dempsey Creek (West) Heavy-Mineral Placer Tract L/C—There is low potential for non-gold bearing heavy-mineral placers, with certainty level C, in the Rock-Camp and Dempsey Creek areas of the southwestern part of the study area. A 200-m-wide buffer is drawn beside the channels of perennial streams in these basins (fig. 34).

The Rock-Camp Creek and Dempsey Creek tracts drain the southern part of the Late Cretaceous Idaho batholith (fig. 34). The country rock in the upper drainage basins consists of biotite granite-granodiorite plutons (Kiilsgaard and others, 2001; Lewis and others, 2012).

Staatz and others (1980) identified one monazite-bearing placer district—the Camp Creek placers—in Blaine County, about 68 km north of Shoshone (located along Camp Creek at lat 43.3746°N, long 114.3992°W; San Juan and others, 2016). The average heavy-mineral content of the Camp Creek placer is 1.06 percent (Robertson and Storch, 1955); however, only a trace amount of monazite is reported. Uranothorite [$(Th,U)SiO_4$] forms about 1.2 percent of the heavy mineral content of the Camp Creek placer (Robertson and Storch, 1955).

East Fork Salmon Tract L/B—Quaternary alluvium in the East Fork of the Salmon River drainage (fig. 35) has low potential to contain heavy minerals, with certainty level B.

The alluvium along the East Fork Salmon River is identified as having potential for heavy-mineral placer deposits because this alluvium is derived from the erosion of granite-granodiorite plutonic units of the Idaho batholith (fig. 3). Rocks of this plutonic unit are known to contain minerals that are locally concentrated in heavy-mineral placers downstream from such source rocks (Schmidt, 1964).

In some locations, the alluvium may have concentrations of minerals that have economic value, including ilmenite, monazite, euxenite, zircon, and uranothorite. However, the lack of historic or current placer mines or prospects along this stretch of river requires a low mineral-resource-potential designation (fig. 35).

Economic Analysis of the Deposit Type

The North-Central Idaho Sagebrush Focal Area has low mineral-resource potential in two tracts for heavy-mineral placer deposits of the non-gold bearing type. The primary commodity of interest is characterized by REEs. For economic analysis of these commodities, see Bleiwas (2016).

Salable Commodities

Active BLM mineral-material authorizations (approved or pending) for all the salable commodities are tabulated for the North-Central Idaho Sagebrush Focal Area, both in and outside of the BLM proposed withdrawal area (table 10), and the sites are shown on figures 36 and 37, respectively. These commodities are (1) pumice, scoria, and volcanic cinder; (2) sand and gravel; (3) soil, including topsoil and fill; and (4) stone including riprap crushed, dimension, and specialty stone; tufa; and weathered granite.

Table 10. Active Bureau of Land Management (BLM) mineral-material authorizations for salable commodities in the study area for the North-Central Idaho Sagebrush Focal Area.

[The number of sites considered to occur within the BLM proposed withdrawal area includes any within a section that includes a proposed withdrawal area, even if the site itself is not actually in a proposed withdrawal area. For information see Dicken and San Juan (2016)]

Commodity	Sites within BLM proposed withdrawal areas		Sites in study area outside BLM proposed withdrawal areas	
	Approved	Pending	Approved	Pending
Pumice, volcanic cinder	1	0	1	1
Sand and gravel, clinker	0	0	1	0
Sand and gravel, gravel	11	1	9	0
Sand and gravel, both	12	0	6	1
Sand and gravel, sand	1	0	2	1
Sand and gravel, shale	3	0	2	2
Soil/other, fill	1	0	7	0
Stone, riprap	3	0	11	1
Stone, dimension	3	0	0	0
Stone, specialty	5	0	0	0
Stone, weathered granite	4	0	1	0

Pumice, Scoria, and Volcanic Cinder

Pumice, scoria, and volcanic cinder are porous volcanic rocks produced by the ejection of molten lava into the air above an erupting volcano, which then cools and falls as glassy rock fragments with abundant gas bubble inclusions. Pumice rocks are low-density (can float in water), light-colored, and consist of relatively silica-rich glass from rhyolitic melts. Scoria and cinder are generally brown or red, and form from relatively silica-poor basaltic and andesitic eruptions. Scoria can also form as frothy, gas-rich tops to subaerial lava flows. One approved BLM mineral-material sales site for pumice, scoria and volcanic cinder occurs within the BLM proposed withdrawal area, and two sites (one approved and one pending) occur outside that area in the study area (fig. 36; table 10); there is no active production. These sites are in Quaternary basaltic lava flow sequences in the Snake River Plain.

Sand and Gravel

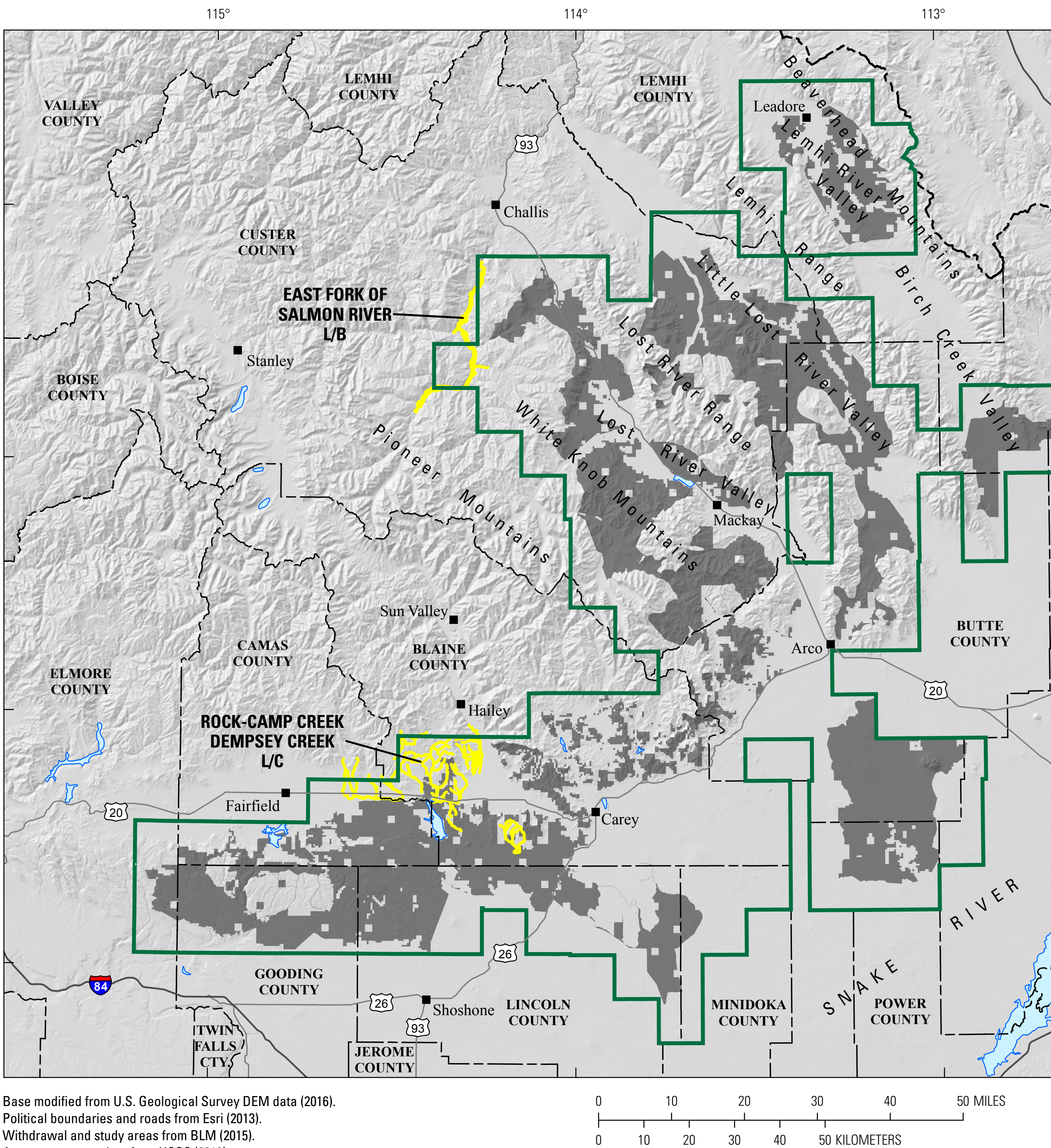
Sand and gravel deposits are natural aggregates produced by erosion of bedrock and the subsequent transport, abrasion, and deposition of the particles by ice, water, gravity, and wind (Langer, 1988). They are widely distributed but can vary greatly in quality, quantity, and ease of mining. Proximity to the site where they are used is an important factor. In the study area, these sites are typically unconsolidated stream gravels preserved outside of any presently active stream channels. There are 27 approved and 1 pending BLM mineral-material sales sites for sand and gravel in the BLM proposed withdrawal area; there are 20 approved and 4 pending sites outside that area in the study area (fig. 36; table 10). One active pit (Gooding County pit) occurs in the BLM proposed withdrawal area.

Soil (Topsoil/Fill)

Soil is generally defined as unconsolidated earthy material over bedrock that is a natural medium for plant growth; it is typically less than 2 m thick. Most (but not all) of the BLM mineral-material sale sites are in alluviated valleys where soils are well-developed in fine alluvial material. There is one approved BLM mineral-material sales site for soil in in the BLM proposed withdrawal area; there are seven approved sites outside that area in the study area (fig. 36; table 10). There is no active production in the proposed withdrawal area.

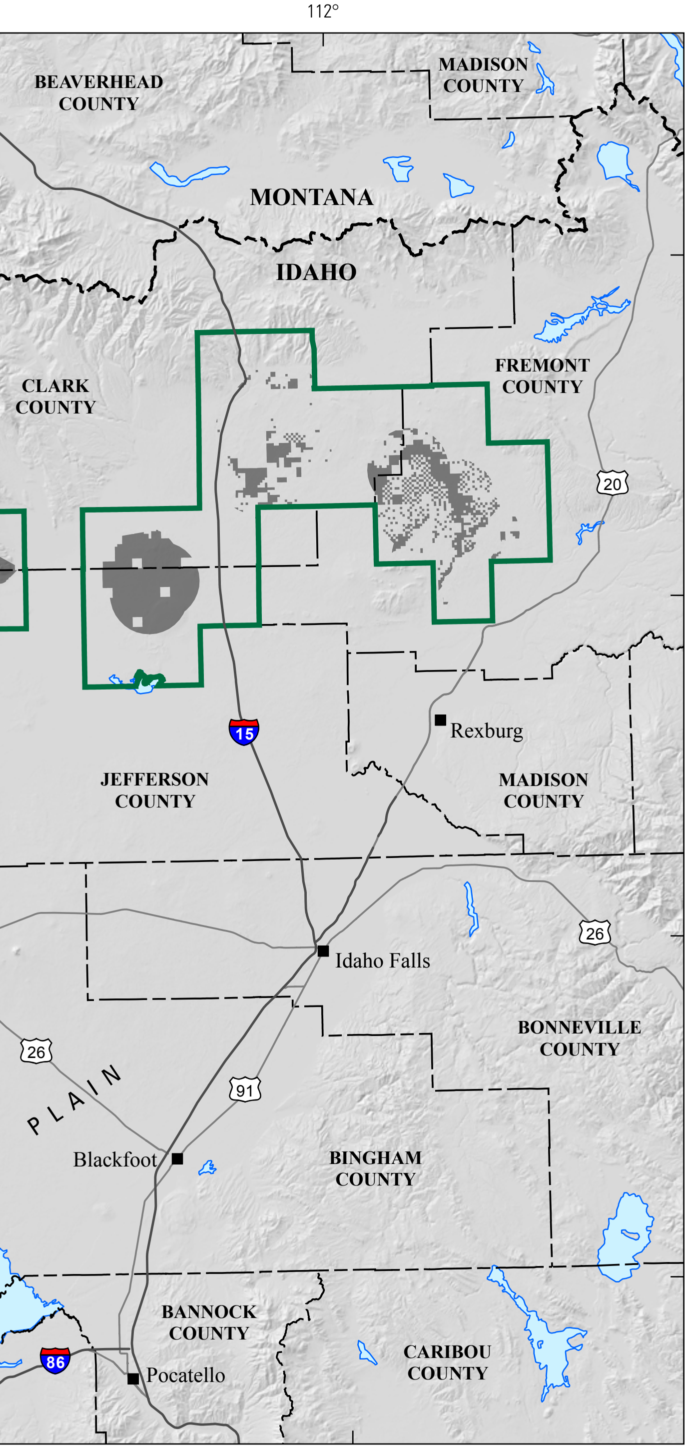
Stone (Riprap, Crushed, Dimension, Specialty, Tufa, Weathered Granite)

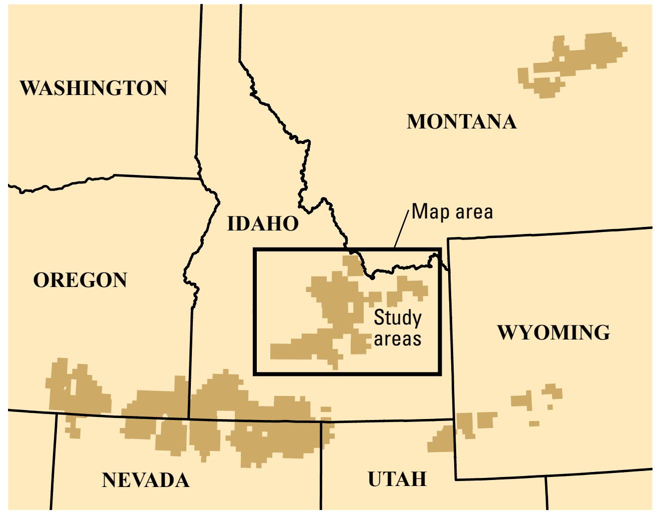
Salable stone commodities include materials quarried for riprap, for crushing to convert to aggregate, for building or dimension stone, or for specific types like tufa or weathered granite. Depending on the uses of the stone, its particular properties can vary widely (Barton, 1968). There are 15 approved BLM mineral-material sales sites for stone in the BLM proposed withdrawal area; there are 13 sites (12 approved and 1 pending) outside that area in the study area (fig. 36; table 10). No active production occurs in the proposed withdrawal area.



Base modified from U.S. Geological Survey DEM data (2016).
Political boundaries and roads from Esri (2013).
Withdrawal and study areas from BLM (2015).
Assessment tract data from USGS (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 33. Map showing mineral-resource-potential for heavy-minerals placer-type deposits in the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – heavy-mineral placers

Low-potential tract with moderate (C) or low (B) certainty

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

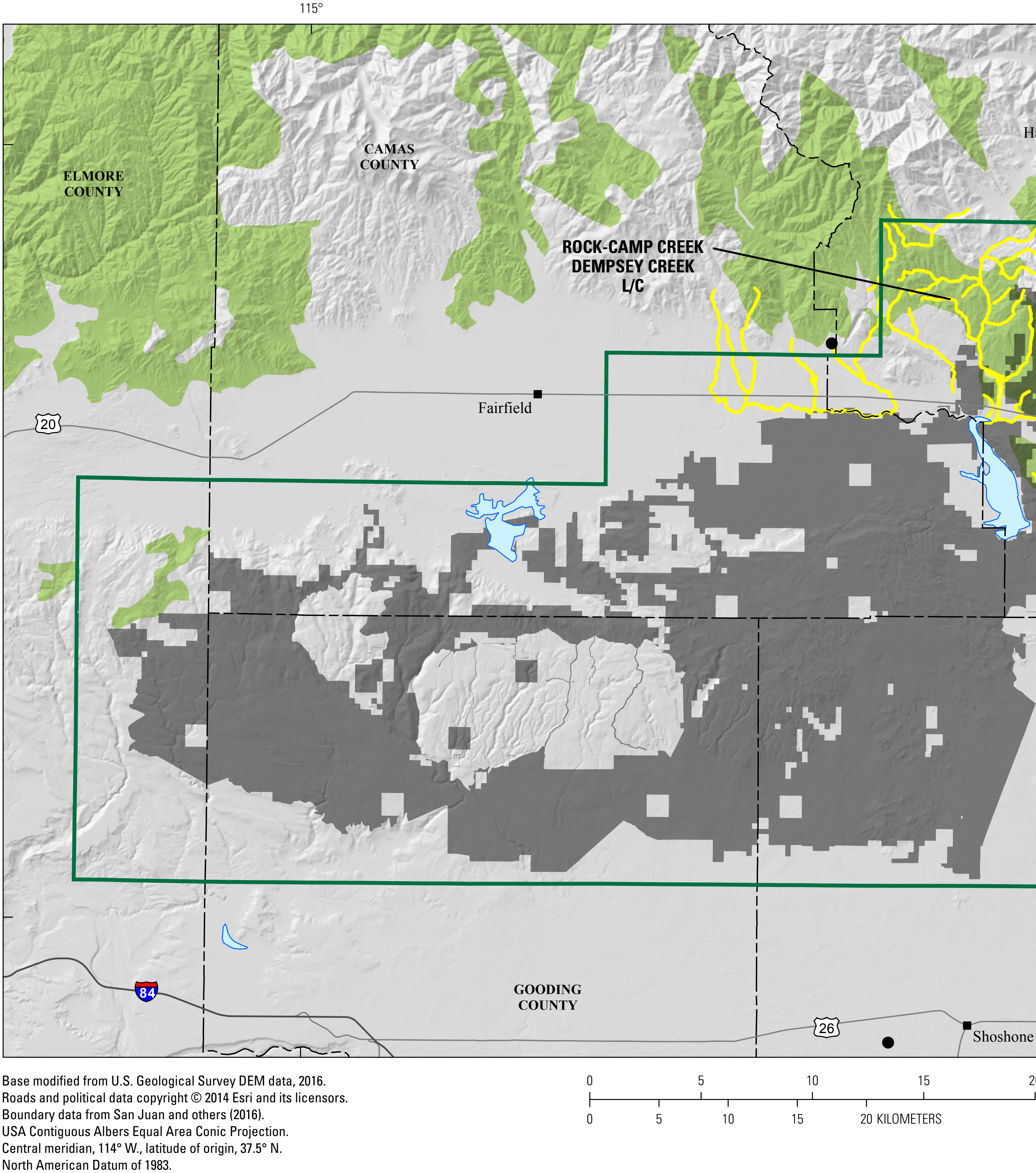
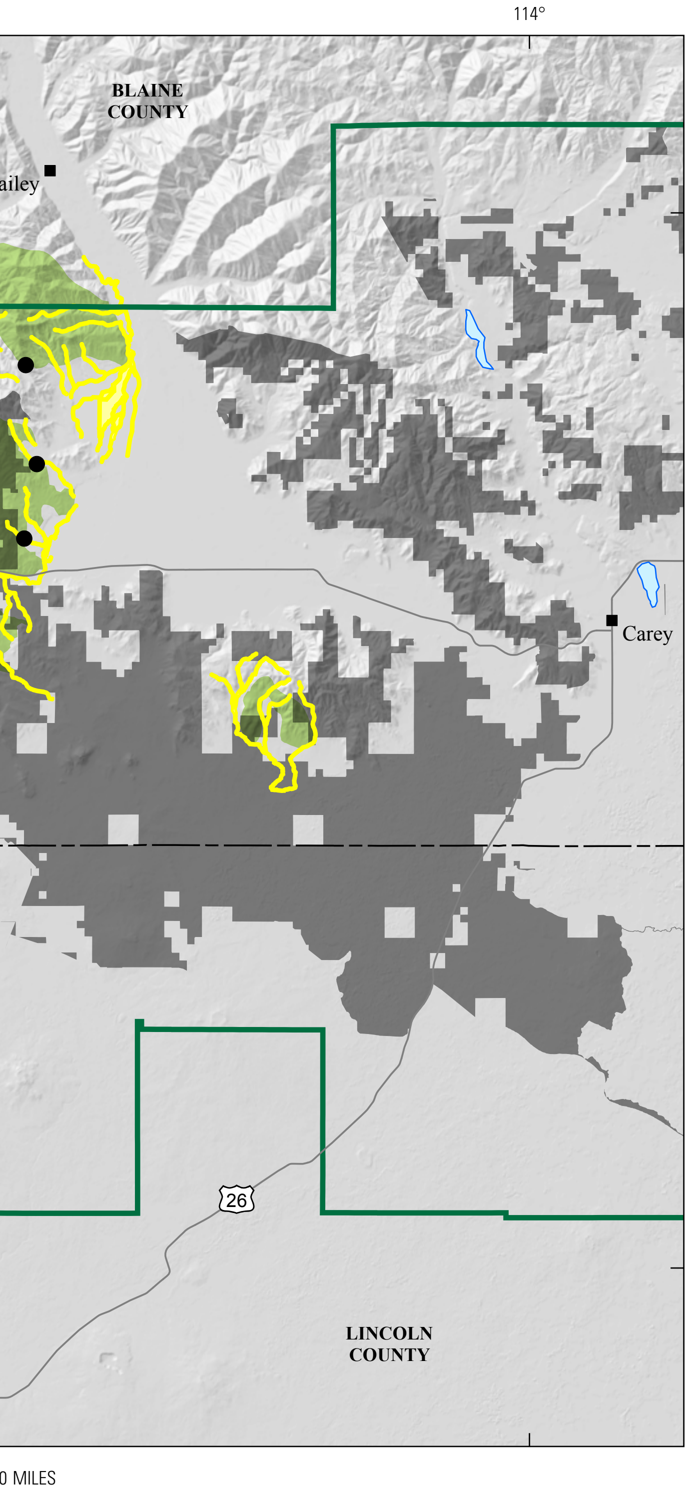
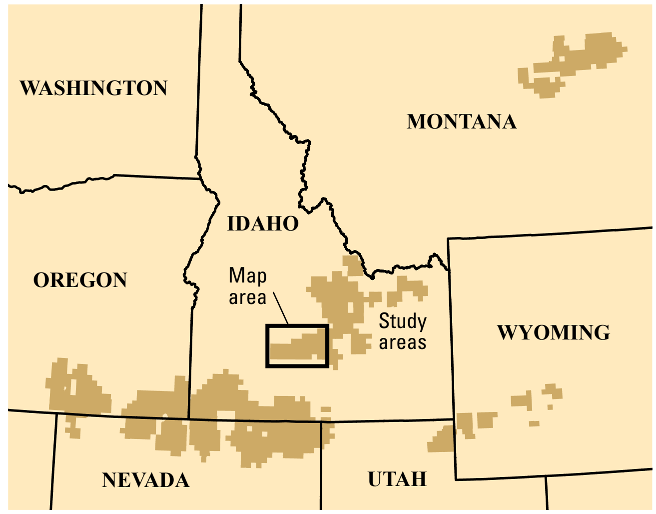


Figure 34. Inset map showing a mineral-resource-potential tract for heavy-mineral placer-type deposits, in context of permissive geology and occurrences for the southwestern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – heavy-mineral placers

Low-potential (L) tract with moderate (C) certainty

Permissive geology

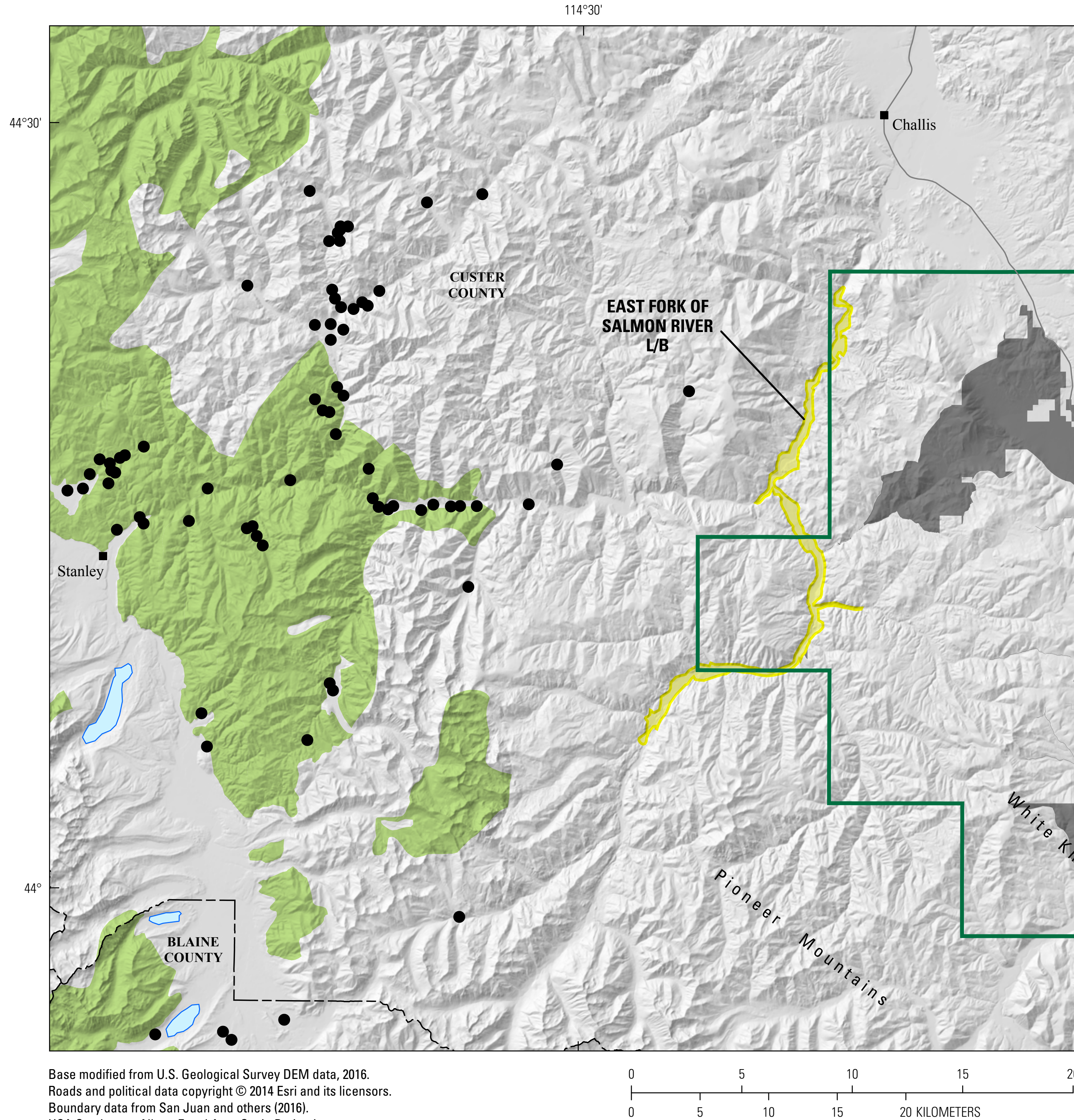
Placer gold occurrences

Base data

USGS study area boundary

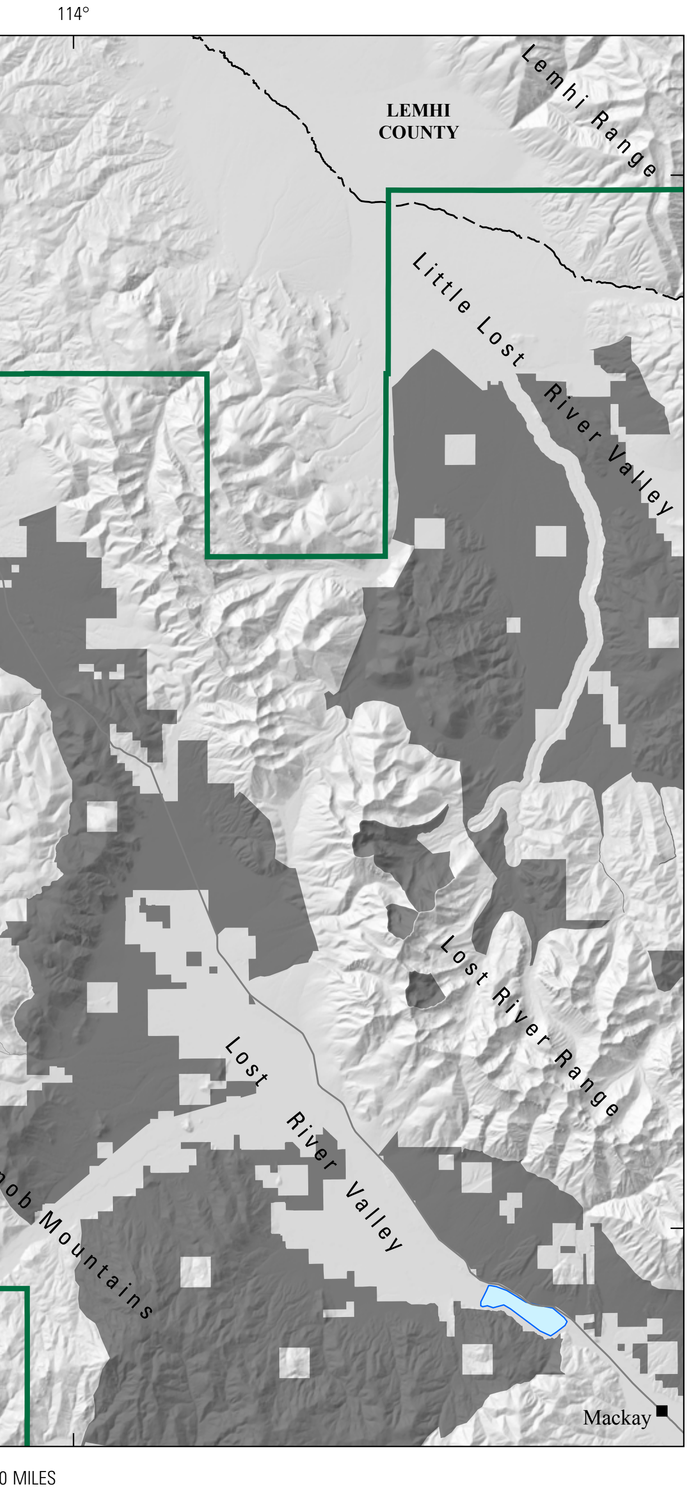
Proposed withdrawal areas

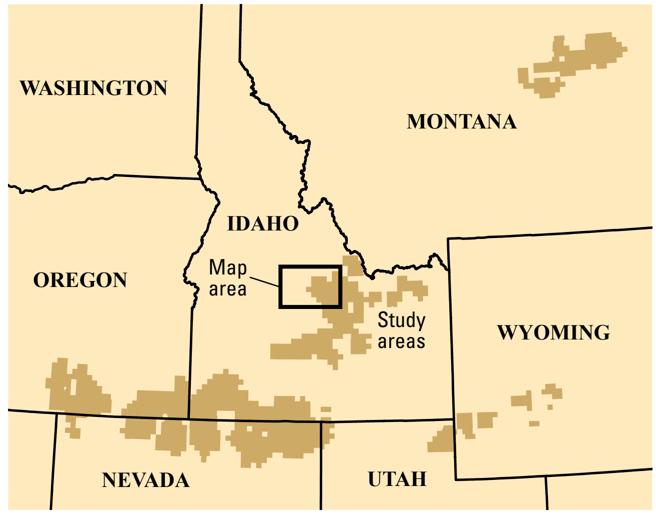
County boundaries



Base modified from U.S. Geological Survey DEM data, 2016.
Roads and political data copyright © 2014 Esri and its licensors.
Boundary data from San Juan and others (2016).
USA Contiguous Albers Equal Area Conic Projection.
Central meridian, 114° W., latitude of origin, 37.5° N.
North American Datum of 1983.

Figure 35. Inset map showing a mineral-resource-potential tract for heavy-mineral placer type deposits in context of permissive geology for the northwestern part of the study area for the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Assessment tract type – heavy-mineral placers

Low-potential (L) tract with low (B) certainty

Permissive geology

Placer gold occurrence

Base data

USGS study area boundary

Proposed withdrawal areas

County boundaries

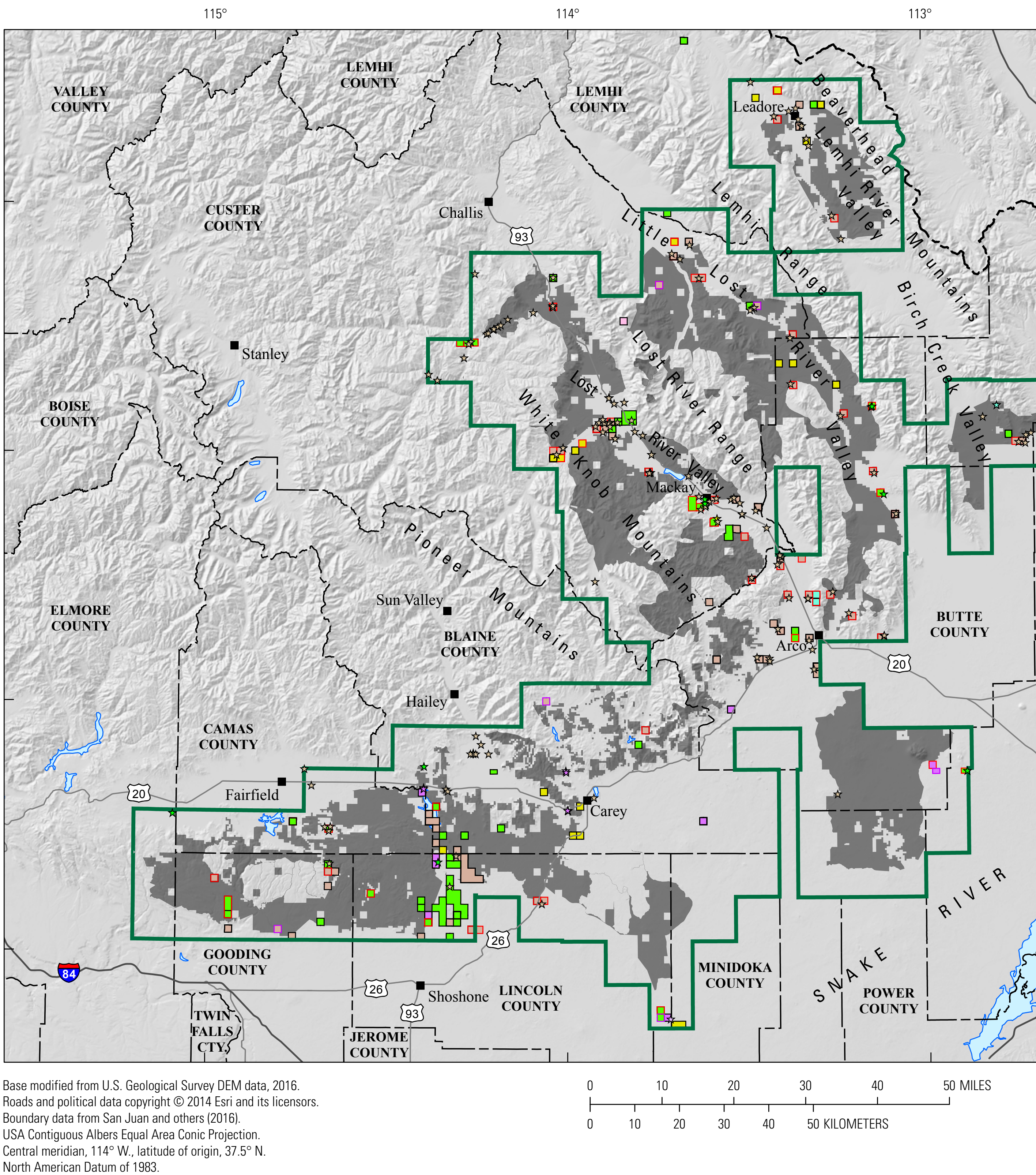
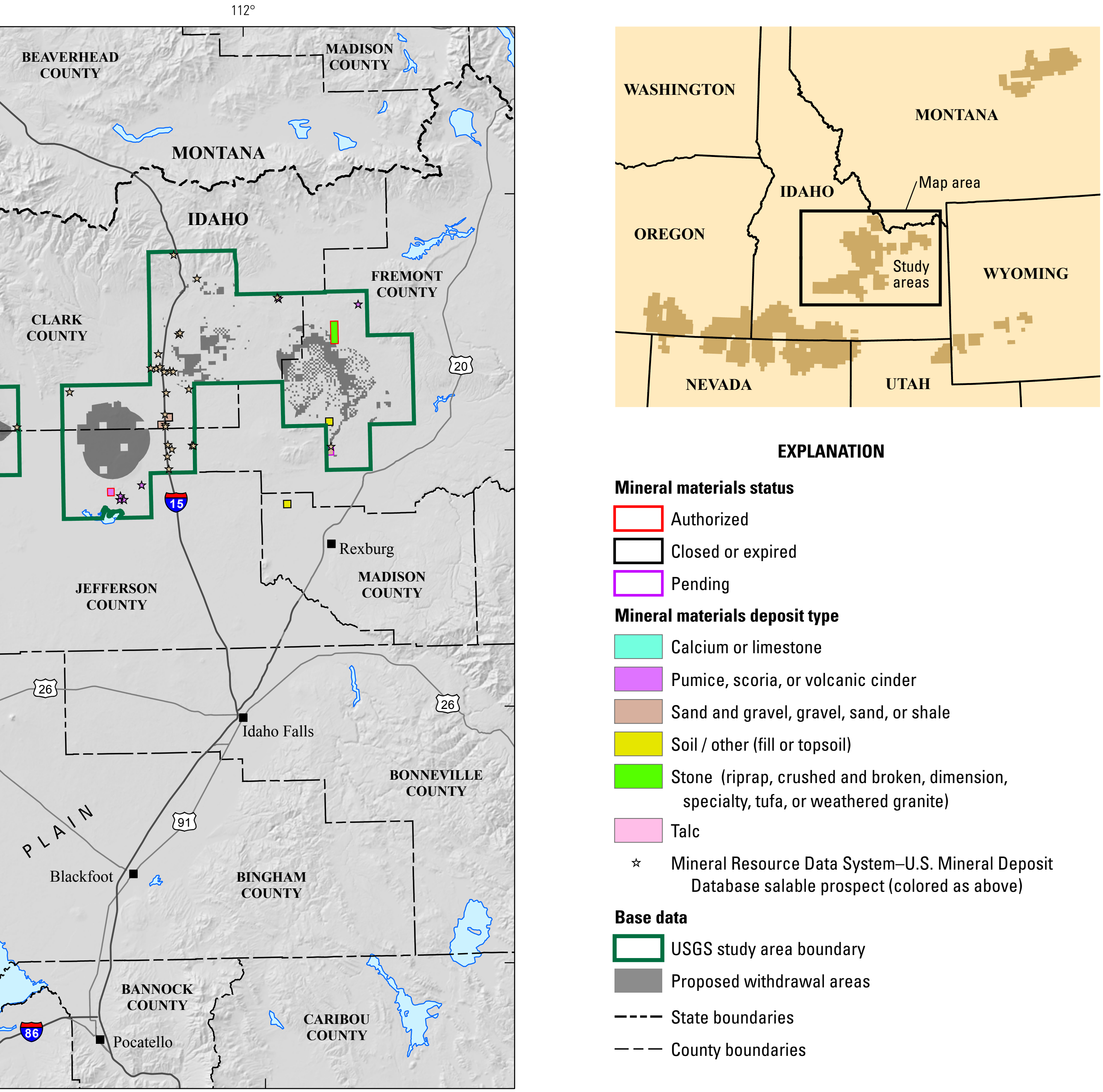


Figure 36. Map showing known deposits of salable minerals and Bureau of Land Management mineral material permit sites in the studied area of the North-Central Idaho Sagebrush Focal Area.


112°
BEAVERHEAD COUNTY
MADISON COUNTY
MONTANA
IDAHO
FREMONT COUNTY
CLARK COUNTY
15
20
Rexburg
MADISON COUNTY
JEFFERSON COUNTY
26
26
Idaho Falls
BONNEVILLE COUNTY
91
PLAIN
Blackfoot
BINGHAM COUNTY
BANNOCK COUNTY
CARIBOU COUNTY
86
Pocatello
WASHINGTON
MONTANA
IDAHO
Map area
OREGON
Study areas
WYOMING
NEVADA
UTAH
EXPLANATION
Mineral materials status
Authorized
Closed or expired
Pending
Mineral materials deposit type
Calcium or limestone
Pumice, scoria, or volcanic cinder
Sand and gravel, gravel, sand, or shale
Soil / other (fill or topsoil)
Stone (riprap, crushed and broken, dimension, specialty, tufa, or weathered granite)
Talc
Mineral Resource Data System–U.S. Mineral Deposit Database salable prospect (colored as above)
Base data
USGS study area boundary
Proposed withdrawal areas
State boundaries
County boundaries

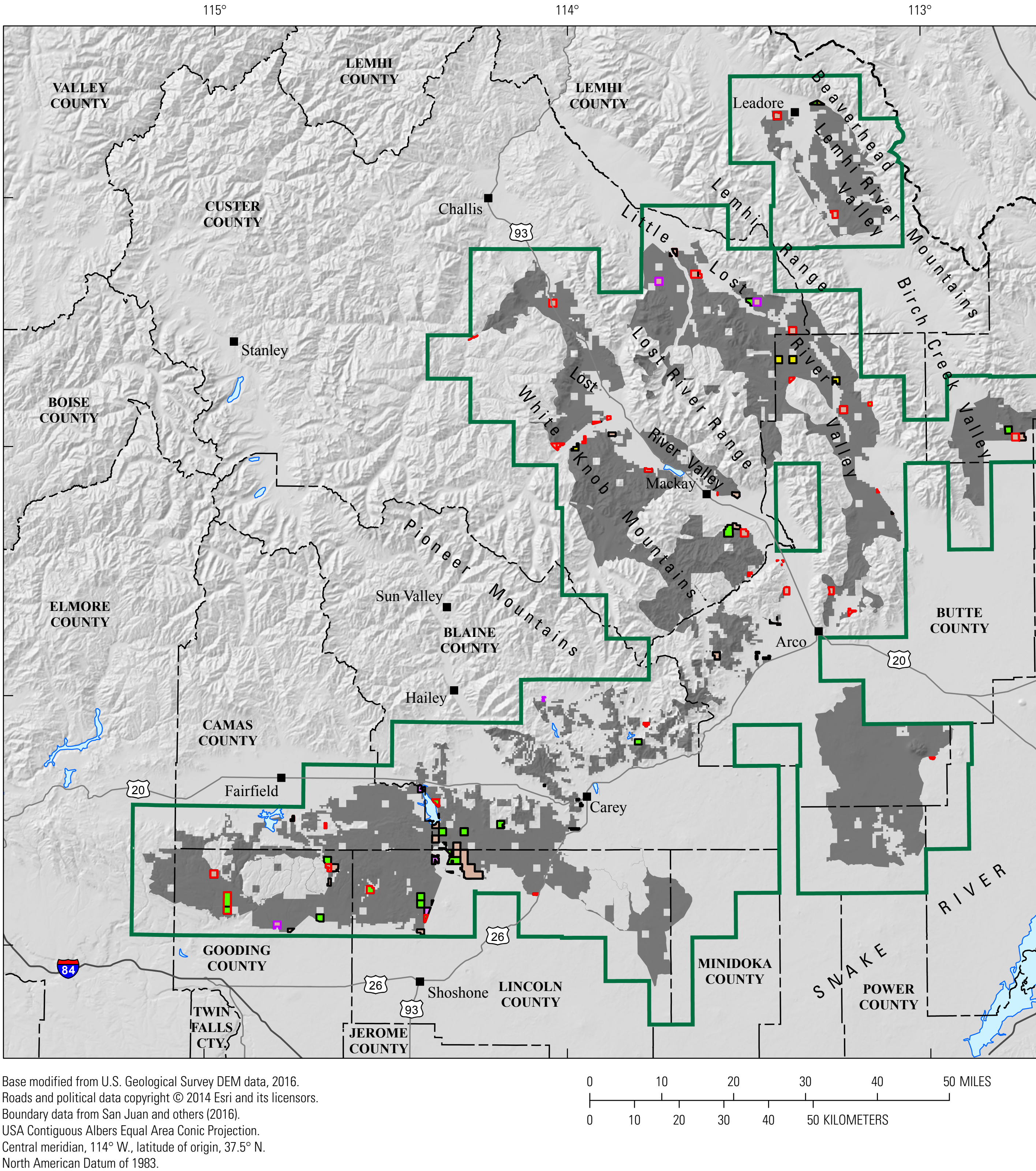
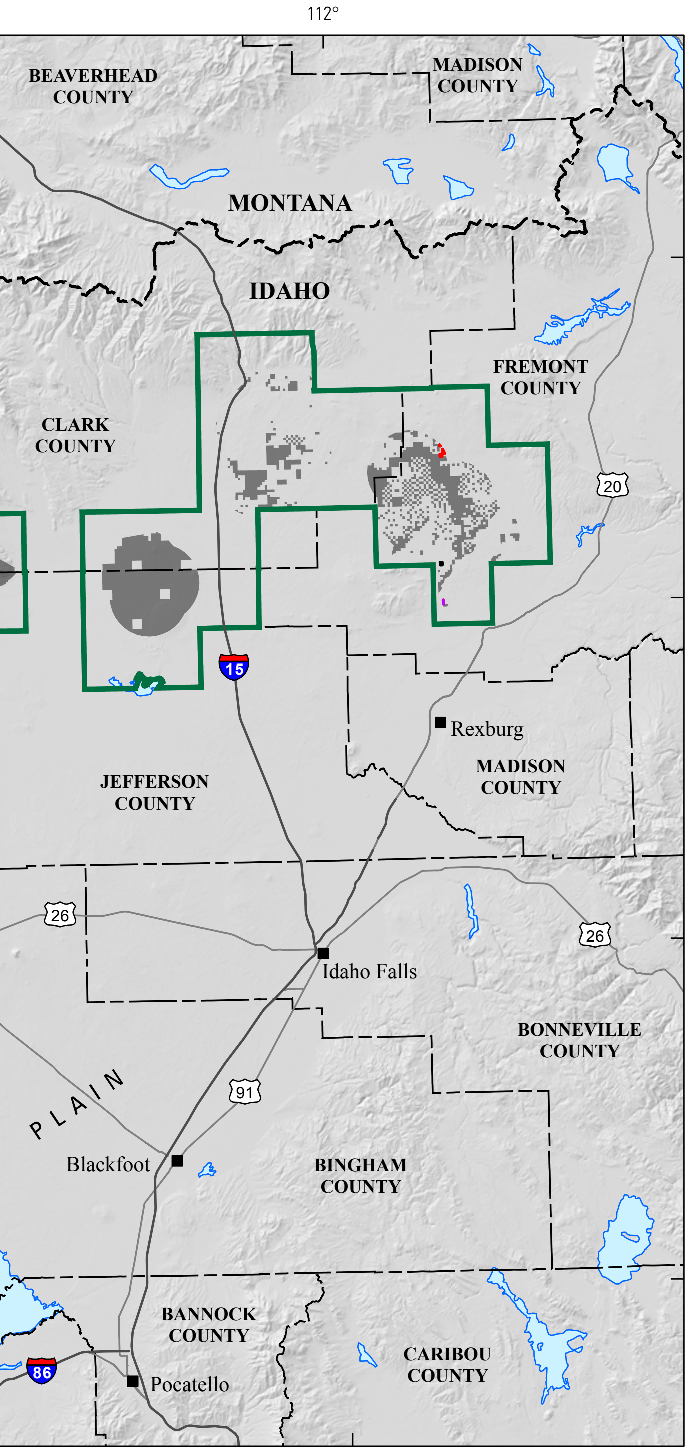
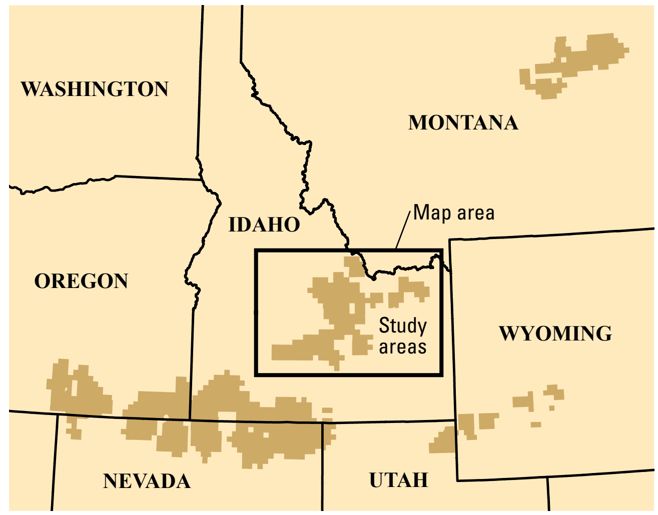


Figure 37. Map showing known deposits of salable minerals and Bureau of Land Management mineral material permit sites in the proposed mineral withdrawal area of the North-Central Idaho Sagebrush Focal Area.





EXPLANATION

Mineral materials status

Authorized

Closed or expired

Pending

Mineral materials deposit type

Pumice, scoria, or volcanic cinder

Sand and gravel, gravel, sand, or shale

Soil / other (fill or topsoil)

Stone (riprap, crushed and broken, dimension, specialty, tufa, or weathered granite)

Base data

USGS study area boundary

Proposed withdrawal areas

State boundaries

County boundaries

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Appendix 1. Mineral Potential Classification System

The approach to classification of the qualitative mineral-resource potential for locatable minerals followed that prescribed in Bureau of Land Management (BLM) Manuals MS–3031 and MS–3060 defined originally by Goudarzi (1984) (fig. 1–1).

Level of Potential

N. The geologic environment, the inferred geologic processes, and the lack of mineral occurrences do not indicate potential for accumulation of mineral resources.

L. The geologic environment and the inferred geologic processes indicate low potential for accumulation of mineral resources.

M. The geologic environment, the inferred geologic processes, and the reported mineral occurrences or valid geochemical/geophysical anomaly indicate moderate potential for accumulation of mineral resources.

H. The geologic environment, the inferred geologic processes, the reported mineral occurrences and (or) valid geochemical/geophysical anomaly, and the known mines or deposits indicate high potential for accumulation of mineral resources. The “known mines and deposits” do not have to be within the area that is being classified, but have to be within the same type of geologic environment.

ND. Minerals potential not determined due to lack of useful data. This does not require a level of certainty qualifier.

Level of Certainty

A. The available data are insufficient and (or) cannot be considered as direct or indirect evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct but quantitatively minimal evidence to support or refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

For the determination of “no potential” use N/D. This class shall be seldom used, and when used it should be for a specific commodity only. For example, if the available data show that the surface and subsurface types of rock in the respective area are batholithic (igneous intrusive), one can conclude, with reasonable certainty, that the area does not have potential for coal.

As used in this classification, potential refers to potential for the presence (occurrence) of a concentration of one or more energy and (or) mineral resources. It does not refer to or imply potential for development and (or) extraction of the mineral resource(s). It does not imply that the potential concentration is or may be economic, that is, could be extracted profitably.

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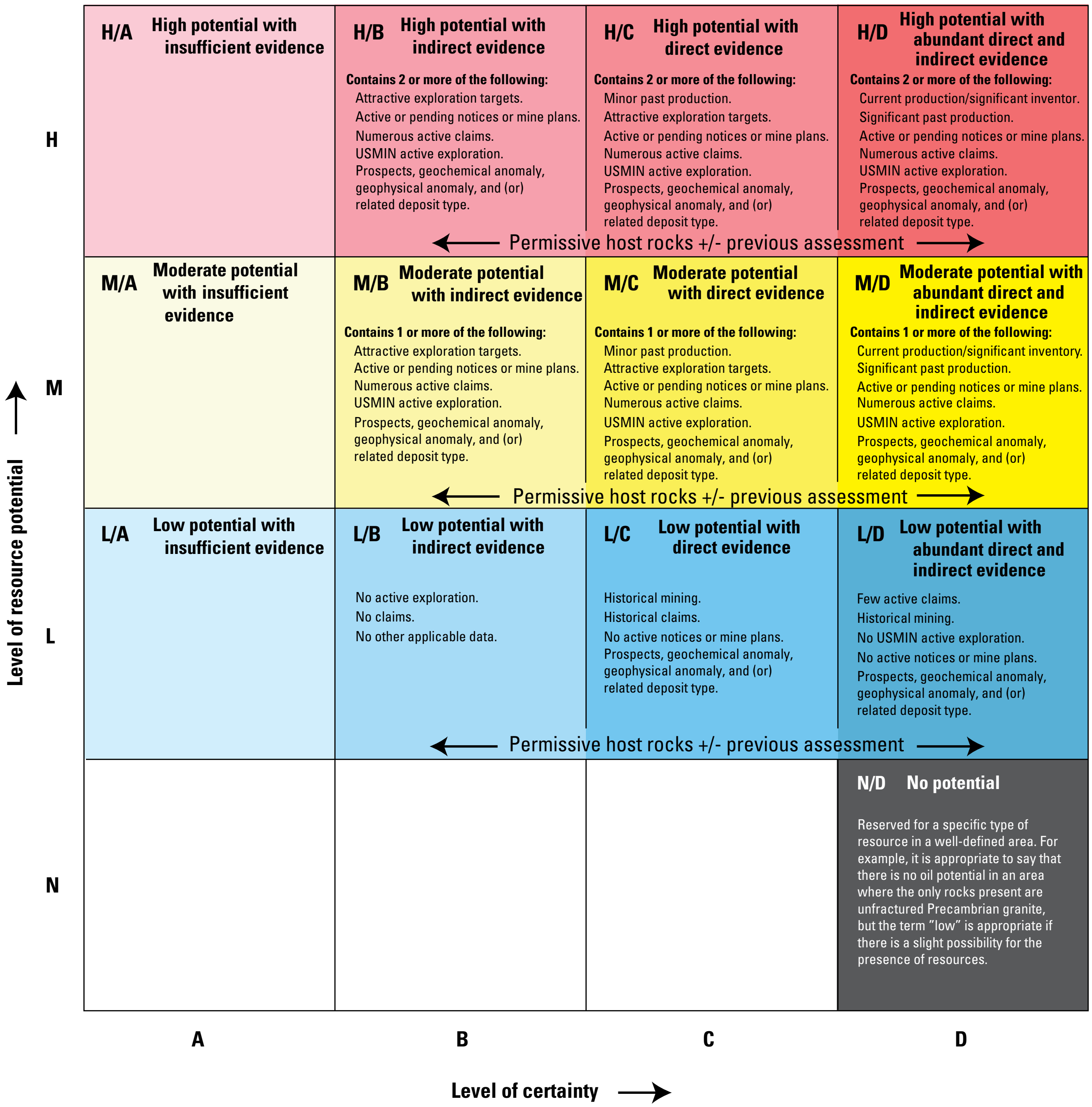

Figure 1–1. Matrix showing the classification system used for qualitative mineral-resource potential for locatable minerals in the Sagebrush Mineral-Resource Assessment (see text for abbreviations). USMIN, U.S. Geological Survey Mineral Deposit Database.

Appendix 2. Mineral-Potential Assessment Tracts for Locatable Minerals in the North-Central Idaho Sagebrush Focal Area

This appendix is available online only as an Excel (.xlsx) table at http://dx.doi.org/10.3133/sir20165089C. The table provides details and criteria about the mineral-potential assessment tracts for locatable minerals in the North-Central Idaho Sagebrush Focal Area in tabulated format.

Appendix 3. Oil and Gas Plays and Assessment Units in the North-Central Idaho Sagebrush Focal Area

This appendix is available online only as an Excel (.xlsx) table at http://dx.doi.org/10.3133/sir20165089C. The table relates Public Land Survey System (PLSS) townships to U.S. Geological Survey (USGS) reports on oil and gas resource assessments for assessment units or plays in the North-Central Idaho Sagebrush Focal Area. If an assessment was conducted in 1995 then the terminology used was "play." After 1995, the terminology became "assessment unit" (AU). In many cases, more than one play or AU may be present in a given PLSS township. The table lists each PLSS township and the associated play or AU, the name of the play or AU, the related USGS publication title, and a link to the published USGS geologic assessment report. The USGS reports include many additional details regarding the source rocks, reservoir rocks, type of trap, reservoir properties, and resource potential.

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